U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

GEOTHERMAL TECHNOLOGIES OFFICE

2012 Peer Review Report

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Geothermal Technologies Office
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April 2013

The photo on the cover page is of the Heber Geothermal power plant located seven miles south of El Centro, CA. Photo courtesy of Warren Gretz, NREL photographer

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U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy
Geothermal Technologies Office
2012 Peer Review Meeting
May 2012

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2012 Geothermal Technologies Peer Review Panel

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Executive Summary

On May 7-10, 2012, the U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Geothermal Technologies Office (GTO or the office) conducted its annual program peer review at the Westin Westminster Hotel in Westminster, CO. In accordance with the EERE Peer Review Guide, the review provides an independent, expert evaluation of the strategic goals and direction of the office and is a forum for feedback and recommendations on future office planning. The purpose of the review was to evaluate DOE-funded projects for their contribution to the mission and goals of the office and to assess progress made against stated objectives. An ancillary benefit is the opportunity for information exchange among scientists and engineers working on geothermal technologies. Principal Investigators (PI), leading approximately 170 projects, came together to disseminate information, progress, and results.

GTO develops innovative geothermal energy technologies to find, access, and use the nation's geothermal resources. Through research, development, and demonstration (RD&D) efforts that emphasize the advancement of Enhanced Geothermal Systems (EGS), GTO is working to provide the United States (U.S.) with an abundant, clean, renewable baseload energy source. GTO works in partnership with industry, academia, and DOE's national laboratories to establish geothermal energy as an economically competitive contributor to the U.S. energy supply. GTO's activities build on the technical research base that has been developed over the last four decades. This technical base provides information and understanding necessary to create new and more efficient and reliable technologies and to enable the U.S. geothermal industry to compete for baseload electricity generation.

The 2012 Geothermal Technologies Office Peer Review Meeting was organized into the following tracks with associated sessions:

- Track 1 - High Temperature Tools, Drilling Systems, and Zonal Isolation; and Systems Analysis, Resources Assessment, Data System Development and Population, Education
- Track 2 - Enhanced Geothermal Systems Demonstrations; Seismicity, Fluid Imaging, and Reservoir Fracture Characterization; and Modeling
- Track 3 - Tracers and Tracer Interpretation and Exploration Validation
- Track 4 – Low-Temperature and Co-Production Demonstration; Supercritical Carbon Dioxide; and Working Fluids

Each project was reviewed by a minimum of three expert reviewers whom provided both numeric evaluations and written comments. Additionally, one overall chairperson, Dr. Kate Baker, was selected to oversee the entire peer review process. The chairperson provided oversight and guidance to ensure consistency, transparency, and independence throughout. As a special note, Mr. Jim Faulds received the Geothermal Technologies Office's Peer Review Excellence Award.

In addition to the reviewed projects, Tracks 3 and 4 also included the presentation of projects too early in their award life to warrant a full review, or for those which had scored highly in previous reviews that the Program Managers determined additional peer evaluation was not warranted in this annual cycle. Projects included in this "Presentation Only" category will be officially evaluated during the 2013 peer review meeting.

The weighted average score of the reviewed projects ranged from poor (3% of reviewed projects) to outstanding (10%). Two-thirds of projects received overall scores indicative of notable progress and impact on GTO mission and goals. The project scoring results, expert reviewer comments, and key findings and recommendations are included in this report.

The comments below, expressed by the 2012 Geothermal Technologies Office Peer Review Panel, summarize the current state of the various technology areas within the Geothermal Technologies Office:

- EGS projects were well selected by GTO and currently provide a good diversity between general stimulation techniques and greenfield innovations. Additionally, the "step-out" projects have the potential to lead to further advancement and may likely be the future of EGS development.
- The most useful projects in the Exploration Validation portfolio are those that are based in fundamental geology and mapping; however it should be noted that some of the projects in the Exploration Validation portfolio were lacking in geochemistry. Additionally, it would be beneficial for GTO to transfer some of the laboratory drilling methods to actual, real-world drilling rigs.
- All High Temperature (greater than or equal to 300°C) work in SiC offers significant impact to the geothermal industry; if there is commercialization of the technology.
- GTO has a well-balanced portfolio of Low-Temperature and Co-Production Demonstration projects with valuable data to collect, but the reviewers stressed that GTO needs to ensure and maintain the integrity and availability of that data.
- Projects in the Modeling portfolio will definitely help to improve the understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing modeling tools to accelerate EGS implementation.
- Application of more measurements to help characterize properties of EGS, which can yield models with more predictive power for management, is a high priority for projects in the Seismicity, Fluid Imaging & Reservoir Fracture Characterization portfolio.
- Duplicative efforts in the Supercritical Carbon Dioxide technology area need to be avoided. GTO should revisit the duplicative efforts in this technology area.
- GTO should develop and implement a solution or protocol for accepting data regarding those projects in the System Analysis, Resource Assessment, Data System Development and Population, and Education technology area.
- Formulation of new tracers, and methods to concentrate effluent, can aid in fracture network characterization for EGS or other fracture-dominated systems. Adopting the use of first principles computational tools along with experimental validations to gain fundamental understanding of new tracer interactions with rock and fluids is a suitable strategy to help fulfil a key geothermal gap.
- Development of fluids and the behavior models of working fluids will have a high impact if inexpensive working fluids with properties focused on specifics can be developed.

1.0 Introduction to the Geothermal Technologies Office

The U.S. Department of Energy (DOE) Geothermal Technologies Office (GTO or the office) develops innovative geothermal energy technologies to find, access, and economically use the nation's geothermal resources. Through research, development, and demonstration efforts that emphasize the advancement of Enhanced Geothermal Systems (EGS) and discovering hidden natural hydrothermal systems, GTO is working to provide the United States (U.S.) with an abundant, clean, renewable baseload energy source. GTO works in partnership with industry, academia, and DOE's national laboratories to establish geothermal energy as an economically competitive contributor to the U.S. clean energy supply. Geothermal energy production, a $1.5 billion a year industry, generates electricity and provides heat for direct applications including aquaculture, crop drying, and district heating, or for use in heat pumps to heat and cool buildings. GTO conducts multi-year research, development, and demonstration (RD&D) on surface and subsurface opportunities for system cost reduction. RD&D priorities are focused on overcoming technology barriers that have the greatest potential to hinder the development of viable resources at acceptable cost, risk, and timeframes.

The Geothermal Technologies Office is currently organized into three subprogram areas: 1) Enhanced Geothermal Systems, 2) Hydrothermal and Resource Characterization, and 3) Systems Analysis. The subprogram goals at the time of the 2012 Peer Review were as follows:

- **Enhanced Geothermal Systems** – Demonstrate reservoir creation and sustainability in various geologic environments (Demonstration and R&D)
- **Hydrothermal and Resource Characterization –** Lower LCOE to 6 cents/kWh by 2020
    - **Innovative Exploration Technologies** – Confirm 400 MWe of undiscovered hydrothermal by 2014 and lower the upfront exploration risk of blind hydrothermal systems
    - **Low-Temperature and Co-produced Resources** – Enable 3 GWe of added geothermal capacity for low temperature and coproduced resources by 2020
- **Systems Analysis** – assess geothermal resources, cost drivers, the impact of policy, and progress toward goals.

The funding and budget history for the Geothermal Technologies Office is illustrated below in Figure 1.1. and Figure 1.2.

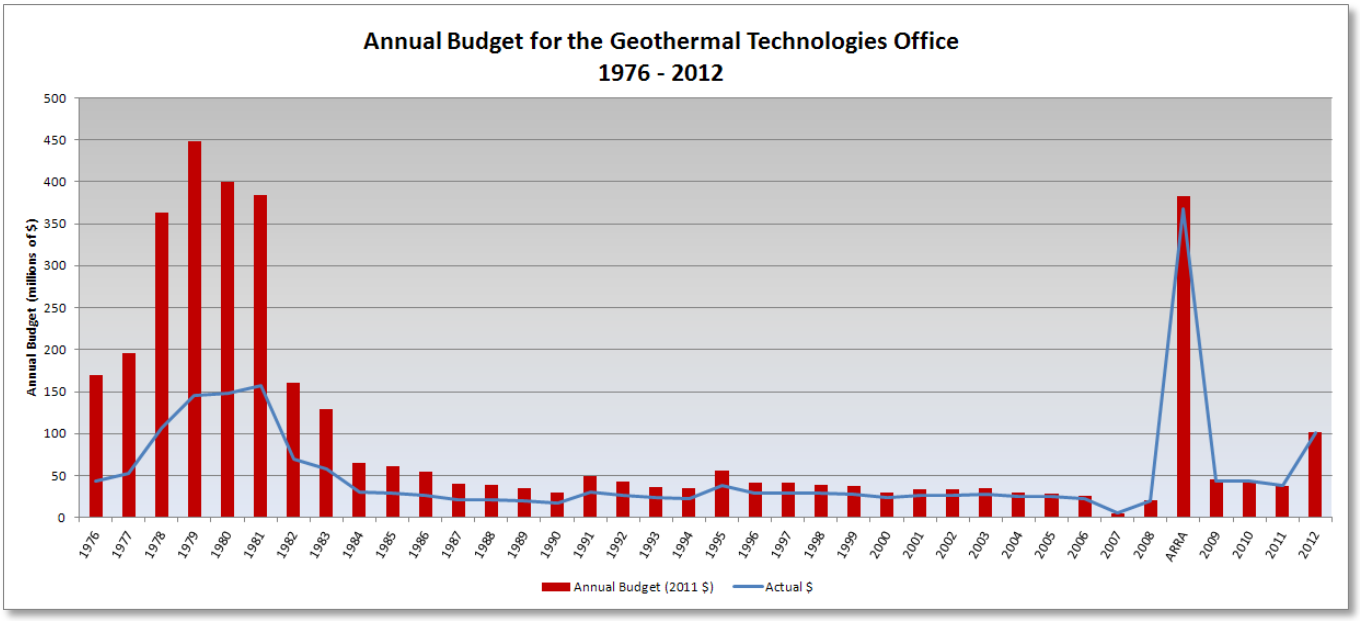


Figure 1.1. *Geothermal Technologies Office Funding History*

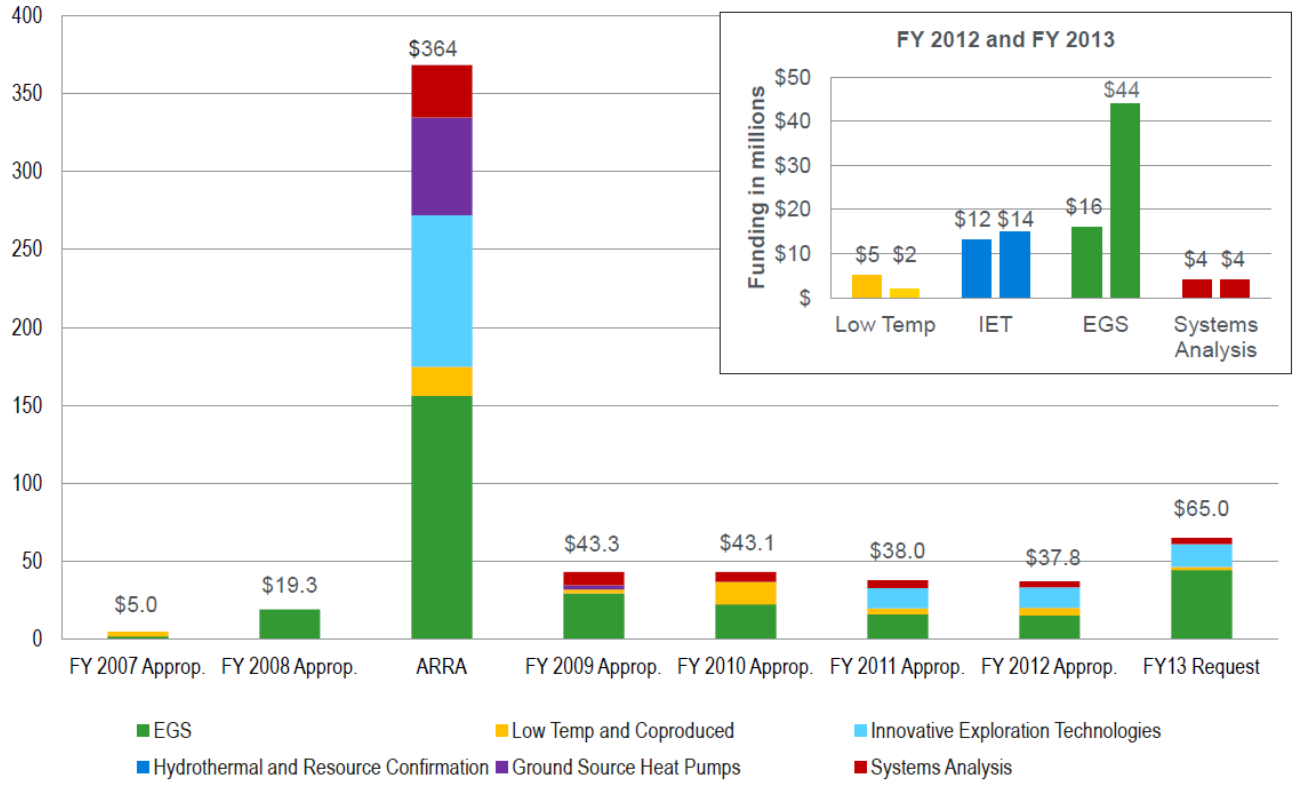


Figure 1.2. *Geothermal Technologies Office Budget History*

The GTO mission is to establish geothermal energy as a significant contributor to America's future electricity generation by partnering with industry, academia, and the national laboratories to discover new geothermal resources; research, develop, and demonstrate innovative technologies; and facilitate commercialization.

GTO's current goal is to reduce the cost of geothermal energy to be competitive with conventional sources of electricity and accelerate the development of geothermal resources.

To achieve this goal, the office's strategy is to:

- Accelerate near-term hydrothermal growth by:
  - Decreasing exploration risks and costs;
  - Lowering levelized cost of electricity (LCOE) to 6¢/kWh by 2020;
  - Accelerating the development of 30 GWe of undiscovered hydrothermal resources.
- Secure the future with EGS by:
  - Demonstrating that EGS is technically feasible by 2020;
  - Lowering EGS cost of electricity to 9 cents/ kWh by 2020 and 6 cents/kWh by 2030;
  - Accelerating the development of 100 GWe by 2050 (MIT).

Additionally, the office has an increased focus on the identification of new geothermal prospects, regulatory roadmaps and streamlining, an EGS Field Laboratory to optimize EGS, strategic mineral assessments, and increasing funding leverage, however these areas were not reviewed in FY 2012.

The Geothermal Technologies Office has a total portfolio of more than 270 research, development, and demonstration projects underway (with very few exceptions) with academia, the national laboratories, and in cost-sharing partnerships with industry. The office also supports some deployment activities designed to move advanced technologies into the market and conducts a broad range of systems analysis that support and direct office activities and provide needed knowledge bases.

It should be noted that ground source heat pumps are no longer part of GTO. Additionally, the previously mentioned GTO subprogram areas were further divided into several additional technology-specific areas for purposes of the peer review. Because there are numerous specialized or niche technologies employed by GTO, further division of the subprogram areas was necessary in order to assign reviewers (based upon their background and technical expertise) to evaluate projects in their area of expertise.

2.0 Geothermal Technologies Office Peer Review Process

Peer reviews are one of the standard mechanisms for assessment of highly complex and/or technically challenging projects and programs and are widely used in industry, government, and academia. Objective review and advice from peers provide DOE managers, staff, and researchers with a powerful and effective tool for enhancing the management, relevance, and productivity of all Office of Energy Efficiency and Renewable Energy (EERE) research, development, demonstration, deployment, and supporting business management programs. The 2004 EERE Peer Review Guide[1] defines a peer review as:

> *A rigorous, formal, and documented evaluation process using objective criteria and qualified and independent reviewers to make a judgment of the technical/scientific/business merit, the actual or anticipated results, and the productivity and management effectiveness of programs and/or projects.*

This definition is drawn from the U. S. Department of Energy, the National Academy of Sciences (NAS), the White House Office of Management and Budget (OMB), the U.S. General Accounting Office (GAO), and other federal agencies and institutions. It clearly distinguishes in-progress peer review from other types of peer review, such as merit review to select winners of competitive solicitations or readiness (stage gate) reviews to determine when a technology is ready to move to the next phase of development, as well as from other management activities such as quarterly milestone reviews or budget reviews.

Peer review is based on the premise that the people best qualified to judge a program or project are experts in that or related fields of knowledge. Seeking advice from experts is useful in all aspects of managing a program to add to the perspective and broaden the knowledge of a program manager. Peer review is essential in providing robust, documented feedback to EERE program planning. Peer review also provides management with independent confirmation of the effectiveness and impact of its programs. Knowledge about the quality and effectiveness of current projects and programs is essential in designing future programs and/or enhancing existing efforts.

GTO conducted a rigorous peer review as a four-day event from May 7 to 10, 2012 at the Westin Westminster Hotel located in Westminster, CO. The purpose of the review was to evaluate DOE-funded projects for their contribution to the mission and goals of the office, and to assess progress made against stated project objectives. To assist in identifying the reasons for success or shortfalls in outcomes, reviewers also evaluated the merits of the technical and managerial approaches of the PIs.

Principal Investigators (PIs), representing a total DOE investment of over $460 million, came together to report progress and results. Peer reviewers included both unaffiliated, unconflicted PIs funded under EERE-GTO programs and experts in geothermal or related technologies who do not and have not received EERE-GTO project funding. In addition to the formal review, this event provided an excellent opportunity for the geothermal community, both funded researchers and stakeholders, to share ideas and solutions to address the challenges facing the geothermal industry.

The 2012 Peer Review meeting was organized into four tracks into which the reviewed projects were grouped:

- Track 1 - High Temperature Tools, Drilling Systems, and Zonal Isolation; and Systems Analysis, Resources Assessment, Data System Development and Population, Education
- Track 2 - Enhanced Geothermal Systems Demonstrations; Seismicity, Fluid Imaging & Reservoir Fracture Characterization; and Modeling
- Track 3 - Tracers and Tracer Interpretation and Exploration Validation
- Track 4 – Low-Temperature and Co-Production Demonstration; Supercritical Carbon Dioxide; and Working Fluids.

[1] Peer Review Guide, Based on a Survey of Best Practices for In-Progress Peer Review, August 2004

There was no formal review of goals and strategies at the office or track level. However, review panels sometimes offered office-level insights during post-session debriefing. Where such insights were voiced, they are captured in this report (see, especially, Section 3.0).

2.1 Scoring Methodology for Projects Reviewed in FY2012

A total of 169 projects in the Geothermal Technologies Office's portfolio were presented at the review. Out of the 169 projects presented, a total of 115 were evaluated and scored by the reviewers. In addition to the reviewed projects, time was included in Tracks 3 and 4 for presentation of projects too early in their award life to warrant review or for those which had scored highly in previous reviews that the office managers determined additional peer evaluation was not warranted in this annual cycle. Projects included in the "Presentation Only" category will be officially evaluated during the 2013 peer review meeting. Approximately 60 reviewers participated in the peer review process, providing a total of approximately 450 project evaluations (not every panel member reviewed every project within a given track).

In accordance with DOE EERE Peer Review Guide Section 6.0[2], the reviewer submitted both quantitative (i.e., numerical scores) and qualitative (i.e., narrative accounts) evaluations as part of their review of the materials and projects presented. The comments herein are the most direct reflection of reviewer's written evaluations, and where possible have been included verbatim.

Quantitative scores were based on the following four criteria:

- Relevance/Impact of Research;
- Scientific/Technical Approach;
- Accomplishments, Results, and Progress; and
- Project Management/Coordination.

Reviewers were asked to provide numeric scores (on a scale of 1 to 4, with 4 being the highest) for each of the four criteria. A description of the numerical scoring is provided below:

[2] Peer Review Guide, Based on a Survey of Best Practices for In-Progress Peer Review, August 2004

Numerical Scoring Descriptions

4 – Outstanding

The project has made substantial progress and impact on the DOE Geothermal Technologies Office missions and goals. The project has demonstrated outstanding advancement in addressing knowledge gaps and barriers. The project has exceptional impact on factors in geothermal energy development.

3 – Good

The project has made notable progress and impact on the DOE Geothermal Technologies Office missions and goals. The project has demonstrated significant advancement in addressing knowledge gaps and barriers. The project has considerable impact on factors in geothermal energy development.

2 – Fair

The project has made modest progress and impact on the DOE Geothermal Technologies Office missions and goals. The project has demonstrated some advancement in addressing knowledge gaps and barriers; impact is below what could be expected. The project has moderate impact on factors in geothermal energy development.

1 – Poor

The project has made little or no progress and impact on the DOE Geothermal Technologies Office missions and goals. The project has demonstrated little to no advancement in addressing knowledge gaps and barriers; impact is below what could be expected. The project has marginal impact on factors in geothermal energy development.

The criteria were weighted differently across the 10 geothermal technology areas that were included in the 2012 Peer Review Meeting. Table 2.1 below illustrates the weighting of each criterion for each technology area. Scoring weight varies by technology area due to an effort by the office to emphasize an alignment of areas of importance with the nature of the work performed.

Table 2.1 *Weighting of scoring criteria or metrics*

Technology Area	Relevance /Impact of Research	Scientific /Technical Approach	Accomplishments, Results, and Progress	Project Management /Coordination
Enhanced Geothermal Systems Demonstrations	20%	25%	40%	15%
Exploration Validation	20%	25%	40%	15%
High Temperature Tools, Drilling Systems, and Zonal Isolation	20%	30%	40%	10%
Low-Temperature and Co-Production Demonstration	20%	25%	40%	15%
Modeling	20%	30%	40%	10%
Seismicity, Fluid Imaging, and Reservoir Fracture Characterization	20%	30%	40%	10%
Supercritical Carbon Dioxide	20%	30%	40%	10%
System Analysis, Resource Assessment, and Education	20%	30%	25%	25%
*Data Systems Development and Population**	*15%*	*30%*	*30%*	*25%*
Tracers and Tracer Interpretation	20%	30%	40%	10%
Working Fluids	20%	30%	40%	10%

**Data Systems Development and Population falls into the Systems Analysis, Resource Assessment, and Education technology area; however these projects were evaluated based on a different weighting scheme.*

Reviews were conducted by different individual reviewers. For each project, a **weighted average score** was calculated (from the combined scores of individual reviewers) for each of the four aforementioned criteria. The weighted average score is an average in which each metric that is being averaged is assigned a weight. The weightings determine the relative contribution of each metric to the average. Weightings are the equivalent of having that many like items with the same value involved in the average.

In this manner, a project's weighted average score can be meaningfully compared to that of another project. The following formula, where x = score and y = weight, was used to calculate the weighted average score:

Calculation:

{(x1*y1) + (x2*y2) + (x3*y3) + (x4*y4)}= total
{(4*.20) + (3 *.40) + (4*.15) + (4*.25)} = total
{(.8) + (1.20) + (.6) + (1)} = 3.6 weighted average score

Scores and comments were submitted by reviewers into the Peer Review Management Information System (P2RMIS). P2RMIS is an online database system that allows for real-time tracking of the review process. P2RMIS interfaces with external electronic application systems, facilities online meeting planning and logistics, and supports evaluations, reviews and scoring.

The qualitative analyses provided in this report are individual comments made by the reviewers, as consolidated by the U.S. DOE for brevity and merging comments with commonalities, and do not represent consensus opinion on the subject matter.

3.0 Technology Area and Program Level Findings and Recommendations of the Peer Review Panels

Below are programmatic findings and recommendations that were compiled from the comprehensive collection of reviewer comments. In many tracks, independent reviewers provided similar comments, which are presented as one collective thought in this section. The comments presented below are focused toward the office's technology areas and away from an individual project. All reviewer comments for an individual project were provided to that project's Principal Investigator (PI) for response. The comprehensive list of reviewer comments and PI responses can be found in Appendix A.

While the peer reviews focused on individual projects, the comments below provide a higher-level indication of strengths and barriers to execution within the named technology areas. Some comments, shown here in particular Technology Areas/Panels, arose during discussions in more than one Panel (e.g. the desire expressed by reviewers to have access to the original project proposals, and concerns about the appropriate role of proprietary information in government-sponsored research may have implications for the conduct and review of government-sponsored research even beyond GTO).

Enhanced Geothermal Systems (EGS) Demonstrations

- Overall, projects in this technology area have been well selected and the office has a good diversity of projects between general stimulation techniques versus greenfield innovation.
- The step-out projects are the logical approach to take, will lead to further advancement, and are most likely the future of EGS development.
- In regards to the test site, the office needs to be careful about upsetting industry by blocking off wells for non-commercial use.
- People seem to like the idea of the test site not being a single site. The office should use sites that are actual geothermal sites (volcanic, existing fractures, sedimentary, metamorphic, hot, etc.).
- The office should take a postmortem look at all projects for lessons learned from failures and successes.
- The office should consider rebranding the Technical Monitoring Team to emphasize its role in coaching PIs for success rather than judging project progress.

Exploration Validation

- The most useful projects funded in this technology area are those that are based in fundamental geology and mapping.
- The office should note that some of the projects funded in this technology were lacking geochemistry.
- The office would benefit by transferring some of the laboratory methods to actual drill rigs. This would allow for more timely answers and would expedite the decision making process.
- Permitting appeared to be a big road block for Exploration Validation projects.
- The office should find a uniform way to have Principal Investigators report the number of jobs created by their projects.
- The office should explore options for removing funding from projects that have not made any progress within a reasonable timeframe.

High-Temperature Tools, Drilling Systems, and Zonal Isolation

- There are many localized, small geothermal plays that are still available within the Great Basin that could be analyzed with existing, relatively Low Temperature televiewers from the oil and gas industry.
- A side-by-side test of the Sandia and Baker Hughes televiewers in the same well in rapid succession would be interesting.

- The application and relevance of the proposed technology was not clear in all projects and/or not recognized by the presenters.
- The office is only funding a few projects within the Zonal Isolation technology area.
- The office should consider creating a working group to assess the current state-of-the-art for fiber optic technology.
- The academic institutions need a commercial/industry partner.
- The office needs to cast tool development as an objective of this technology area.
- The office should collect and publish a set of real world needs for targeting a bigger EGS project. Part of the impetus might be to put together the needs and guidance for integration efforts.
- The geothermal community is doing a much better job of sharing data than it has in the past.

Low-Temperature and Co-Production Demonstration

- The office has a good collection of projects with good data to collect going forward. The office needs to ensure that this data is not lost.

Modeling

- No key findings comments were received for this technology area.

Seismicity, Fluid Imaging, and Reservoir Fracture Characterization

- No key findings comments were received for this technology area.

Supercritical Carbon Dioxide

- Principal Investigators should investigate permitting issues before applying for funding. Many of the oil and gas partners had a significant learning curve on the National Environmental Policy Act (NEPA) process, etc.
- The office needs to avoid duplicative efforts in the Supercritical Carbon Dioxide Area.

Systems Analysis, Resource Assessment, Data System Development, and Population, and Education

- This work has exceptional relevance to the mission and goals of the GTO. A reliable resource assessment is the starting point for a well-founded, productive R&D program, and the means by which industry can assess the developmental potential of various resource areas.
- Developing and implementing a way to track the impacts of these projects should be a continuing goal of the GTO. The use of Specific, Measurable, Attainable, Relevant, and Timely (SMART) objectives must be complemented, and more teams should use this method.
- The development of consistent standards for data structure and metadata is a strong step towards making the discovery of distributed data resources a success for the larger NGDS.
- The Life Cycle Analysis projects provide an important baseline for understanding the environmental and economic impacts of geothermal energy. These projects also meet the goals of the GTO by improving the understanding of water uses versus the quality of various geothermal technologies.
- The office should develop an overall solution or protocol for accepting data, especially after the project periods have ended.

Tracers

- The office should focus on “environmental” tracers (such as naturally occurring dissolved minerals) in addition to synthetic tracers.
- The office should develop specific technical targets for the tracer technologies projects.
- Full development of the tracers should be completed prior to field testing. The emphasis on field testing may have been encouraged by generic Funding Opportunity Announcement (FOA) language, applicable to all research topic areas.

- The office should integrate tracers with geochemistry and reservoir engineering. Reactive tracers seem to focus on fracture surface area while reservoir engineers focus on flow of geothermal fluids.

Working Fluids

- No key findings comments were received for this technology area.

4.0 Project Scoring Evaluation Analysis and Results

As part of the 2012 U.S. DOE Geothermal Technologies Office (GTO) Peer Review, 115 projects in 10 technology areas were reviewed by approximately 60 reviewers. Analysis was performed based on project scores to determine if a correlation existed between the project scores and various project attributes. Project attributes considered for this analysis include total project funding, project scoring metric results, panel category, reviewer profile, project age, and standard deviation. These attributes were collected from the information given by the Principal Investigators in their presentation material. Correlation between project scores and project attributes (i.e., total project funding, panel category, etc.) could be either positive or negative. Please note that the correlation results are presented later in this section of the report.

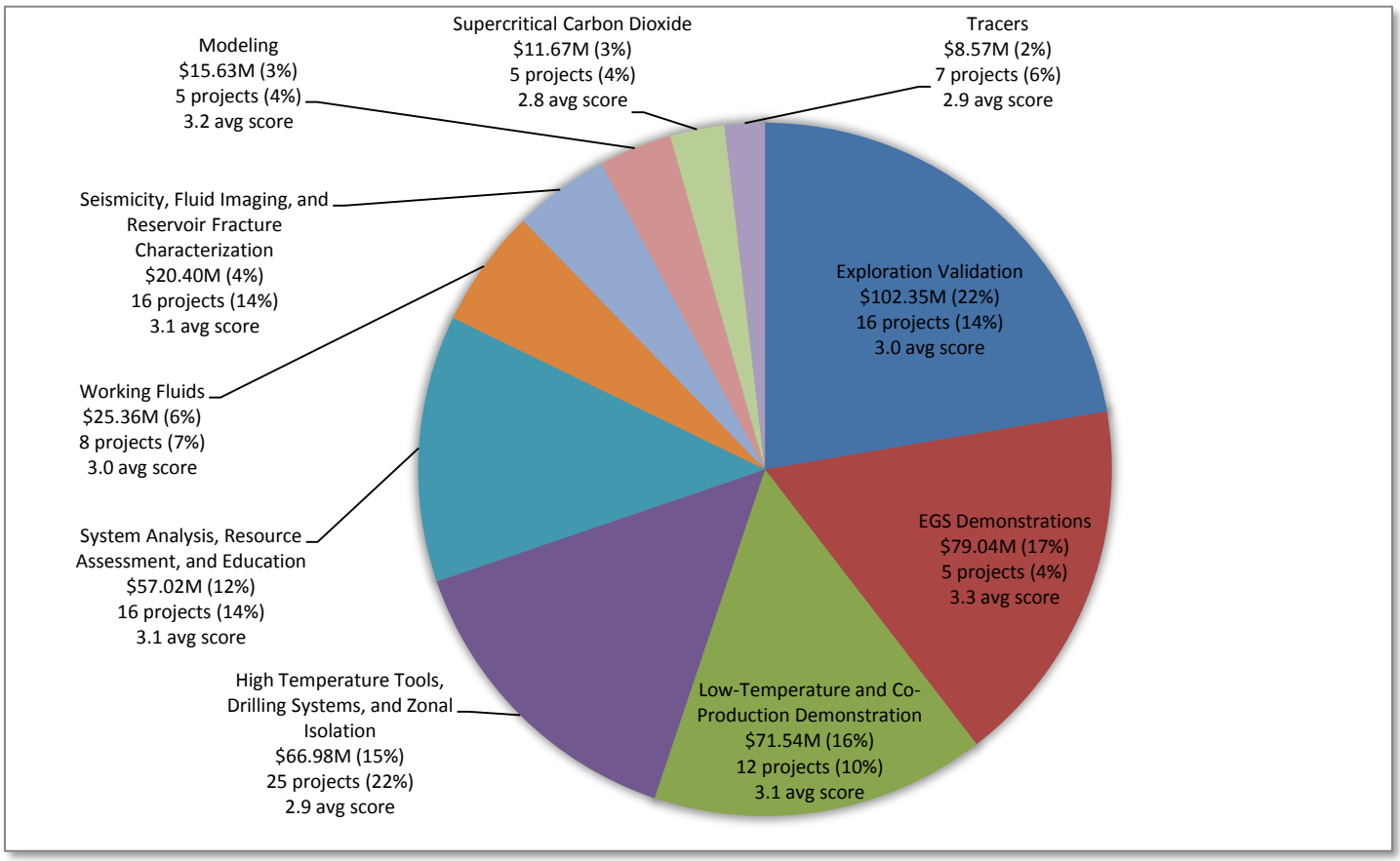


Figure 4.1. *Total Project Funding*

The budgetary attributes pertain to the entire project duration and are not indicative of or limited to project spending in the fiscal year of the peer review. The projects reviewed in 2012 totaled nearly $460 million in total project funding, and as seen in Figure 4.1, there is a diverse distribution of project funding within the technology areas of GTO. The office's portfolio includes demonstration, validation, and operation projects, which, due to the large-scale construction typically required for these types of research, tend to have larger budgets than the projects with a research focus targeted at specific geothermal industry needs or research areas. The total project funding shown in Figure 4.1 includes funding from the DOE as well as cost-share funding, and the statistics shown on the chart represent the aggregate of all the projects within a technology area. Further project funding analysis is shown in Figure 4.11.

The charts in Figures 4.2 – 4.6 were generated from the peer review scoring data across the entire GTO, and the charts show the distributions of reviewer scores for all four scored metrics of the review as well as the weighted average score. It should be noted that, as shown in Table 2.1, the weighted average score calculation varies slightly between technology areas, so conclusions drawn from comparing technology areas should take this into account. Figures 4.2 – 4.5 show narrow distributions around the top of the scoring range, where each of the four metrics were scored as a "3" (Good) or "4" (Outstanding) for 74% to 82% of all projects. DOE takes great care in project selection and accurate project reporting, so it is not surprising that, in general, projects were scored highly. Interestingly, the weighted average score chart shown in Figure 4.6 has a wider distribution than the individual project metric charts. This indicates that, while each individual metric received high scores for many projects, it was uncommon for individual projects to score above the average for all four scoring metrics. Programmatically, this disparity of scoring metric results within individual projects offers potential opportunities to determine overall best practices and areas for improvement that could be communicated to Principal Investigators to continually improve methodology and project management.

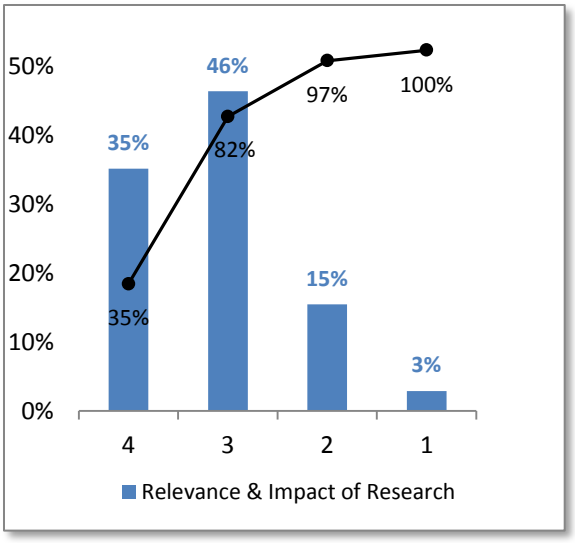


Figure 4.2. *Relevance & Impact of Research*

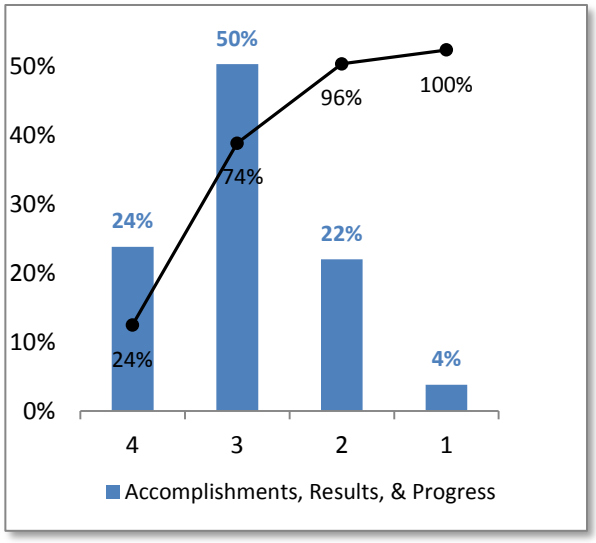


Figure 4.3. *Accomplishment, Results, & Progress*

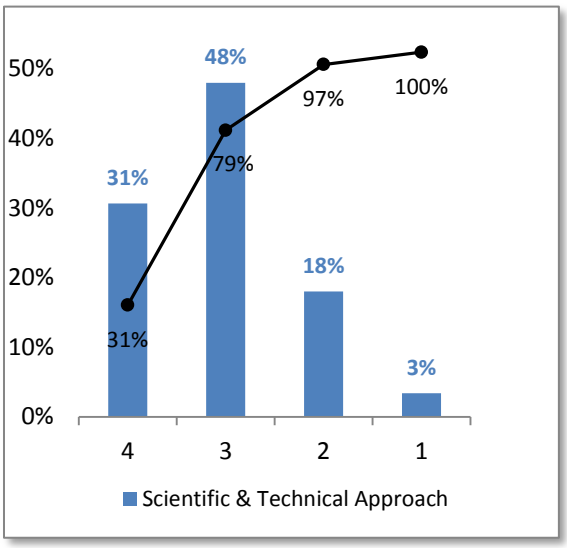


Figure 4.4. *Scientific & Technical Approach*

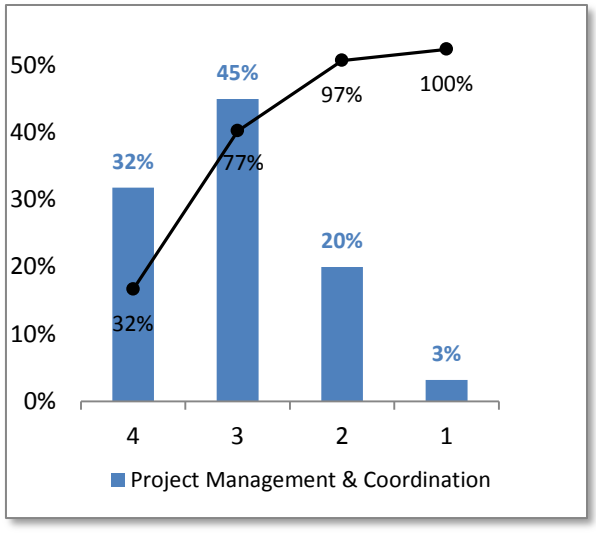


Figure 4.5. *Project Management & Coordination*

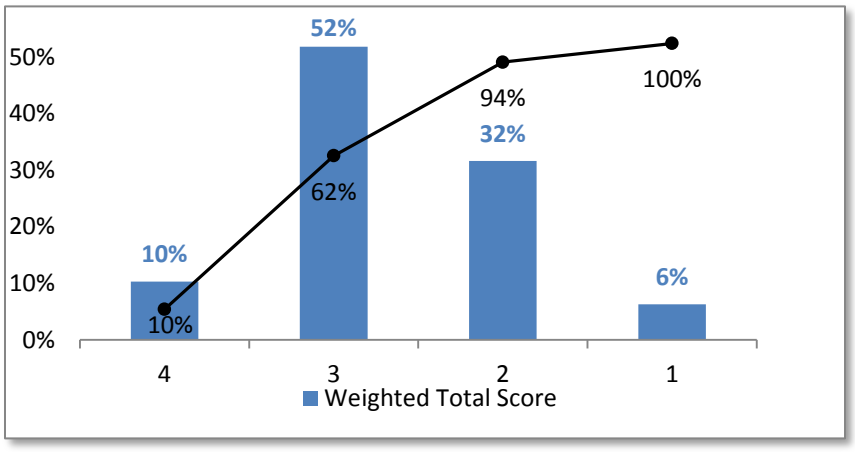


Figure 4.6. *Weighted Total Score*

Analysis was conducted to compare how projects that scored either very high or low in Accomplishments, Results, and Progress (Accomplishments) scored in Scientific and Technical Approach (Approach) and Project Management. Projects that scored lower in Accomplishments were more likely to score lower in Approach. Twelve projects scored low for Accomplishments and had a range of scores of 1.5-3.0 for Approach, with an average score of 2.4. Similarly, the top 8 high scoring projects in Accomplishments had a range of scores of 3.3-4.0 for Approach, with an average score of 3.7. The correlation between scoring in Accomplishments and Approach was 0.33 for low projects and 0.43 for high projects. The averaged correlation for Accomplishments and Approach was 0.36.

It was likely that projects which scored higher or lower in Accomplishments also scored higher or lower in Project Management. The 12 projects scoring low in Accomplishments had a range of scores of 1.5-3.3 for Project Management, with an average score of 2.2. Similarly, the top 8 projects scoring high in Accomplishments had a range of scores of 3.3-4.0 for Project Management, with an average score of 3.6. The correlation between scoring in Accomplishments and Project Management was 0.35 for low projects and 0.73 for high projects. The averaged correlation for Accomplishments and Project Management was 0.54.

Quantitative analysis was used to perform a detailed comment analysis targeted at the projects scoring high or low for Accomplishments. The findings of this qualitative analysis support those from the quantitative analysis. It was found that projects scoring high or low in Accomplishments typically had key elements that influenced the scores for Approach and Project Management. As one might expect, the predominant element for driving these scores was the quality, accuracy, plausibility, and/or transparency of results.

Common themes of projects with low scores in Accomplishments include (1) changes in project approach, (2) an errant initial approach, (3) a lack of experience or key expertise, (4) slow progress, (5) a lack of clearly defined project goals, requirement, plans, schedules, budgets, and/or approaches, (6) reviewer disagreement with the engineering or scientific methodology, (7) issues with project management, (8) insufficient review of available literature, research, tools, expertise, and/or approaches, (9) a disconnect or a lack of experimental, field-tested, and/or real-world data, (10) staff and/or funding changes during the project period, (11) questionable or lacking field testing, data validation, and/or site selection, (12) a project scope that is inappropriate or has expanded detrimentally, (13) insufficient project funding, and/or (14) insufficient collaboration. In some cases, these factors were outside of the project team's control, such as team members unexpectedly leaving or unanticipated changes in funding. Permitting difficulty was common with projects where site selection was a negative aspect, and this lesson learned could be important to carry forward as one reviewer noted a potential solution – "In general, for all GTO funded projects that propose a field test site, a backup test site should also be identified." It should also be noted that some projects received low scores for Accomplishments when, despite being on schedule, were not at a point where results are available, and other projects with positive results received low scores due

to vague results where poor presentation or proprietary concerns impeded clear dissemination of data. Low scores, by themselves, do not always indicate poor projects. The comments must be examined to determine whether scores are low due to substantial structural issues in the project, or if the scores are a function of the commercial readiness level or surmountable barriers to project success identified by reviewers.

Common themes of projects scoring highly in Accomplishments include (1) good collection, consolidation, correlation, and/or visualization of large data sets, (2) sufficient review of existing literature, tools, methodology, and/or data, (3) obvious technology transfer efforts or capability, (4) application of industry or project lessons learned, (5) strong project management and/or technical team, (6) strong project comprehensiveness or experiment methodology, (7) accomplishments that obviously further the industry, (8) ability to overcome barriers, (9) novel project component, and/or (10) actively avoiding redundancy with other work. The elements of this list with the highest frequency are a strong project management and/or technical team and accomplishments that further the industry. This is congruent with the most common themes of low scoring projects where the usefulness of the results and the creativity of the project teams in solving problems were key attributes in reviewer scoring. Many of the high scoring projects will provide results immediately useful to furthering the industry whereas low scoring project results were not as mature. It is anticipated that as the low scoring project results progress towards maturity, their project scores will improve. The utility of this analysis is to provide key challenges faced by low scoring projects and best practices of the high scoring projects so that these lessons learned can be applied by the office to continually improve all projects in the office portfolio and avoid common pitfalls.

Additional analysis was performed on the reviewer profile of projects to constrain scores; the reviewer profile can include direct factors such as number of reviewers per project or reviewer affiliations, or the profile can include various external factors such as time of day of the project review or proximity to breaks in the review schedule. Cursory analysis of some external factors yielded no correlation to these factors and the resulting project scores. Figures 4.7 and 4.8 focus on direct factors and show the scatter plot of weighted average scores versus the number of reviewers on the panel of a specific project and the weighted average score versus reviewer affiliations, respectively. As required by the EERE Peer Review Guide, each project was reviewed by a minimum of three reviewers, and Figure 4.7 shows that the number of reviewers on a given project had little effect on the weighted average score. In all cases the distributions centered around an average of 3.0.

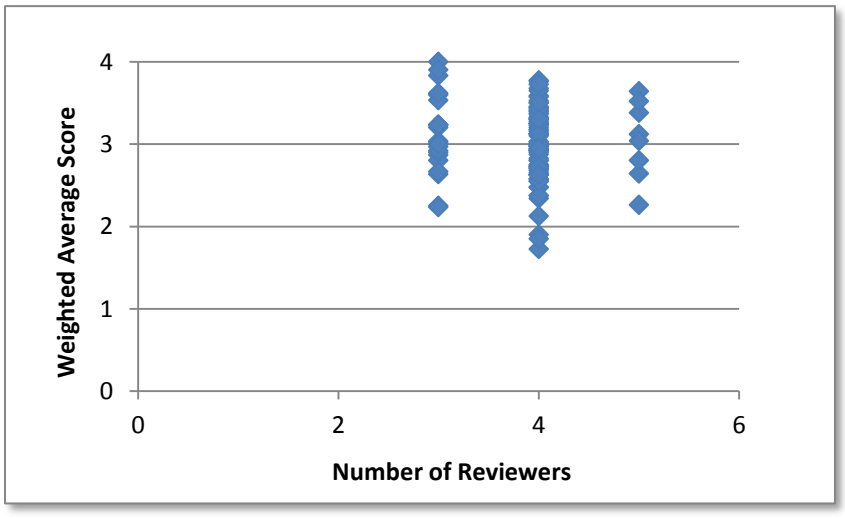


Figure 4.7. *Weighted Average Score vs. Number of Reviewers*

Figure 4.8 shows the scores from reviewers in five affiliation groups – Academia (87 total reviews performed), Government (29 total reviews), Industry (101 total reviews), National Lab (126 total reviews), and Blank (104 total reviews) – presented in ascending order. Regarding the affiliations, nine National Labs were represented on the various panels, Government officials from local, state, and national organizations and agencies were included, and industry representatives from private companies, industry organizations, and consultants sat on review panels. Industry and undesignated or "blank" reps (who are thought largely to be consultants) scored 2/3 of projects "good" or better. Reviewers who left their affiliation blank scored projects the highest with an average of 3.1, which was only 0.005 higher than Industry reviewer's average of 3.095. Government and National Labs reviewers scored only 1/3 of projects "good" or better. Reviewers from academia were a little more lenient in their scoring than the government reviewers, but less so than their industrial colleagues. Reviewers from academia, government, and National Labs scored projects the lowest with averages of 2.91, 2.92, and 2.98 respectively. Reasons for these differing perceptions are not known.

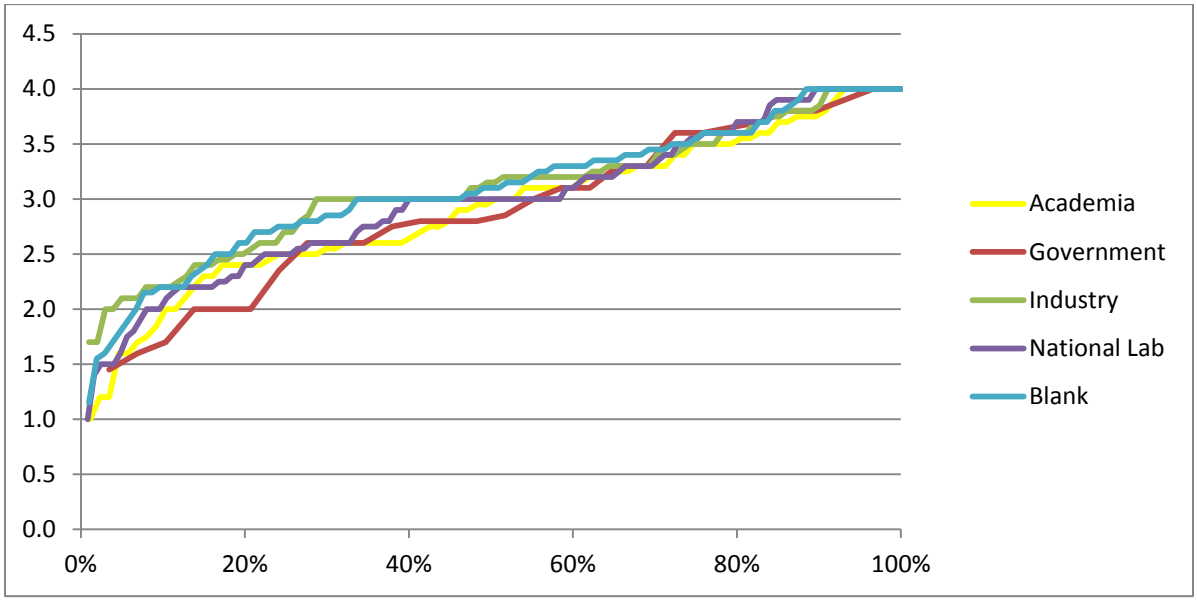


Figure 4.8. *Weighted Average Score vs. Reviewer Affiliation*

Figure 4.9 shows the year-to-year scores of projects in the GTO portfolio. Only 74 projects were reviewed in both 2011 and 2012. These can be identified in Figure 4.9 as the projects that have a line between the two data points. Green lines indicate that a project's score rose from 2011 to 2012 whereas red lines indicate projects that received a lower score in 2012 than they had previously in 2011. Overall, projects were scored lower in 2011 than in 2012 with average weighted scores of 2.81 in 2011 and 3.02 in 2012. In 2012, there were 38 projects reviewed that were not reviewed in 2011, and in 2011, there were 72 projects that were not reviewed in 2012. The EERE Peer Review Guide requires that projects are reviewed every two years, so with EERE Programs that perform annual reviews it is common that some subsets of projects are reviewed every other year, while other subsets are reviewed every year with considerable migration between subsets. Out of the 74 projects that were reviewed in both 2011 and 2012, 53 improved their scores by an average of .482 with a maximum improvement of 2.25. Twenty-one (21) projects saw a decline in their scores with an average difference of .388, with a maximum decline of 1.43.

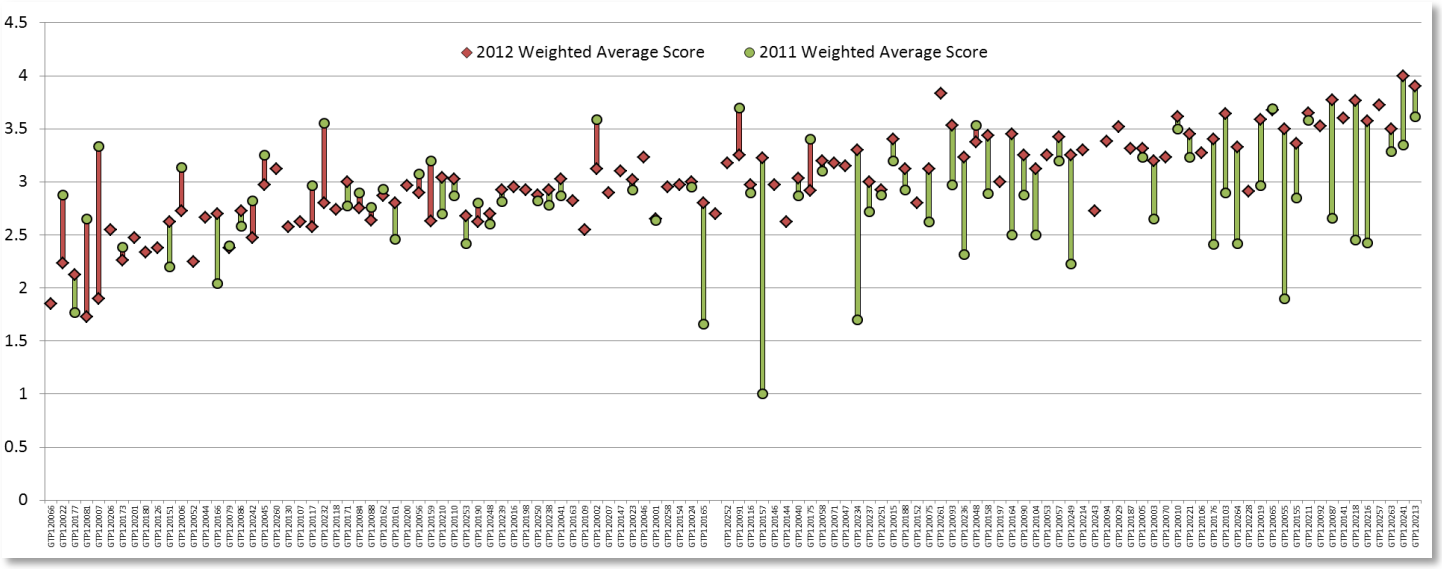


Figure 4.9. *2011 Weighted Average Scores vs. 2012 Weighted Average Scores**

Figure 4.10 shows a comparison of all projects categorized by panel. While direct comparisons should not be made due to slightly different weighting structures between panels, it is obvious that each panel had similar averages and included both high and low performing projects. It is also observed that few projects fell outside of one standard deviation with only nine projects below one standard deviation and six projects above one standard deviation. No project scored less or more than two standard deviations from the weighted average score.

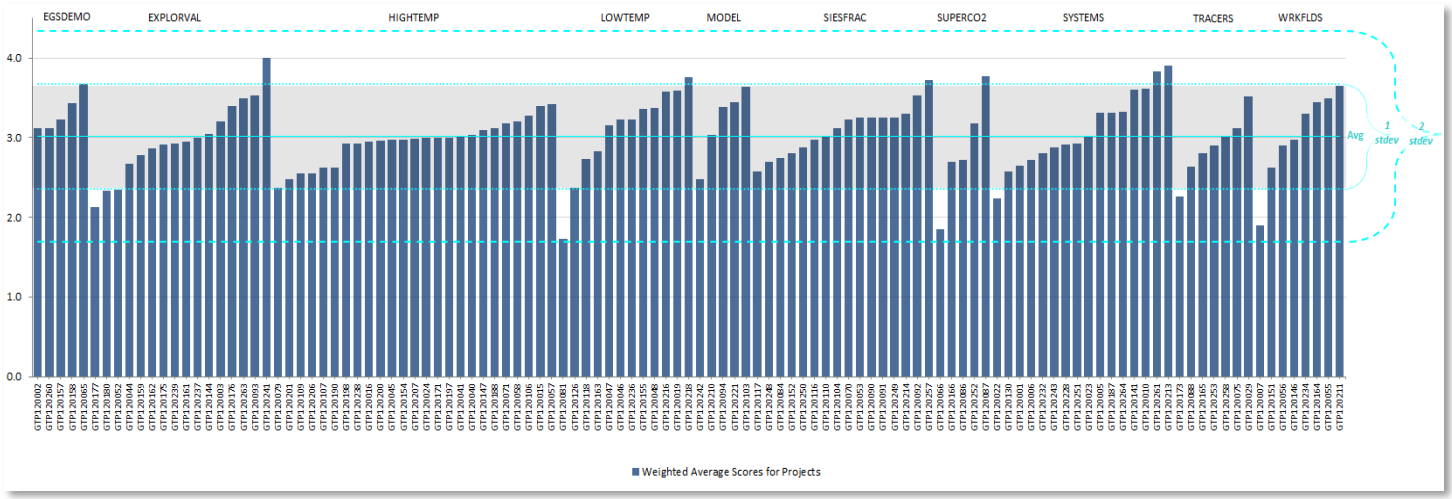


Figure 4.10. *Weighted Average Scores – Panel Comparison**

**Please see Appendix B for the correlation of project ID numbers to project title and organization.*

In general, demonstration projects, which have high budgets due to their large-scale physical nature, were scored above the office average. EGS Demonstrations was the top performing panel with all projects scoring above the office average. These large-budget projects (average budget of $15.8M is the highest in the office) were generally praised by reviewers for site diversity and advancing the industry by putting concepts into practice. Both the Supercritical Carbon Dioxide and the Tracers and Tracer Interpretation panels scored less than the office average for more than half of the reviewed projects. The Tracers and Tracer Interpretation projects (average budget of $1.22M is the lowest in the office) and the Supercritical Carbon Dioxide projects (average budget of $2.33M is the third lowest in the office) are experimental in nature as opposed to high-scoring demonstration projects. Reviewers concerns with these projects centered around potentially inconclusive results, unclear technology transfer pathways, failures to address permitting barriers before receiving funding, and premature field testing. These results may indicate that as technology areas move closer to commercialization, fewer barriers to success exist, which result in higher scores, whereas technology areas that are experimental still have challenging and significant barriers before commercialization can be achieved. As shown by Figure 4.9, continued research and peer assessments could help in the identification and mitigation of barriers, which will improve scoring results and, more importantly, advance the state of the technology.

Further analysis on total project funding is shown in Figure 4.11. The x-axis represents a project's average weighted score and the y-axis represents a project's "Relevance" score. The intervals from the axes represent standard deviations from the average. The magnitude of the bubbles indicates the funding level of the projects. From Figure 4.11, we see that there is no obvious correlation between the weighted average score of the project, the relevance of a project, and the total funding for the project. It is seen that large budget projects are not more or less likely to perform well based on project evaluations. This trend also holds true for the relevance of a project. Project budget information was included in the review materials, and based on the equal distribution in Figure 4.11; it does not appear that budget information biased the scoring of the reviewers. While qualitative analysis of the trends in reviewer scores and comments is performed in the preparation of this report, this simple quantitative analysis further demonstrates the independent nature of the GTO peer review process.

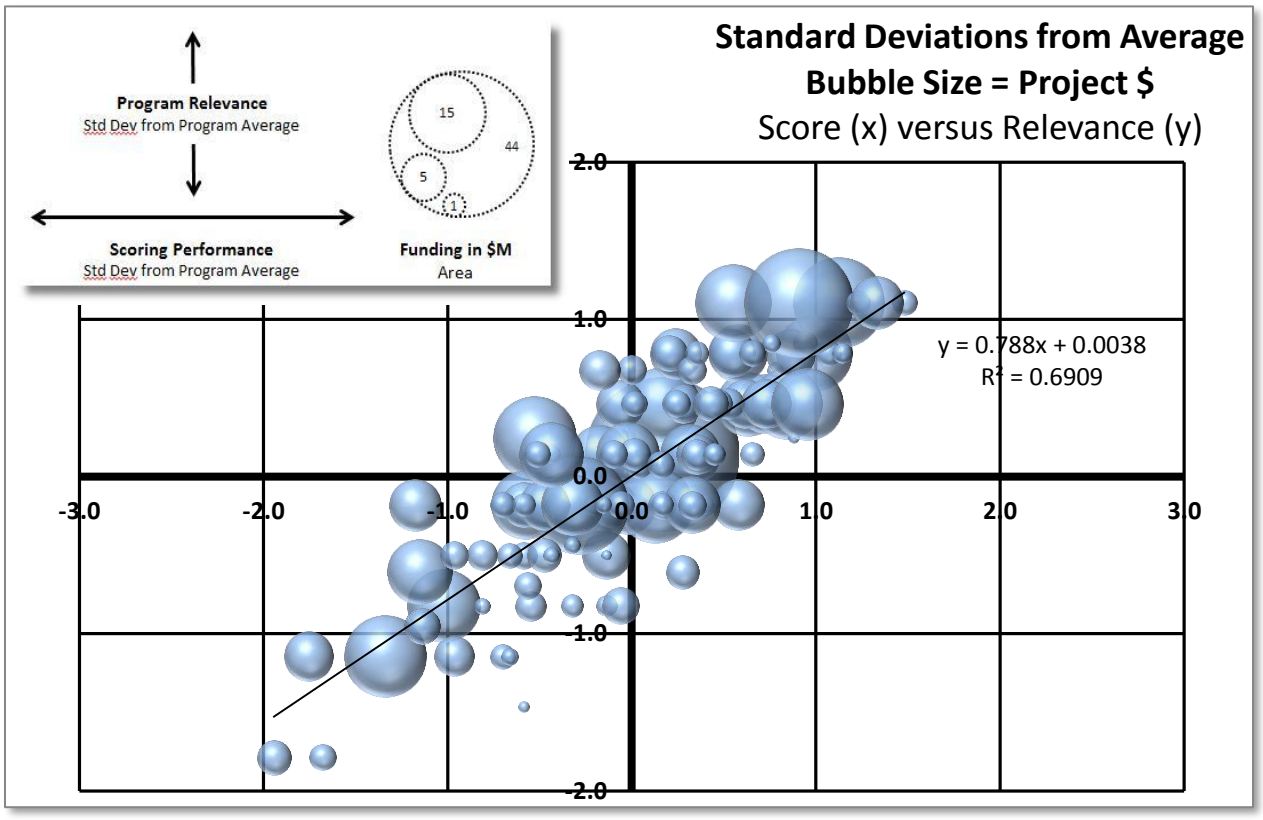


Figure 4.11. *Weighted Average Score versus Relevance – Project Funding*

Figure 4.12 uses age rather than budget for the bubble magnitude, which shows a clear standard deviation distribution of projects from the average "Relevance" score and the average weighted score. The distinct bands of projects seen at various standard deviation levels from the Relevance score are an artifact arising from the required use by reviewers of whole numbers on a four point rating scale. Programmatically, nonetheless, these bands can be analyzed to determine why projects of similar quality are perceived as more or less relevant, and they can be used to determine areas of improvement or best practices for projects with similar relevance but very different weighted average project scores.

Like the total project funding chart in Figure 4.11, Figure 4.12 compares projects based on the age of a project to determine if there is potential for reviewer bias based on a project's duration. In 2011, a scatter plot of project lifecycle was shown to indicate no correlation between the percentage of completion for a project and the average weighted score. While Figure 4.13 does not show a strong correlation between project age and the relevance or average weighted score of a project, it should be noted that all of the oldest projects (largest bubbles) scored above the review average and only one was below the review's relevance average. It is not surprising that older projects tended to score slightly higher, as most projects with a long-standing are either projects with a demonstrated history of accomplishments or are long-term research projects with missions essential to furthering the geothermal industry.

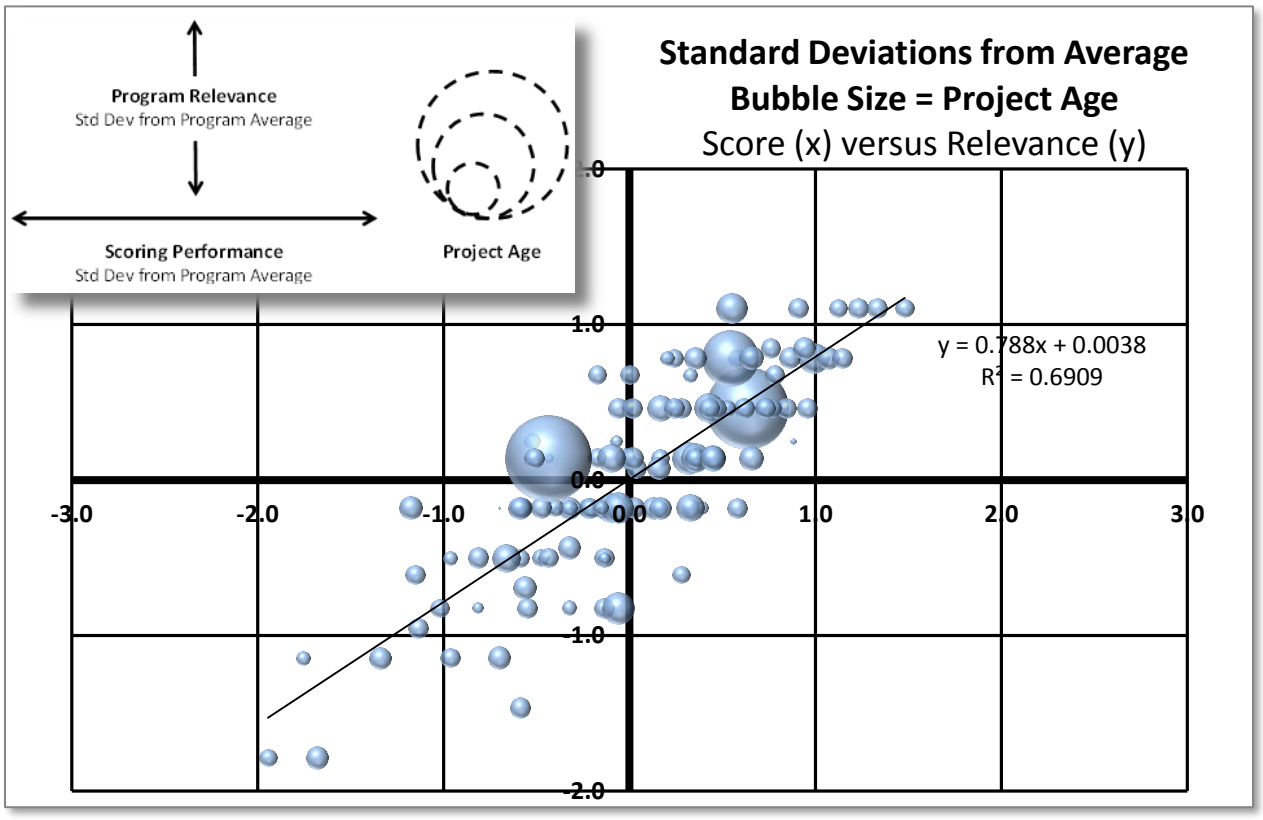


Figure 4.12. *Weighted Average Score versus Relevance – Project Age*

The following subsections describe the analysis of individual project scoring for each technology area included in the 2012 Peer Review. Also included in these subsections are callouts containing general or overview comments made by expert reviewers for each technology area. Detailed reviewer comments on individual projects and Principal Investigator responses to reviewer comments are included in Appendix A. Please see Appendix B for the correlation of project ID numbers to project title and organization.

4.1 Enhanced Geothermal Systems (EGS) Demonstrations

Enhanced Geothermal Systems (EGS) are engineered reservoirs created to produce energy from geothermal resources that are otherwise not economical due to a lack of water and/or permeability. EGS technology has the potential to unlock the vast amount of heat and energy located at depths accessible to current and future drilling technologies. This is a strategic domestic resource that can supply more than 100,000 MWe of clean baseload energy. The technical targets for this technology area are to demonstrate the technical feasibility of EGS at a commercial scale by 2020 and to lower the levelized cost of energy (LCOE) to 6 cents/kWh by 2020. While achieving cost-competitive electricity generation from EGS is a long-term goal, in the near-term, R&D projects will move industry along the learning curve toward technological readiness. The office supports RD&D activities through academia, national laboratories, and industry partnerships that advance EGS technologies.

Key EGS activities are currently focused on:

- Five EGS demonstrations to validate reservoir creation in different geologic conditions;
- Research and development (R&D) funded by the American Recovery and Reinvestment Act (ARRA) and through a FY 2011 Funding Opportunity Announcement (FOA) - Key research areas include: zonal isolation, observation and monitoring tools, well completions, subsurface modeling, and induced seismicity;
- National Laboratory Annual Operating Plan (AOP) projects focused on key office priorities and aligned with core lab capabilities; and
- Technology roadmapping.

The office invests in both near-hydrothermal field and greenfield EGS. The near-hydrothermal field EGS resource includes the areas around identified hydrothermal sites that lack sufficient permeability and/or in-situ fluids to be economically produced as conventional hydrothermal resources. Greenfield EGS is used to describe technology demonstration in geologic settings that have not been previously exploited as hydrothermal resources. Technologies of R&D solicitations have included: temperature-hardened submersible pumps; zonal isolation tools; smart tracers; high temperature, high pressure monitoring and logging tools; advanced seismic analysis for interpretation of fluid flow and induced seismicity; coupled models to predict reservoir development and performance; advanced mineral recovery from geothermal fluids; high temperature cements; directional drilling systems; measurement while drilling tools; well stimulation technologies; advanced fracture characterization technologies; and power conversion. While these technologies are vital to the success of EGS, they also apply to other types of geothermal power generation technologies (e.g., hydrothermal systems). Recent successes include improved reservoir models and the expansion of the suite of high temperature downhole tools available for geothermal energy applications.

The office's EGS R&D efforts are currently focused on reservoir creation and monitoring, as well as FY 2011 awards as they progress to phase II. In FY 2013, an EGS field lab effort will be launched. The goals of this effort are to establish the technical and operational settings and parameters where EGS can be commercially successful.

Table 4.1 provides a list of the EGS Demonstrations projects that were included in the 2012 Peer Review Meeting and their scores. The scoring data are presented graphically in Figure 4.13. Overall, this technology review area had five projects reviewed. The five projects were scored by an average of four reviewers. The weighted average scores had an average, maximum, and minimum value of 3.3, 3.7, and 3.1 respectively. Table 4.1 also shows the job creation numbers to date. The job creation numbers are self-reported by the organization or Principal Investigator. Please refer to Table 2.1 for the weighting criteria used to determine the final scoring, and see Appendix A for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

TABLE *4.1 EGS Demonstration projects*

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field	Geysers Power Company, LLC	Mark Walters	3.8	4.0	3.5	3.5	**3.7**	None Provided
Desert Peak East EGS Project	Ormat Nevada, Inc.	Peter Drakos	3.5	3.5	3.3	3.8	**3.4**	None Provided
Feasibility of EGS Development at Brady's Hot Springs	Ormat Nevada, Inc.	Peter Drakos	3.3	3.3	3.0	3.8	**3.2**	None Provided
Newberry Volcano EGS Demonstration	AltaRock Energy, Inc.	Susan Petty	3.3	3.3	2.8	3.8	**3.1**	10.0
Concept Testing and Development at the Raft River Geothermal Field, Idaho	University of Utah -	Joseph Moore	3.5	3.8	2.5	3.3	**3.1**	None Provided

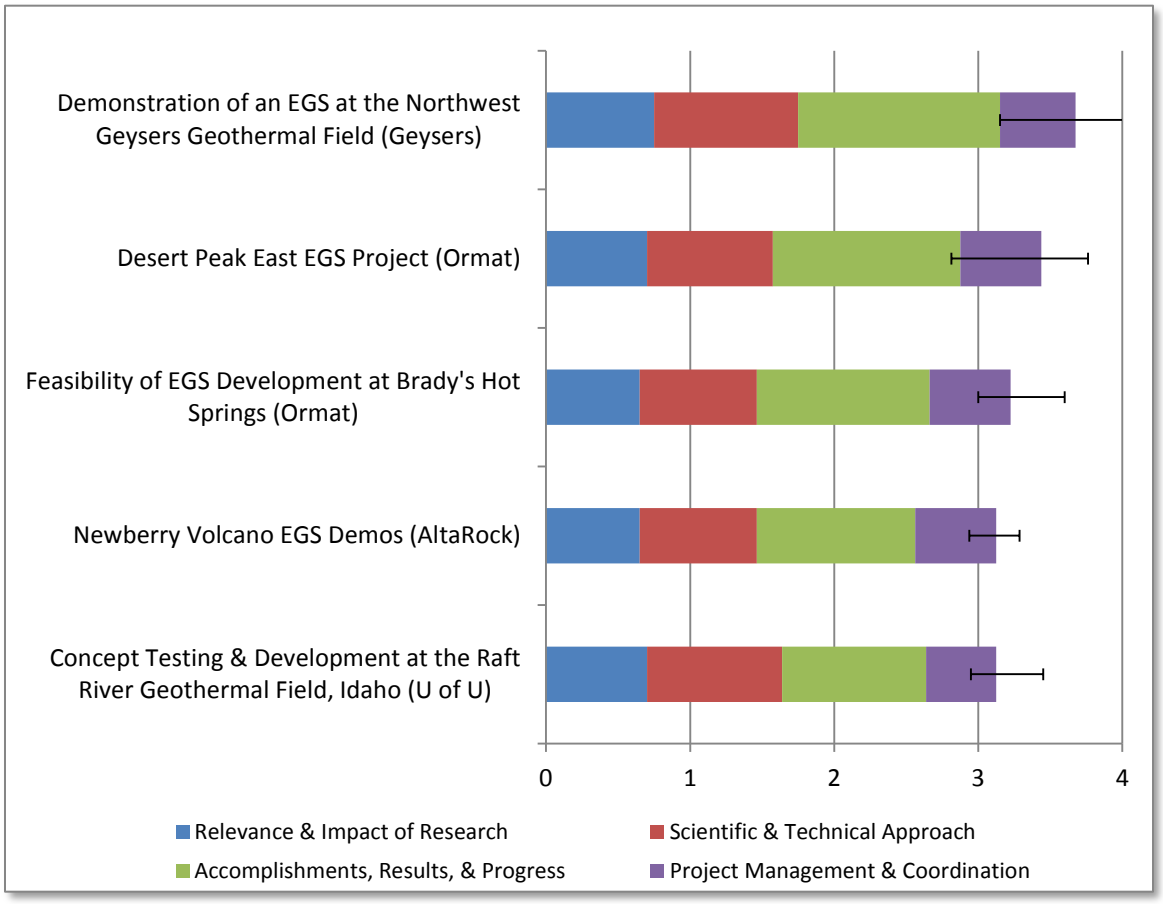


FIGURE 4.13. *EGS Demonstration projects*

Figure 4.13 EGS Demonstration projects. Shown are the scoring metric's weighted contribution to the weighted average score for each individual project. The error bars represent the maximum and minimum weighted average score received by project from individual reviewers.

PROJECT SPOTLIGHT

Demonstration of Enhanced Geothermal System at the Northwest Geysers Geothermal Field, *Geysers Power Company LLC*

Scoring Summary:
This project scored exceptionally high in both the Relevance and Impact of Research (3.8 out of 4.0) and Scientific and Technical Approach (4.0 out of 4.0) categories.

Key Reviewer Comments:
An excellent experiment in a very productive geothermal system. This project is well planned and documented. Much of the background research and project documentation could serve as an operations manual for EGS projects. Returns from this project will be significant, and the knowledge gained will help guide development strategies for the roots of many other high temperature geothermal systems. Strengths are in the areas of high temperature instrumentation, modeling, public outreach, understanding induced seismicity, mitigation of non-condensable gas, and cold water stimulation methods.

4.2 Exploration Validation

High exploration risks and costs are a major barrier to expanded development of the Nation´s hidden hydrothermal resources. To address this challenge the office is developing exploration tools and techniques to create a lower and more predictable risk profile for geothermal development projects. In addition to reducing exploration risk, office exploration RD&D priorities are the following: increase the economic viability of exploration technologies, confirm new hydrothermal resources, and foster useful data for the National Geothermal Data System. Best practices for geothermal exploration, which include geologic research, remote sensing, and both surface and downhole geochemistry and geophysical techniques and how they are used throughout the U.S, are being developed. These best practices will help establish technical and cost targets. Additionally, the portfolio of Recovery Act Exploration Validation projects has the specific goal of confirming 400 MWe of new geothermal resources by 2014.

Significant investment was made in R&D and validation of innovative exploration technologies with the 2009 American Recovery and Reinvestment Act. A funding opportunity in 2011 further added to the portfolio of exploration technology development projects. The office has also been engaged in roadmapping efforts for the past two years. For more successful targeting of exploration wells, technical advancement is needed in several areas: noninvasive geophysical techniques including improved data collection and interpretation of existing techniques; improved invasive measurement tools and techniques; geophysical airborne data gathering techniques; improved geochemical techniques; high resolution remote sensing data and reliable automated processing methods; stress/strain data mapping; multidisciplinary conceptual models; 3-D modeling software; and the creation of case study examples of geothermal systems in different geologic settings. The office is working in cooperation with industry, academia and the national labs to address many of these technology challenges.

Table 4.2 provides a list of the Exploration Validation projects that were included in the 2012 Peer Review Meeting and their scores. The scoring data are presented graphically in Figure 4.14. Overall, this technology review area had 16 projects reviewed. The 16 projects were scored by an average of 3.4 reviewers. The weighted average scores had an average, maximum, and minimum value of 3.0, 4.0, and 2.1 respectively. Table 4.2 also shows the job creation numbers to date. The job creation numbers are self-reported by the organization or Principal Investigator. Please Refer to Table 2.1 for the weighting criteria used to determine the final scoring, and see Appendix A for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

TABLE 4.2 *Exploration Validation projects*

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Characterizing Structural Controls of EGS-Candidate and Conventional Geothermal Reservoirs in the Great Basin: Developing Successful Exploration Strategies in Extended Terranes	University of Nevada, Reno	James Faulds	4.0	4.0	4.0	4.0	**4.0**	15.0
Integrated Chemical Geothermometry System for Geothermal Exploration	Lawrence Berkeley National Laboratory	Nicolas Spycher	3.7	3.7	3.3	3.7	**3.5**	1.3
The Snake River Geothermal Drilling Project - Innovative Approaches to Geothermal Exploration	Utah State University	John W. Shervais	3.5	3.3	3.8	3.3	**3.5**	12.0

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Comprehensive Evaluation of the Geothermal Resource Potential within the Pyramid Lake Paiute Reservation	Pyramid Lake Paiute Tribe	Donna Noel	3.0	3.5	3.5	3.5	**3.4**	20.0
Development of Exploration Methods for Engineered Geothermal Systems through Integrated Geophysical, Geologic and Geochemical Interpretation	AltaRock Energy, Inc.	Joe Iovenitti	2.7	3.3	3.3	3.3	**3.2**	6.0
High Precision Geophysics & Detailed Structural Exploration & Slim Well Drilling	Nevada Geothermal Power Inc.	John Casteel	3.0	3.0	3.0	3.3	**3.1**	5.5
Validation of Innovative Exploration Techniques at Pilgrim Hot Springs, Alaska	University of Alaska Fairbanks	Gwen Holdmann	3.0	3.0	3.0	3.0	**3.0**	2.0
Conducting a 3D Converted Shear Wave Project to reduce exploration risk at Wister, CA	Ormat Technologies Inc.	Patrick Walsh	3.0	3.3	2.7	3.0	**3.0**	66.1
Recovery Act: Detachment Faulting and Geothermal Resources – An Innovative Integrated Geological and Geophysical Investigation of Pearl Hot Spring, Nevada	University of Texas	Daniel Stockli	2.8	3.8	2.8	2.3	**2.9**	None Provided
Innovative Exploration Techniques for Geothermal Assessment at Jemez Pueblo, New Mexico	Pueblo of Jemez	Greg Kaufman	3.0	2.7	3.0	3.0	**2.9**	6.0
Advanced Seismic data Analysis Program (The "Hot Pot Project")	Oski Energy, LLC	Theodore De Rocher	3.0	3.0	2.7	3.0	**2.9**	0.0
Merging High Resolution Geophysical and Geochemical Surveys to Reduce Exploration Risk at Glass Buttes, Oregon	Ormat Technologies Inc.	Patrick Walsh	3.0	2.7	2.7	3.0	**2.8**	5.5
Validation of Innovative Exploration Technologies for Newberry Volcano	Davenport Power, LLC	Albert F. Waibel	3.3	2.7	2.3	2.7	**2.7**	46.0
Direct Confirmation of Commercial Geothermal Resources in Colorado using Remote Sensing and On-Site Exploration, Testing and Analysis	Flint Geothermal LLC	Lee Robinson	2.7	2.3	2.3	2.0	**2.4**	1.0
El Paso County Geothermal Electric Generation Project: Innovative Research Technologies Applied to the Geothermal Resource Potential at Ft. Bliss	Ruby Mountain, Inc	Jon Lear	2.5	2.3	2.3	2.5	**2.3**	None Provided
Alum Innovative Exploration Project	Ram Power Corp.	Clay Miller	2.3	3.0	1.8	1.5	**2.1**	0.0

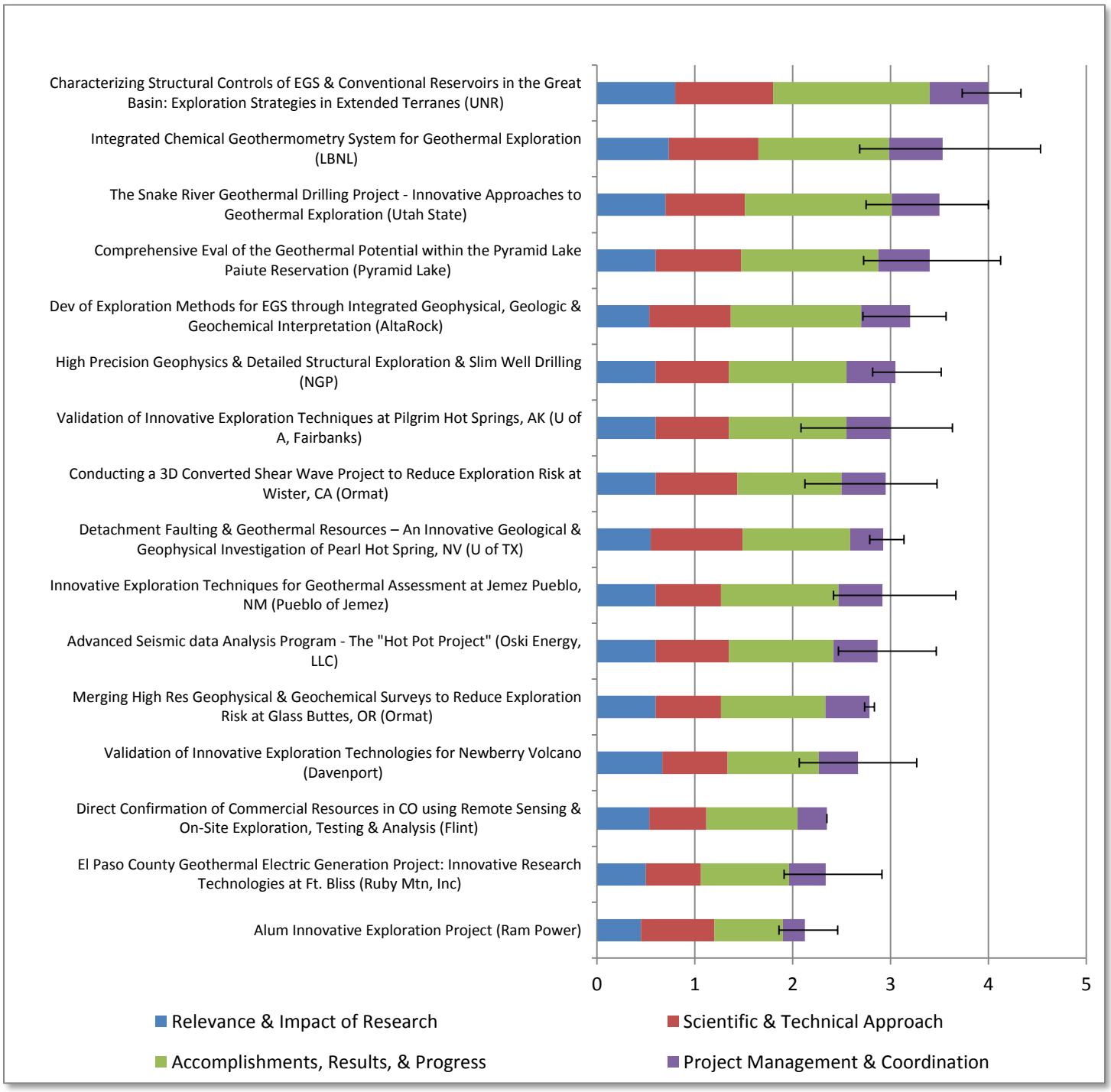


FIGURE 4.14. *Exploration Validation projects*

Figure 4.14 Exploration Validation Project. Shown are each scoring metric's weighted contribution to the weighted average project score for each individual project. The error bars represent the maximum and minimum weighted average score received by project from individual reviewers.

PROJECT SPOTLIGHT

Characterizing Structural Controls of EGS-Candidate and Conventional Geothermal Reservoirs in the Great Basin, *University of Nevada, Reno*

Scoring Summary:
This project scored a perfect 4.0 out of 4.0 in all of the metrics that were evaluated as part of the 2012 peer review process.

Key Reviewer Comments:
This project is creating foundational work that will lead to successful exploration on future geothermal projects and categorization of structures within geothermal reservoirs to facilitate communication throughout the industry. This is an important project as it will help with structural predictions of reservoirs to reduce the risk of drilling. The strength of this project is that it is systematically carrying out evaluations in an area (the Great Basin) that is critical to EGS exploitation.

4.3 High-Temperature Tools, Drilling Systems, and Zonal Isolation

In order to effectively develop EGS reservoirs, the subsurface must be comprehensively characterized prior to and during EGS stimulation, therefore, the office is working with partners to develop high temperature sensors and electronics for both transient and permanent downhole applications, including tools for reservoir characterization and tracking reservoir evolution; real-time down-hole monitoring of temperature, pressure, fluid characteristics, and seismicity; tools for identifying and tracking fluid flow paths, pre- and post-stimulation; and tools, techniques, and technologies for drilling/well completion. The office is also developing enabling technologies for reservoir creation and sustainable operation including high-temperature borehole packers and submersible pumps.

The American Recovery and Reinvestment Act of 2009 allowed the office to support research and development of various High-Temperature Tools, Drilling Systems, and Zonal Isolation technologies tailored for use in harsh geothermal environments. High temperature tools and sensors are being designed for temperatures of 374°C and depths up to 10,000 m (supercritical reservoirs). In Drilling Systems, technologies are being developed that provide increased rates of penetration (3x the current rates of 10 ft/hr), reduced costs for drilling in hard rock environments, and 300°C tolerance with capabilities of reaching depths of up to 10,000 m. The Directional Drilling and Measurement-While-Drilling (MWD) technologies focus on tool development to guide directional drilling operations and facilitate characterization of the rock mass/reservoir during drilling, including telemetry methods to transmit data to the surface and design and development of high performance bottom-hole assemblies. The objectives of the Zonal Isolation efforts are to seal off unwanted flow regions using both physical and chemical diverters, and to facilitate multi-stage fracturing in high-temperature (>200°C) environments as well as to increase power production per well.

Table 4.3 provides a list of the High-Temperature Tools, Drilling Systems, and Zonal Isolation projects that were included in the 2012 Peer Review Meeting and their scores. The scoring data are presented graphically in Figure 4.15. Overall, this technology review area had 25 projects reviewed. The 25 projects were scored by an average of four reviewers. The weighted average scores had an average, maximum, and minimum value of 2.9, 3.4, and 2.4 respectively. Table 4.3 also shows the job creation numbers to date. The job creation numbers are self-reported by the organization or Principal Investigator. Please Refer to Table 2.1 for the weighting criteria used to determine the final scoring, and see Appendix A for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

TABLE 4.3 *High-Temperature Tools, Drilling Systems, and Zonal Isolation projects*

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Pressure Sensor and Telemetry Methods for Measurement While Drilling in Geothermal Wells	GE Global Research	Alexey Vert	3.5	3.8	3.3	3.0	**3.4**	3.0
High Temperature 300°C Directional Drilling System	Baker Hughes Oilfield Operation, Inc.	Aaron Dick	3.8	3.5	3.3	3.0	**3.4**	5.5
Application of geothermally produced silica in Reservoir Management	Lawrence Livermore National Laboratory	William Bourcier	3.0	3.0	3.5	3.8	**3.3**	1.0
Multiparameter Fiber Optic Sensing System for Monitoring Enhanced Geothermal Systems	GE Global Research	William Challener	3.5	3.3	3.0	3.3	**3.2**	10.3
OM-300 - MWD Geothermal Navigation Instrument	Honeywell International, Inc.	Bruce Ohme	3.8	3.0	3.0	3.3	**3.2**	5.5

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Technology Development and Field Trials of EGS Drilling Systems	Sandia National Laboratories	David Raymond	3.0	3.0	3.3	3.3	**3.1**	4.0
Stinger enhanced bits for engineered geothermal systems (EGS)	Novatek, Inc.	David Hall	3.0	3.3	3.0	3.3	**3.1**	23.0
High-Temperature Circuit Boards for use in Geothermal Well Monitoring Applications	Composite Technology Development, Inc.	Matthew W. Hooker	3.0	3.0	3.0	3.3	**3.0**	2.0
High Temperature, High Pressure Devices for Zonal Isolation in Geothermal Wells	Composite Technology Development, Inc.	Paul Fabian	3.5	3.0	2.8	3.3	**3.0**	1.0
Geopolymer Sealing Materials	Brookhaven National Laboratory	Toshi Sugama	3.0	3.0	3.0	3.0	**3.0**	0.5
Development of a Hydrothermal Spallation Drilling System for EGS	Potter Drilling, Inc.	Jared Potter	3.3	3.0	2.8	3.5	**3.0**	4.0
Development of a Multichip Module(MCM) to Enhance High Temperature Accelerometer Measurements	Sandia National Laboratories	Scott Lindblom	3.0	2.8	3.3	2.8	**3.0**	None Provided
Perforating System for Geothermal Applications	Schlumberger Technology Corporation	Moises Smart	3.3	3.0	2.8	3.3	**3.0**	6.0
Evaluation of Corrosion/Erosion of Casing Materials Under Extreme Conditions	Oak Ridge National Laboratory	John Jy-An Wang	3.0	2.8	3.0	3.5	**3.0**	None Provided
Complete Fiber/Copper Cable Solution for Long-Term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells	Draka Cableteq USA	Mark Lowell	3.5	3.3	2.5	3.0	**3.0**	4.1
High Temperature Downhole Motor	Sandia National Laboratories	David Raymond	3.3	3.0	2.7	3.3	**3.0**	None Provided
Detecting Fractures Using Technology at High-Temperatures and Depths	Baker Hughes Oilfield Operation, Inc.	Doug Patterson	3.0	3.3	2.8	2.8	**3.0**	None Provided
Harsh Environment Silicon Carbide Sensor Technology	University of California, Berkeley	Albert Pisano	3.0	3.0	2.8	3.3	**2.9**	2.8
Enhanced High Temperature/High Speed Data Link for Logging Cables	Sandia National Laboratories	Scott Lindblom	2.8	3.3	2.8	3.0	**2.9**	None Provided
Base Technologies and Tools for Supercritical Reservoirs	Sandia National Laboratories	Scott Lindblom	2.8	2.5	2.8	2.3	**2.6**	0.5
Modeling of thermally induced spall of brittle geomaterials	Lawrence Livermore National Laboratory	Ilya Lomov	2.0	2.8	2.8	3.0	**2.6**	None Provided
Energetic Materials for EGS Well Stimulation	Sandia National Laboratories	Doug Blankenship	3.0	2.8	2.0	3.3	**2.6**	None Provided

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Multipurpose Acoustic Sensor for Downhole Fluid Monitoring	Los Alamos National Laboratory	Cristian Pantea	2.3	2.5	2.8	2.5	**2.6**	1.0
Auto-Indexer for Percussive Hammers	Sandia National Laboratories	JiAnn Su	2.5	2.8	2.3	2.5	**2.5**	None Provided
Microhole Arrays Drilled With Advanced Abrasive Slurry Jet Technology To Efficiently Exploit Enhanced Geothermal Systems	Impact Technologies, LLC	Kenneth Oglesby	2.3	2.3	2.5	2.5	**2.4**	4.2

FIGURE 4.15. *High Temperature Tools, Drilling Systems, and Zonal Isolation projects*

Figure 4.15 High Temperature Tools, Drilling Systems, and Zonal Isolation projects. Shown are each scoring metric's weighted contribution to the weighted average project score for each individual project. The error bars represent the maximum and minimum weighted average score received by project from individual reviewers.

4.4 Low-Temperature and Co-Production Demonstration

The Geothermal Technologies Office (GTO) works with industry and academia to develop and deploy new low temperature and co-production technologies that will help the geothermal community achieve widespread adoption of under-utilized, low temperature resources. The Low-Temperature and Co-produced technology area benefits from office-wide component research and development to drive down capital and operating costs through improved efficiencies in working fluids, cooling systems, heat exchangers, and other system components. Additional capital, operations and maintenance (O&M), and waste disposal costs will be driven down by knowledge gained and technical advances made in both the demonstration projects and applied research and development (R&D) science.

Low-Temperature geothermal energy is defined as heat obtained from geothermal fluid at temperatures of 300°F (150°C) or less. These resources are typically used in direct-use applications, such as district heating, greenhouses, fisheries, mineral recovery, and industrial process heating. However, some low-temperature resources can be harnessed to generate electricity using binary-cycle power-system technology.

Approximately 15-30 billion barrels of co-produced hot water is produced each year from oil and gas operation in the United States. Historically, this hot water has been an inconvenience and requires proper disposal; however, it is now being looked at as a resource to produce electricity for in-field use or to be sold to the grid. Co-produced geothermal resources have the potential to extend the economic life of oil and gas fields as well as engage the oil and gas sector in the geothermal market.

Projects funded by GTO in this technology area work toward a goal of achieving widespread production of low-temperature power through demonstration of economic power generation from low-temperature and co-produced fluids, data collection and dissemination, and increased collaboration between government and industry. GTO is working toward a goal of achieving widespread production of low-temperature power by 2020 through surface and down-hole technology advances and improved education and outreach.

Table 4.4 provides a list of the Low-Temperature and Co-Production Demonstration projects that were included in the 2012 Peer Review Meeting and their scores. The scoring data are presented graphically in Figure 4.16. Overall, this technology review area had 12 projects reviewed. The 12 projects were scored by an average of 3.8 reviewers. The weighted average scores had an average, maximum, and minimum value of 3.1, 3.8, and 1.7 respectively. Table 4.4 also shows the job creation numbers to date. The job creation numbers are self-reported by the organization or Principal Investigator. Please Refer to Table 2.1 for the weighting criteria used to determine the final scoring, and see Appendix A for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

TABLE 4.4 *Low-Temperature and Co-Production Demonstration projects*

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Dixie Valley Bottoming Binary Project	Terra-Gen	Dale McDonald	4.0	3.8	3.8	3.5	**3.8**	None Provided
Beowawe Bottoming Binary Project	Beowawe Power, LLC	Dale McDonald	3.8	3.5	3.5	3.8	**3.6**	None Provided
Rural Cooperative Geothermal Development- Electric and Agriculture	Surprise Valley Electrification Corp.	Daniel Silveria	3.5	3.3	3.8	3.8	**3.6**	0.0
Demonstration of a Variable Phase Turbine Power System for Low Temperature Geothermal Resources	Energent Corporation	Lance Hays	3.8	3.5	3.3	3.0	**3.4**	None Provided

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Osmotic Heat Engine for Energy Production from Low Temperature Geothermal Resources	Oasys Water	Robert McGinnis	3.5	3.3	3.5	3.0	**3.4**	None Provided
Small Scale Electrical Power Generation from Heat Co-Produced in Geothermal Fluids: Mining Operation	ElectraTherm, Inc.	Tom Clark	3.7	3.0	3.0	3.7	**3.2**	5.0
Technical Demonstration and Economic Validation of Geothermally-Produced Electricity from Coproduced Water at Existing Oil/Gas Wells in Texas	Universal GeoPower, LLC	Chris Luchini	3.0	3.0	3.3	3.7	**3.2**	0.2
Scale Resistant Heat Exchangers for Low Temperature Geothermal Binary Cycle Power Plant	Energent Corporation	Phillip Welch	3.8	3.0	3.0	3.0	**3.2**	None Provided
Kalex Advanced Low Temperature Geothermal Power Cycle (The Bald Mountain Project)	Oski Energy, LLC	Larry Bandt	3.0	3.0	2.8	2.5	**2.8**	0.0
The Canby Cascaded Geothermal Development Project	Modoc Contracting Company	Dale Merrick	3.0	2.8	2.5	3.0	**2.7**	None Provided
Low Temperature Power Production Field Validation	National Renewable Energy Laboratory	Tom Williams	2.8	2.5	2.3	2.0	**2.4**	None Provided
Novel Energy Conversion Equipment for Low Temperature Geothermal Resources	Johnson Controls, Inc.	Eric Minor	1.8	1.5	1.8	2.0	**1.7**	None Provided

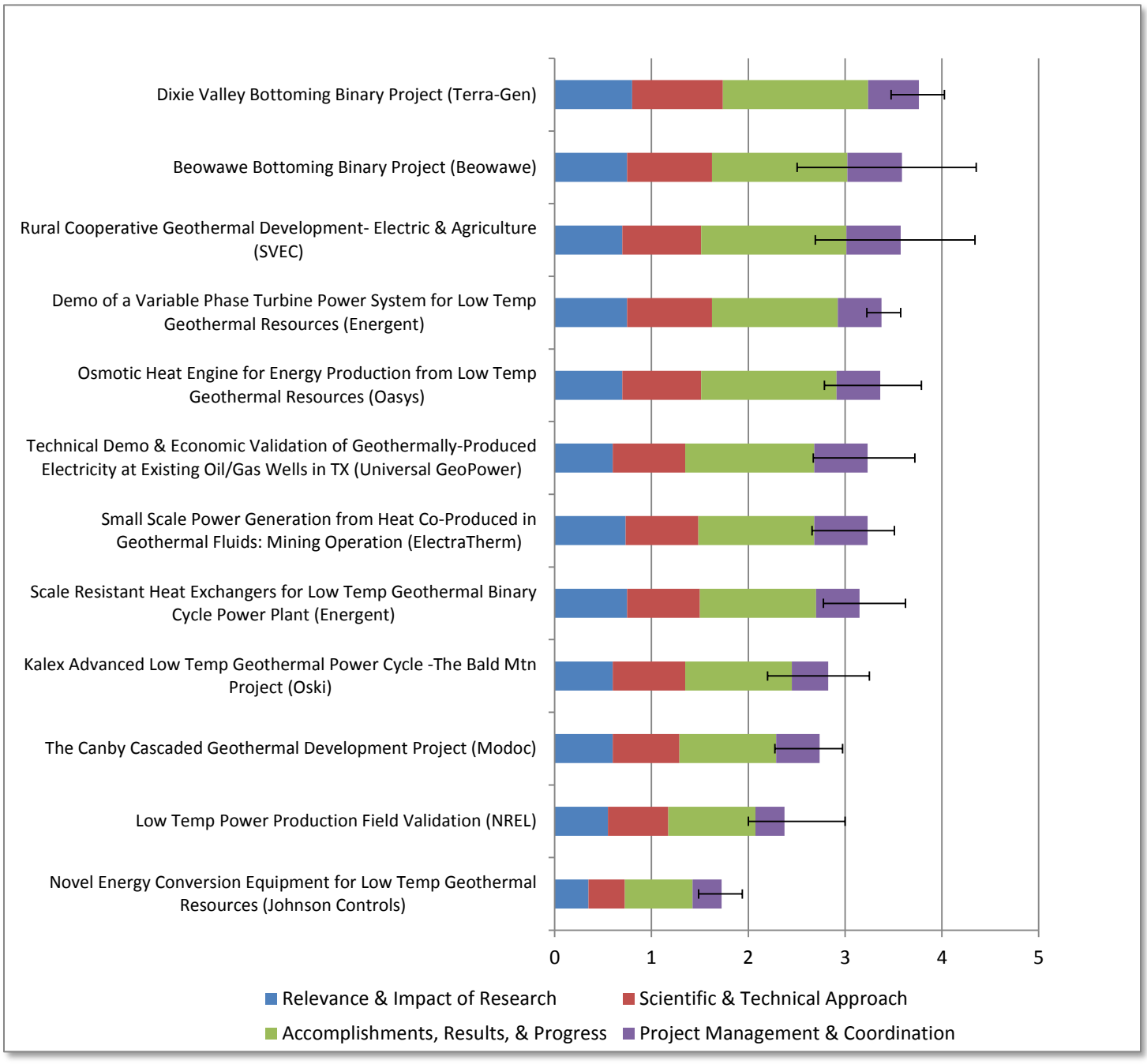


FIGURE 4.16. *Low-Temperature and Co-Production Demonstration projects*

Figure 4.16 Low-Temperature and Co-Production Demonstration projects. Shown are each scoring metric's weighted contribution to the weighted average project score for each individual project. The error bars represent the maximum and minimum weighted average score received by project from individual reviewers.

PROJECT SPOTLIGHT

Dixie Valley Bottoming Binary Project, *Terra-Gen*

Scoring Summary:
This project scored exceptionally high in the Relevance and Impact of Research (4.0 out of 4.0), Scientific and Technical Approach (3.8 out of 4.0), and Accomplishments, Results, and Progress (3.8 out of 4.0) categories.

Key Reviewer Comments:
The major potential strength of this project is to generate additional electricity from ostensibly spent geothermal fluids. Additionally, this project carries through two years of pilot plant operation. The demonstration data will allow the evaluation of the economics of whether the additional electricity can cover the capital investment and debt service costs. Project management team was strong and capably administered DOE and match share funds in a prudent and acceptable manner.

4.5 Modeling

The objectives of GTO's predictive modeling efforts are to assess the productive capacity and longevity of potential EGS or known geothermal systems and to design the creation and exploitation of reservoirs. For both the initial native state of geothermal systems, and in response to alternative exploitation scenarios that may be considered, predictive modeling of geothermal systems primarily involves fluid and heat flow modeling. However, prediction of rock response to enhancement activities is of particular importance for EGS. The objectives of GTO's reservoir/seismicity modeling efforts are to develop a computational test bed to produce realistic models of EGS stimulation-response scenarios, and to serve as a general guide for the geothermal developer to address induced seismicity issues.

Subsurface energy technologies associated with shale gas exploration, carbon capture and storage, and geothermal energy utilization can give rise to microseismic activity. Thus, modeling capabilities are needed to predict such activity from perturbations induced by stimulation, production, and injection operations, and to identify and implement operational conditions that eliminate or limit the potential for large and/or numerous earthquakes.

Within the Modeling technology area, activities are focused on:

- Developing reservoir-scale fully coupled thermal-hydraulic-mechanical-chemical models;
- Developing joint geophysical inversion techniques;
- Identifying geologic environments that are favorable to creating EGS;
- Improving fracture and flow imaging using surface technologies, and;
- Identifying the most cost-effective geophysical methods and how they are applied for identifying undiscovered geothermal resources.

Table 4.5 provides a list of the Modeling projects that were included in the 2012 Peer Review Meeting and their scores. The scoring data are presented graphically in Figure 4.17. Overall, this technology review area had five projects reviewed. The five projects were scored by an average of five reviewers. The weighted average scores had an average, maximum, and minimum value of 3.2, 3.6, and 2.5 respectively. Table 4.5 also shows the job creation numbers to date. The job creation numbers are self-reported by the organization or Principal Investigator. Please Refer to Table 2.1 for the weighting criteria used to determine the final scoring, and see Appendix A for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

TABLE 4.5 *Modeling projects*

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Predicting Stimulation-Response Relationships for Engineered Geothermal Reservoirs	Lawrence Livermore National Laboratory	Charles Carrigan	3.8	3.8	3.4	3.8	**3.6**	3.0
Analysis of Geothermal Reservoir Stimulation using Geomechanics-Based Stochastic Analysis of Injection-Induced Seismicity	Texas A&M University	Ahmad Ghassemi	3.3	3.5	3.5	3.5	**3.5**	None Provided
Modeling Supporting the Demonstration of a Deep Enhanced Geothermal System at the Northwest Geysers Geothermal Field, California	Lawrence Berkeley National Laboratory	Jonny Rutqvist	4.0	3.2	3.2	3.4	**3.4**	None Provided
Development of an Advanced Stimulation/Production Predictive Simulator for Enhanced Geothermal Systems	Science Applications International Corporation	John Pritchett	3.2	3.2	2.8	3.2	**3.0**	0.5

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
A new analytic-adaptive model for EGS assessment, development and management support	University of Nevada, Reno	George Danko	2.8	2.3	2.5	2.5	**2.5**	7.0

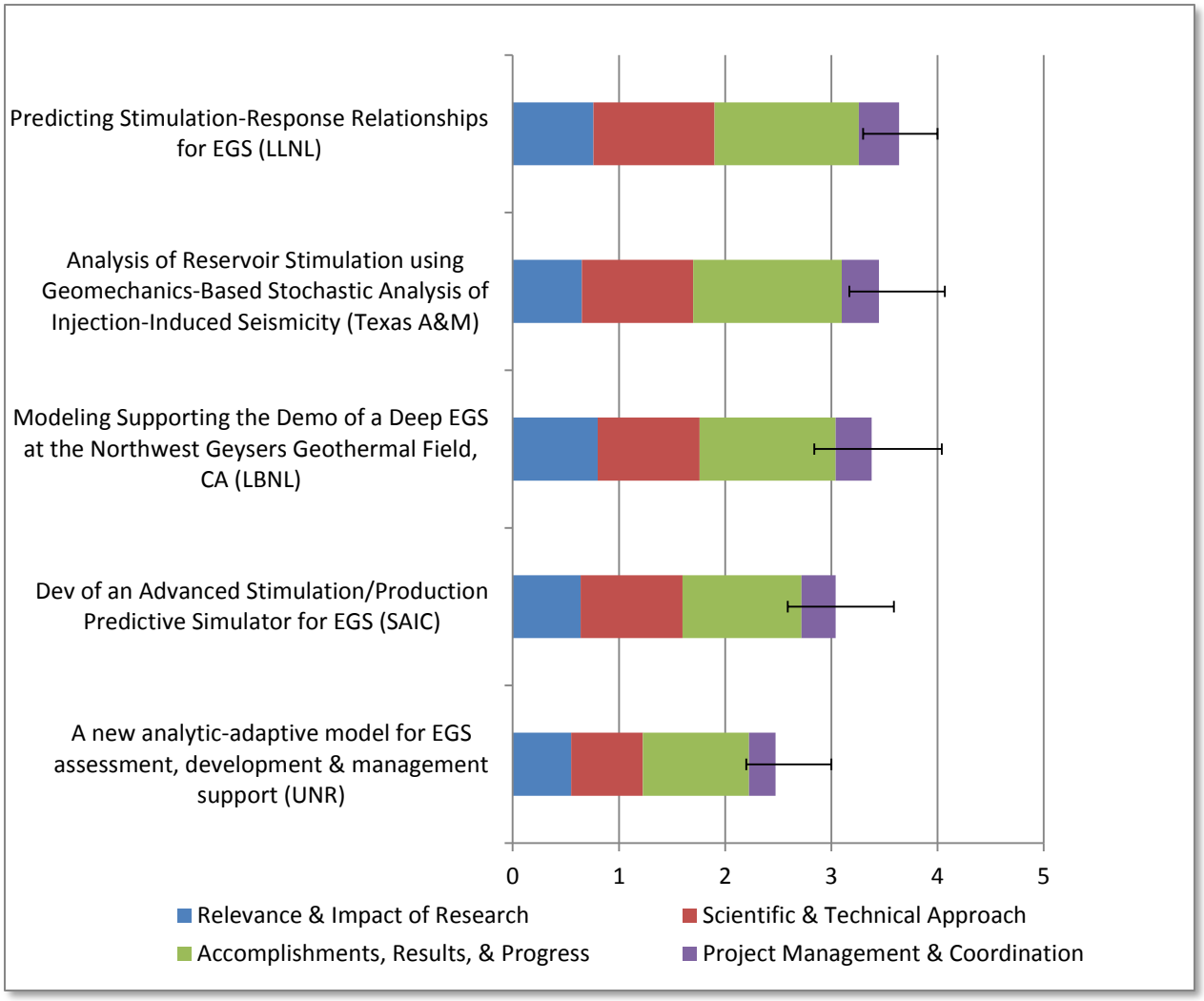


FIGURE 4.17. *Modeling projects*

Figure 4.17 Modeling projects. Shown are each scoring metric's weighted contribution to the weighted average project score for each individual project. The error bars represent the maximum and minimum weighted average score received by project from individual reviewers.

4.6 Seismicity, Fluid Imaging, and Reservoir Fracture Characterization

Mapping seismicity and subsurface fluid flow pathways during stimulation and throughout the life of Enhanced Geothermal Systems (EGS) projects is critical from both a monitoring and reservoir management perspective; these data provide a means to identify the location of critically stressed fractures through both observation and modeling approaches. When collected over time, information on fracture location and orientation and the ability to predict fracture characteristics will promote an understanding of reservoir evolution and will lower EGS and Hydrothermal development costs by facilitating the drilling of preferentially oriented (and inherently successful) wells.

In general, the objectives of the Seismicity, Fluid Imaging, and Reservoir Fracture Characterization technology area are to understand and predict the mechanical characteristics of a reservoir including the state of stress on existing or induced fractures in reservoir formations. Specifically, projects in this technology category seek to image natural or EGS-induced fluid-filled fractures at depths of 1,000 to10,000 meters in rocks of various compositions and to monitor and record seismicity to sub-zero magnitudes with 99% reliability and a small location error. The Geothermal Technologies Office (GTO) is developing surface and borehole seismic methodologies using both compressional and shear waves for characterizing fractures in EGS. Additionally, GTO is developing high resolution, microearthquake (MEQ) tools and methods suited to monitoring EGS-induced microearthquakes.

Reservoir stimulation (hydraulic, thermal, and/or chemical) is an essential step in creating an EGS. Seismic imaging and monitoring MEQs, as well as fracture characterization, are critical R&D areas for EGS and have relevance to hydrothermal systems as well. The seismic energy released during reservoir stimulation provides the best means of locating and characterizing induced or reactivated fractures. The collection and interpretation of these seismic signals is thus crucial for understanding the extent, density, and quality of the reservoir created by the stimulation. Moreover, EGS risk and hazard assessment will benefit greatly from better microearthquake predictions and simulation abilities currently under development.

Table 4.6 provides a list of the Seismicity, Fluid Imaging, and Reservoir Fracture Characterization projects that were included in the 2012 Peer Review Meeting and their scores. The scoring data are presented graphically in Figure 4.18. Overall, this technology review area had 16 projects reviewed. The 16 projects were scored by an average of 3.9 reviewers. The weighted average scores had an average, maximum, and minimum value of 3.1, 3.7, and 2.6 respectively. Table 4.6 also shows the job creation numbers to date. The job creation numbers are self-reported by the organization or Principal Investigator. Please Refer to Table 2.1 for the weighting criteria used to determine the final scoring, and see Appendix A for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

TABLE 4.6 *Seismicity, Fluid Imaging, and Reservoir Fracture Characterization projects*

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
The Role of Geochemistry and Stress on Fracture Development and Proppant Behavior in EGS Reservoirs	University of Utah	Joseph Moore	3.8	3.8	3.8	3.5	**3.7**	None Provided
Imaging Fluid Flow in Geothermal Wells Using Distributed Thermal Perturbation Sensing	Lawrence Berkeley National Laboratory	Barry Freifeld	3.5	3.5	3.5	3.8	**3.5**	None Provided
The Use of Downhole Technologies to Characterize Fractures in EGS Reservoirs	Stanford University	Roland Horne	3.5	3.3	3.3	3.3	**3.3**	None Provided
Micro-earthquake Technology for EGS Fracture Characterization	Foulger Consulting	Gillian Foulger	3.3	3.3	3.3	3.3	**3.3**	None Provided

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Joint Seismic-Electromagnetics Inversion for Iceland Geothermal Systems	Lawrence Berkeley National Laboratory	Greg Newman	3.3	3.3	3.3	3.3	**3.3**	None Provided
Application of Microearthquake (MEQ) Monitoring for Characterizing Enhanced Geothermal Systems	Lawrence Berkeley National Laboratory	Ernie Majer	3.8	3.3	3.0	3.3	**3.3**	None Provided
Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-Exposed High-Velocity Rocks	University of Texas at Austin	Bob A. Hardage	3.3	3.3	3.3	3.3	**3.3**	6.0
Seismic Fracture Characterization Methods for Enhanced Geothermal Systems	Hi-Q Geophysical Inc.	John H. Queen	3.0	3.3	3.3	3.0	**3.2**	None Provided
Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing	Lawrence Livermore National Laboratory	Dennise Templeton	3.0	3.0	3.3	3.3	**3.1**	2.0
Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in Enhanced Geothermal Systems (EGS) Reservoirs	Los Alamos National Laboratory	Lianjie Huang	3.3	3.3	2.8	3.0	**3.0**	None Provided
Detection and Characterization of Fractures for the Development of EGS	Massachusetts Institute of Technology	M. Nafi Toksoz	3.0	3.0	3.0	2.8	**3.0**	None Provided
Fracture Network and Fluid Flow Imaging for Enhanced Geothermal Systems: Applications from Multi-Dimensional Electrical Resistivity Structure	University of Utah	Philip Wannamaker	3.0	3.0	2.8	2.8	**2.9**	2.0
Ultra High Resolution Cold Neutron Imaging of Fluid Flow and Fracture in EGS Environments	Oak Ridge National Laboratory	Philip R. Bingham	2.5	2.5	3.3	2.5	**2.8**	None Provided
Fluid Imaging of Enhanced Geothermal Systems through Joint 3D Geophysical Inverse Modeling	Lawrence Berkeley National Laboratory	Greg Newman	3.0	2.8	2.8	2.3	**2.8**	None Provided
Characterizing Fractures in Geysers Geothermal Field by Micro-seismic Data, Using Soft Computing, Fractals, and Shear Wave Anisotropy	University of Southern California	Fred Aminzadeh	2.8	2.5	2.8	3.0	**2.7**	2.5
Monitoring and Modeling Fluid Flow in a Developing EGS Reservoir	Massachusetts Institute of Technology	Michael Fehler	2.8	2.5	2.5	2.8	**2.6**	None Provided

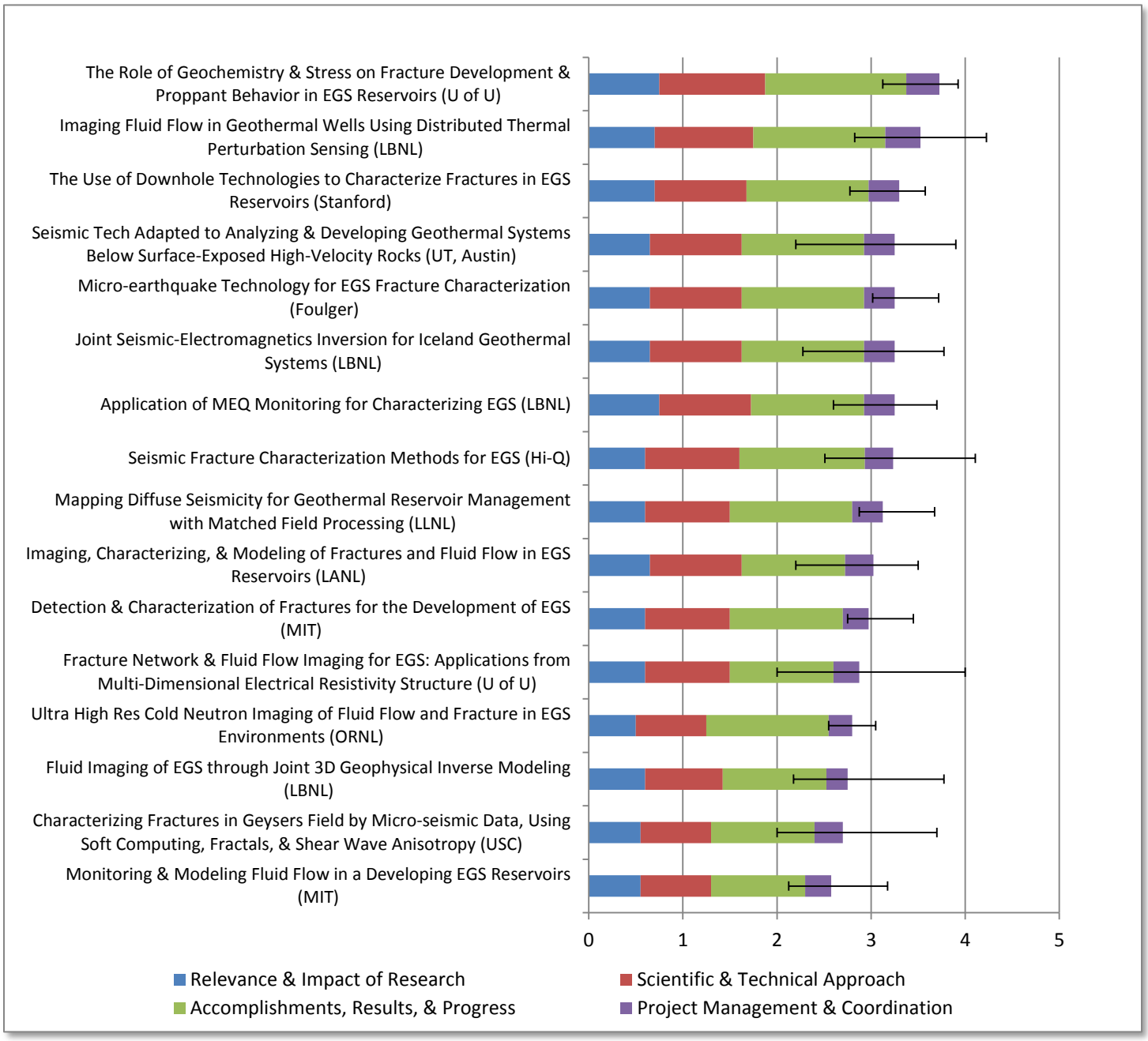


FIGURE 4.18. *Seismicity, Fluid Imaging, and Reservoir Fracture Characterization projects*

Figure 4.18 Seismicity, Fluid Imaging, and Reservoir Fracture Characterization projects. Shown are each scoring metric's weighted contribution to the weighted average project score for each individual project. The error bars represent the maximum and minimum weighted average score received by project from individual reviewers.

PROJECT SPOTLIGHT

The Role of Geochemistry and Stress on Fracture Development and Proppant Behavior in EGS Reservoirs, *University of Utah*

Scoring Summary:
This project scored exceptionally high in the Relevance and Impact of Research (3.8 out of 4.0), Scientific and Technical Approach (3.8 out of 4.0), and Accomplishments, Results, and Progress (3.8 out of 4.0) categories.

Key Reviewer Comments:
This project is addressing critical issues relative to EGS development and has found some insightful results. The use of geothermal materials under geothermal conditions is a big plus. The lab experiments are well designed and focused on geothermal issues. The coupling with numerical codes should prepare these and other geothermal workers for use and integration of these data into reservoir modeling and permeability creation assessment.

4.7 Supercritical Carbon Dioxide

The Geothermal Technologies Office's Supercritical Carbon Dioxide technology area has numerous activities that are currently focused on:

- Modifying an existing numerical simulator (e.g. TOUGH2) to allow coupling of experimentally observed chemical interactions between supercritical carbon dioxide ($scCO_2$) and reservoir rocks with spatial and temporal variations in pore/fracture geometries and in associated permeability and flow fields;
- Elucidating the carbonation reaction mechanisms between the supercritical carbon dioxide and reservoir rocks consisting of different mineralogical compositions in aqueous and non-aqueous environments, and developing chemical modeling capabilities for CO_2-reservoir rock interactions;
- Assessing the geochemical impact of CO_2 on geothermal energy production by analyzing the geochemistry of existing geothermal fields with elevated natural CO_2;
- Measuring realistic rock-water reaction rates for geothermal systems using laboratory and field-based experiments and developing reactive transport models using field-based rates to determine/stimulate the effects of carbonate scale on production;
- Developing a CO_2 reactive-transport model that predicts mineral precipitation and dissolution reactions within EGS reservoirs and surface facilities;
- Developing a new geochemical model capable of simulating an EGS-CO_2 reservoir during the transition from water to $scCO_2$;
- Estimating the performance of CO_2-based EGS and enhancing and calibrating modeling capabilities for such systems; and
- Utilizing synchrotron X-ray measurements to monitor atomic to nanoscale structural changes resulting from chemical interactions of $scCO_2$-H_2O binary fluids in EGS reservoir rocks.

Table 4.7 provides a list of the Supercritical Carbon Dioxide projects that were included in the 2012 Peer Review Meeting and their scores. The scoring data are presented graphically in Figure 4.19. Overall, this technology review area had five projects reviewed. The five projects were scored by an average of four reviewers. The weighted average scores had an average, maximum, and minimum value of 2.8, 3.8, and 1.9 respectively. Table 4.7 also shows the job creation numbers to date. The job creation numbers are self-reported by the organization or Principal Investigator. Please Refer to Table 2.1 for the weighting criteria used to determine the final scoring, and see Appendix A for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

TABLE 4.7 *Supercritical Carbon Dioxide projects*

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Enhanced Geothermal Systems (EGS) with CO2 as Heat Transmission Fluid	Lawrence Berkeley National Laboratory	Tim Kneafsey	3.8	4.0	3.8	3.3	**3.8**	None Provided
Development of Chemical Model to Predict the Interactions between Supercritical CO2 and Fluid, Rocks in EGS Reservoirs	University of Utah	Brian Mcpherson	3.5	3.3	3.0	3.0	**3.2**	3.1
Laboratory and Field Experimental Studies of CO2 as Heat Transmission Fluid in Enhanced Geothermal Systems (EGS)	Lawrence Berkeley National Laboratory	Tianfu Xu	2.8	3.0	2.5	2.8	**2.7**	None Provided
Experiment-Based Model for the Chemical Interactions between Geothermal Rocks, Supercritical Carbon Dioxide and Water	PARC (Palo Alto Research Center)	Miroslav Petro	3.0	2.8	2.5	2.8	**2.7**	3.3
Single-Well Low Temperature CO2-Based Engineered Geothermal System	GreenFire Energy	Alan D. Eastman	2.3	1.8	1.8	1.8	**1.9**	None Provided

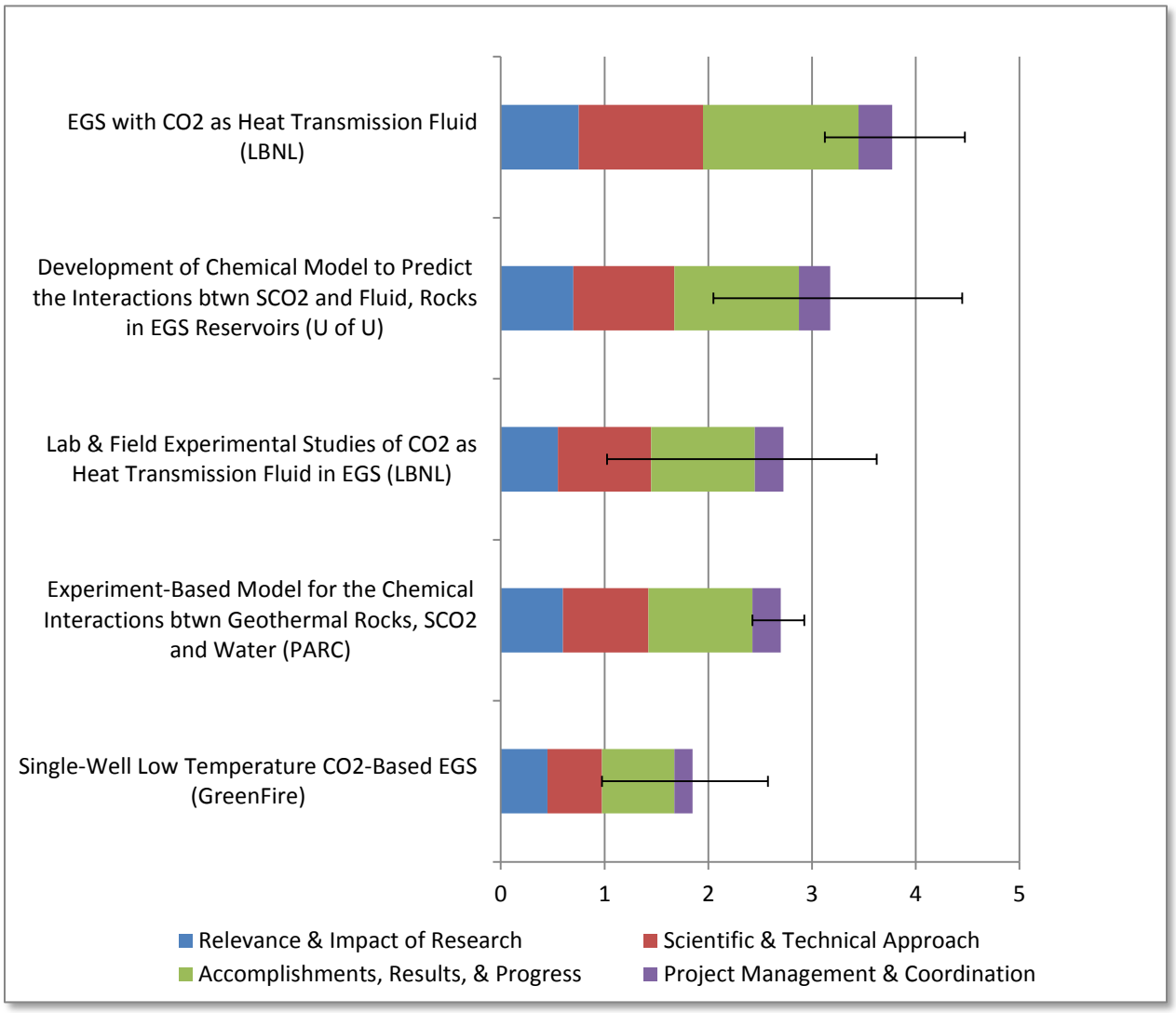


FIGURE 4.19. *Supercritical Carbon Dioxide projects*

Figure 4.19 Supercritical Carbon Dioxide projects. Shown are each scoring metric's weighted contribution to the weighted average project score for each individual project. The error bars represent the maximum and minimum weighted average score received by project from individual reviewers.

PROJECT SPOTLIGHT

Enhanced Geothermal Systems (EGS) with CO2 as Heat Transmission Fluid,
Lawrence Berkeley National Laboratory

Scoring Summary:
This project scored exceptionally high in the Relevance and Impact of Research (3.8 out of 4.0), Scientific and Technical Approach (4.0 out of 4.0), and Accomplishments, Results, and Progress (3.8 out of 4.0) categories.

Key Reviewer Comments:
This project addressed several critical areas of R&D for the GTO and made significant advances in understanding benefits and technical issues associated with use of CO_2 as a heat transfer fluid in EGS. This project is well grounded technically and the validation against field studies is very important to the possible success of using CO_2 as an energy carrier. The simulation development, reporting and publication record are strong. Combination of model development, laboratory experiments, and simulation of both laboratory and field experiments is unique to this project.

4.8 Systems Analysis, Resources Assessments, Data Systems Development & Population, and Education

The Geothermal Technologies Office's (GTO) Systems Analysis technology area conducts financial, environmental, and policy analysis, implements data gathering, and assesses the geothermal-resource base for all geothermal resources. This technology area also provides analytical and technical support to inform the direction of GTO and project prioritization, and evaluates the office's performance and ability to achieve its goals.

In general, Systems Analysis is responsible for:

- identifying technology, market, and industry barriers;
- supporting informed decision-making;
- analyzing the economic, environmental, and energy security benefits of geothermal development; and
- demonstrating progress toward GTO goals and directing research efforts.

Development of analytical tools aims to reduce the costs and risks associated with geothermal development, which inhibit the growth of geothermal in the U.S. Economic competitiveness of geothermal technologies is assessed through the evaluation of implementation costs incurred by current technologies. Such an analysis is necessary to help determine which projects might have the highest potential for near-, mid-, and long-term success. Geothermal technologies are broken down into categories such as exploration and confirmation, well construction and drilling, reservoir engineering, power conversion, geofluid purchase, leasing and permitting, and operations and maintenance.

Geothermal resource assessments, including information contained in the National Geothermal Data System, will help industry to determine the available, accessible, and cost-effective geothermal resources in the U.S., ultimately reducing costs and risks. Resource assessments and supply curves are also valuable to the office for techno-economic modeling and office planning. In partnership with the U.S. Geological Survey (USGS), the GTO will complete the sedimentary basin resource assessment.

The GTO's international partnerships are intended to accelerate the development of geothermal technologies. Through cooperative projects and information sharing, the participating countries limit blind alleys and unnecessary duplication. The office participates in two major international efforts: the International Partnership for Geothermal Technology (IPGT) and the International Energy Agency's Geothermal Implementing Agreement (IEA-GIA). The IPGT's goals closely match those of GTO, and all IPGT collaborations will lead to material gains for the office and the U.S. geothermal industry. A collaborative project between Iceland and the U.S. on advanced 3D geophysical imaging for resource characterization to explore valuable tools for reservoir exploration and characterization began in FY 2010.

Table 4.8 provides a list of the Systems Analysis, Resources Assessments, Data Systems Development & Population, and Education projects that were included in the 2012 Peer Review Meeting and their scores. The scoring data are presented graphically in Figure 4.20. Overall, this technology review area had 16 projects reviewed. The 16 projects were scored by an average of 3.7 reviewers. The weighted average scores had an average, maximum, and minimum value of 3.1, 3.9, and 2.2 respectively. Table 4.8 also shows the job creation numbers to date. The job creation numbers are self-reported by the organization or Principal Investigator. Please Refer to Table 2.1 for the weighting criteria used to determine the final scoring, and see Appendix A for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

TABLE 4.8 *Systems Analysis, Resources Assessments, Data Systems Development & Population, and Education projects*

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Heat Flow Database Expansion for NGDS Data Development, Collection and Maintenance	Southern Methodist University	David Blackwell	4.0	3.7	4.0	4.0	**3.9**	15.6
Geothermal Workforce Education Development and Retention	UNR	Wendy Calvin	4.0	4.0	3.3	4.0	**3.8**	None Provided
State Geological Survey Contributions to NGDS Data Development, Collection and Maintenance	Arizona Geological Survey	Lee Allison	4.0	3.7	3.3	3.7	**3.6**	237.3
Geothermal Prospector and other data provision tasks at NREL	National Renewable Energy Laboratory	Kermit Witherbee	3.3	3.7	3.7	3.7	**3.6**	None Provided
Analysis of Low Temperature Utilization of Geothermal Resources	West Virginia University	Brian Anderson	3.5	3.3	3.3	3.5	**3.3**	6.0
Life Cycle Analysis of Geothermal Systems	Argonne National Laboratory	John Sullivan	3.3	3.3	3.3	3.5	**3.3**	None Provided
Geothermal Systems Engineering and Analysis	Sandia National Laboratories	Tom Lowry	3.3	3.3	3.3	3.5	**3.3**	None Provided
DOE Geothermal Data Repository	Boise State University	Walter Snyder	3.7	3.0	3.0	2.7	**3.0**	5.9
Economic Impact Analysis for EGS	University of Utah	Varun Gowda	2.5	2.8	3.3	3.0	**2.9**	8.0
Northern Nevada Renewable Energy Training Project (NV)	Truckee Meadows Community College	Jim Nichols	3.0	2.5	3.5	2.8	**2.9**	None Provided
UNR - Great Basin Center for Geothermal Energy	University of Nevada, Reno	Wendy Calvin	3.3	2.0	3.3	3.3	**2.9**	None Provided
National Geothermal Resource Assessment and Classification	U.S. Geological Survey	Colin Williams	3.0	2.8	2.5	3.0	**2.8**	None Provided
Water Resource and Water Quality Assessment of Geothermal Systems	Argonne National Laboratory	Corrie Clark	3.3	2.8	2.3	2.8	**2.7**	None Provided
Estimation and Analysis of Life Cycle Costs of Baseline Enhanced Geothermal Systems	Adi Analytics, LLC	Uday Turaga	2.5	2.5	2.8	3.0	**2.7**	11.2
Hydrothermal and Resource Confirmation analysis - Data Gap Analysis, Exploration Success Metric and Case Studies	National Renewable Energy Laboratory	Katherine Young	2.3	2.5	2.5	3.0	**2.6**	None Provided
National Geothermal Data System Architecture Design, Testing and Maintenance	Boise State University	Walter Snyder	3.0	2.3	1.7	2.3	**2.2**	23.0

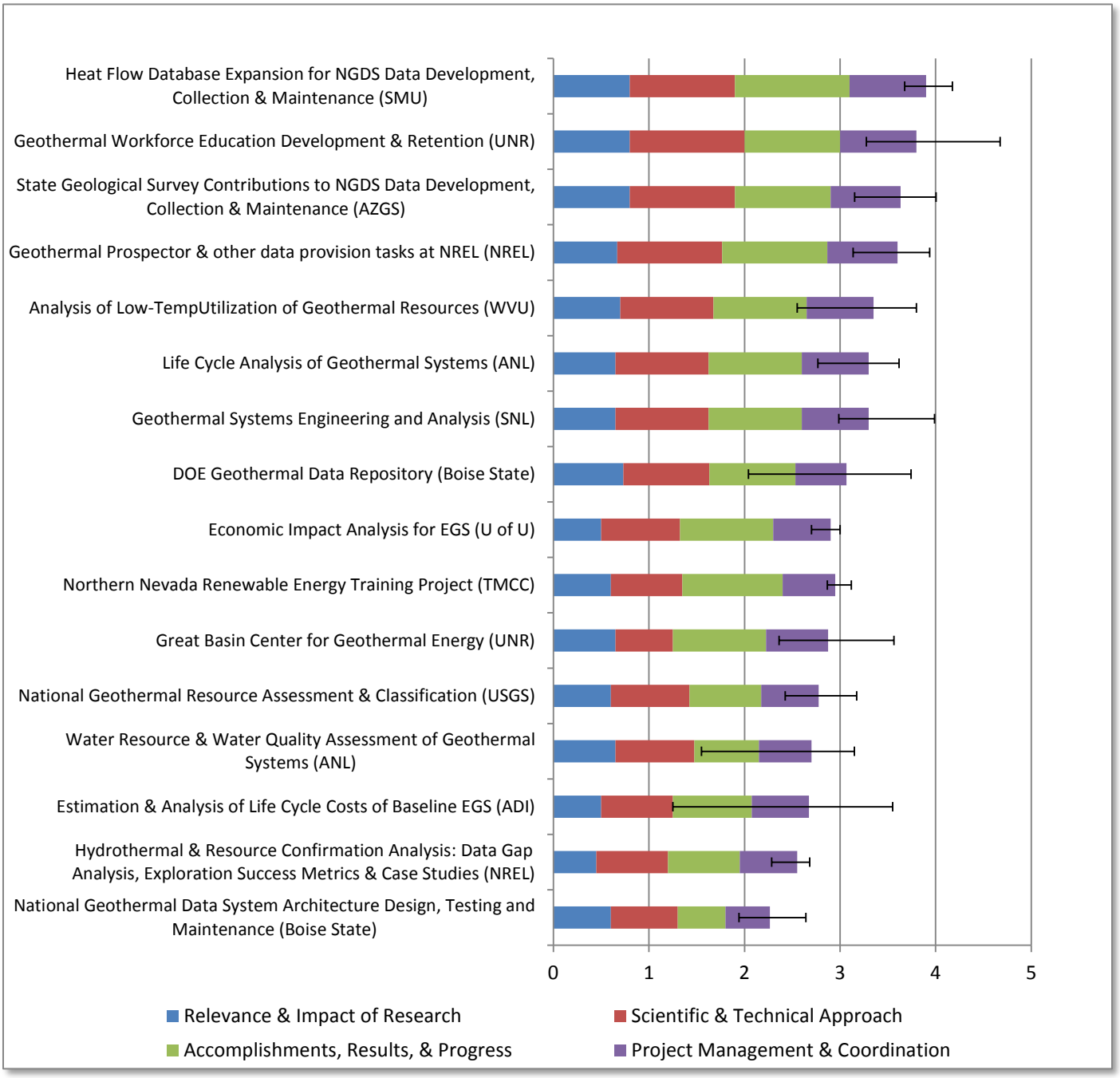


FIGURE 4.20. *Systems Analysis, Resources Assessments, Data Systems Development & Population, and Education projects*

Figure 4.20 Systems Analysis, Resources Assessments, Data Systems Development & Population and Education. Shown are each scoring metric's weighted contribution to the weighted average project score for each individual project. The error bars represent the maximum and minimum weighted average score received by project from individual reviewers.

PROJECT SPOTLIGHT

Heat Flow Database Expansion for NGDS Data Development, Collection and Maintenance, *Southern Methodist University*

Scoring Summary:
This project scored exceptionally high in the Relevance and Impact of Research (4.0 out of 4.0), Accomplishments, Results, and Progress (4.0 out of 4.0), and Project Management and Coordination (4.0 out of 4.0) categories.

Key Reviewer Comments:
The main strength of this project is its focus on developing a comprehensive database for heat flow data in the US. This information will serve as an important resource of existing and future geothermal exploration projects, as thermal data is a key component in identifying potential geothermal systems, especially hidden systems that have no surface features. Rigorous system development methodology. Domain and system development expertise on the team. Solid architecture and technology foundation. Partnership representing academia, industry, government.

PROJECT SPOTLIGHT

Geothermal Workforce Education Development and Retention, *University of Nevada, Reno*

Scoring Summary:
This project scored exceptionally high in the Relevance and Impact of Research (4.0 out of 4.0), Scientific and Technical Approach (4.0 out of 4.0), and Project Management and Coordination (4.0 out of 4.0) categories.

Key Reviewer Comments:
The Great Basin Center for Geothermal Energy (University of Nevada, Reno) is well-run with a well-qualified, hard-working staff. The Center has the backing of the University with good working relationships with the geothermal industry in Nevada and the geothermal community at large.

4.9 Tracers and Tracer Interpretation

Tracers are important tools for reservoir characterization and can be divided generally into two groups: 1) chemically inert and 2) physicochemically reactive. Inert tracers are useful in providing information on the degree of well-to-well connectivity, tortuosity of the interwell pathway, and dispersive characteristics. Temperature sensitive, chemically reactive, or adsorbing and fluorescing tracers can provide additional insight into flow in fractured media, heat extraction efficiency along various flow paths, and fracture surface area. This information facilitates the development of reservoir models with predictive capabilities. Quantitative analysis of tracer and hydrologic data provides one of the only means for gathering information about reservoirs.

Interpretation of tracer data is difficult and subjective, which can lead to differing interpretations of a given set of tracer data. Tracers, whether they are conservative or smart tracers, only directly contact a fraction of the geothermal reservoir. Thus, interpretation of the data collected is always conducted with many unknown parameters. As the GTO proceeds with the tracer and tracer analysis/interpretation technology area in the future, the goal will be to develop new technologies and data interpretation methods that reduce the number of unknown variables and yield data that is essential to characterizing the geothermal reservoir, as any heat exchanger would normally be characterized.

The office is developing multidimensional geothermal tracer systems that offer great promise for use in characterizing fracture networks in EGS reservoirs. The GTO is also providing integrated tracer and tracer interpretation tools to facilitate quantitative characterization of temperature distributions and surface area available for heat transfer. The office is designing and analyzing laboratory and field experiments that would identify tracers with sorption properties favorable for EGS applications. Additionally, the office is applying reversibly sorbing tracers to determine the fracture-matrix interface area available for heat transfer, and exploring the feasibility of obtaining fracture-matrix interface area from non-isothermal, single-well injection-withdrawal (SWIW) tests.

Table 4.9 provides a list of the Tracers and Tracer Interpretation projects that were included in the 2012 Peer Review Meeting and their scores. The scoring data are presented graphically in Figure 4.21. Overall, this technology review area had seven projects reviewed. The seven projects were scored by an average of 4.7 reviewers. The weighted average scores had an average, maximum, and minimum value of 2.9, 3.5, and 2.3 respectively. Table 4.9 also shows the job creation numbers to date. The job creation numbers are self-reported by the organization or Principal Investigator. Please Refer to Table 2.1 for the weighting criteria used to determine the final scoring, and see Appendix A for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

TABLE 4.9 *Tracers and Tracer Interpretation projects*

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Verification of Geothermal Tracer Methods in Highly Constrained Field Experiments	California State University - Long Beach	Matthew Becker	3.8	3.8	3.2	3.4	**3.5**	1.5
Advancing Reactive Tracer Methods for Measuring Thermal Evolution in CO2- and Water-Based Geothermal Reservoirs	Idaho National Laboratory	Laurence Hull	3.2	2.8	3.2	3.6	**3.1**	1.0
Use of Tracers to Characterize Fractures in Engineered Geothermal Systems	University of Utah	Peter Rose	3.3	3.3	2.8	3.0	**3.0**	None Provided
Quantum Dot Tracers for Use in Engineered Geothermal Systems	University of Utah	Peter Rose	3.3	3.0	2.8	2.5	**2.9**	1.0
Using Thermally Degrading, Partitioning and Nonreactive Tracers to Determine Temperature Distribution and Fracture/Heat Transfer Surface Area in Geothermal Reservoirs	Pacific Northwest National Laboratory	Vince Vermeul	2.8	2.8	2.8	2.8	**2.8**	x
Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS Systems	Lawrence Berkeley National Laboratory	Mack Kennedy	2.6	2.8	2.6	2.4	**2.6**	3.0
Novel Multidimensional Tracers for Geothermal Inter-Well Diagnostics	Power, Environmental and Energy Research Institute	Yongchun Tang	2.4	2.4	2.2	1.8	**2.3**	8.0

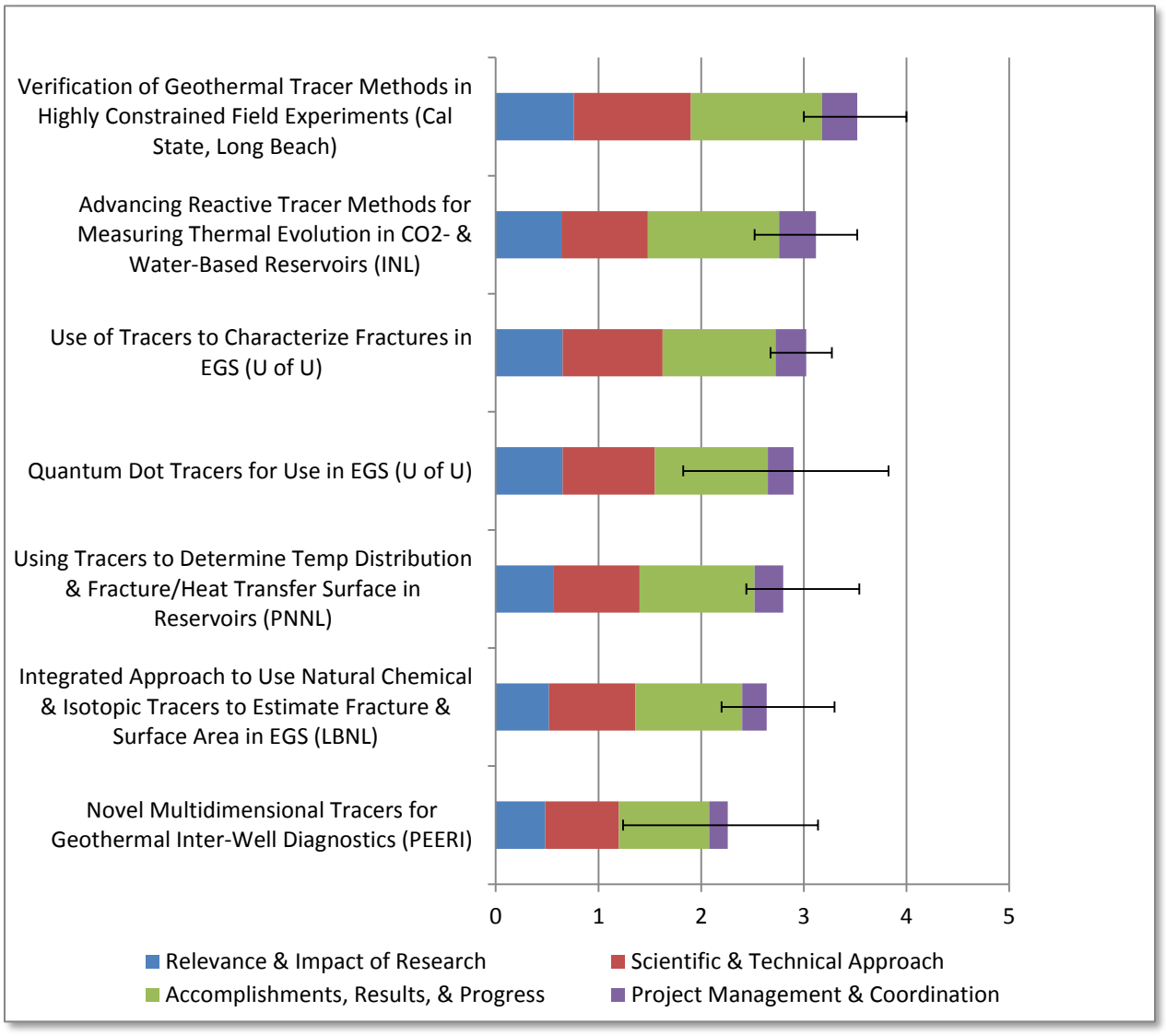


FIGURE 4.21. *Tracers and Tracer Interpretation projects*

Figure 4.21 Tracers and Tracer Interpretation projects. Shown are each scoring metric's weighted contribution to the weighted average project score for each individual project. The error bars represent the maximum and minimum weighted average score received by project from individual reviewers.

4.10 Working Fluids

There are currently eight projects in the Geothermal Technologies Office (GTO) portfolio focused on research and development (R&D) for geothermal working fluids. The majority of these projects were the result of the American Recovery and Reinvestment Act of 2009 (ARRA) or ARRA Laboratory R&D opportunities that were originally funded in 2009. As such, many are now nearing completion and detailed analysis of their work to develop new and innovative technologies to advance the utilization of geothermal energy is nearing completion. One example is Argonne National Laboratory's work on Chemical Energy Carriers (CECs). If successfully implemented, this advanced geofluid-working fluid could potentially double the power output of EGS power generation plants. Another very promising and ongoing project is Pacific Northwest National Laboratory's work with Metal Organic Heat Carriers (MOHCs). This project is in the process of developing a new type of biphasic working fluid for subcritical geothermal systems that utilizes microporous metal-organic solids as the primary heat carrier and heat transfer medium to support an organic Rankine cycle for low temperature EGS and traditional hydrothermal systems. Finally, a newly awarded project to Oak Ridge National Laboratory, will attempt to maximize binary-cycle efficiency through the development of a specialized working fluid that can be used in a hybrid-organic Rankine cycle/ Brayton cycle plant. While these projects pursue various technologies, their overarching goal to increase efficiency, improve energy utilization and decrease cost for Low-Temperature, Hydrothermal and EGS systems is the same.

Table 4.10 provides a list of the Tracers and Tracer Interpretation projects that were included in the 2012 Peer Review Meeting and their scores. The scoring data are presented graphically in Figure 4.22. Overall, this technology review area had eight projects reviewed. The eight projects were scored by an average of 3.8 reviewers. The weighted average scores had an average, maximum, and minimum value of 3.0, 3.7, and 1.9 respectively. Table 4.10 also shows the job creation numbers to date. The job creation numbers are self-reported by the organization or Principal Investigator. Please Refer to Table 2.1 for the weighting criteria used to determine the final scoring, and see Appendix A for detailed reviewer comments and rebuttals by the Principal Investigators for each individual project.

TABLE 4.10 *Working Fluids projects*

Title	Organization	Principal Investigator	Relevance & Impact of Research	Scientific & Technical Approach	Accomplishments, Results, & Progress	Project Management & Coordination	Weighted Average Scores for Projects	Job numbers (FTEs to date)
Technologies for Extracting Valuable Metals and Compounds from Geothermal Fluids	Simbol Materials	Stephen Harrison	3.5	4.0	3.5	3.5	**3.7**	16.0
High-Potential Working Fluids for Next Generation Binary Cycle Geothermal Power Plants	GE Global Research	Jalal Zia	3.5	3.5	3.5	3.5	**3.5**	None Provided
Development of New Biphasic Metal Organic Working Fluids for Subcritical Geothermal Systems	Pacific Northwest National Laboratory	Peter McGrail	3.8	3.8	3.3	2.8	**3.5**	2.0
Tailored Working Fluids for Enhanced Binary Geothermal Power Plants	United Technologies Research Center	Ahmad Mahmoud	3.5	3.5	3.0	3.5	**3.3**	30.0
Geothermal Working Fluids	Notre Dame University	Joan Brennecke	2.5	3.3	3.0	3.0	**3.0**	None Provided
High-Temperature-High-Volume Lifting For Enhanced Geothermal Systems	GE Global Research	Norm Turnquist	3.7	2.7	2.7	3.0	**2.9**	34.0
Working Fluids and Their Effect on Geothermal Turbines	Oak Ridge National Laboratory	Adrian S. Sabau	3.0	3.0	2.3	2.3	**2.6**	6.2
Chemical Energy Carriers (CEC) for the Utilization of Geothermal Energy	Argonne National Laboratory	Bassam Jody	1.8	1.8	2.0	2.3	**1.9**	1.0

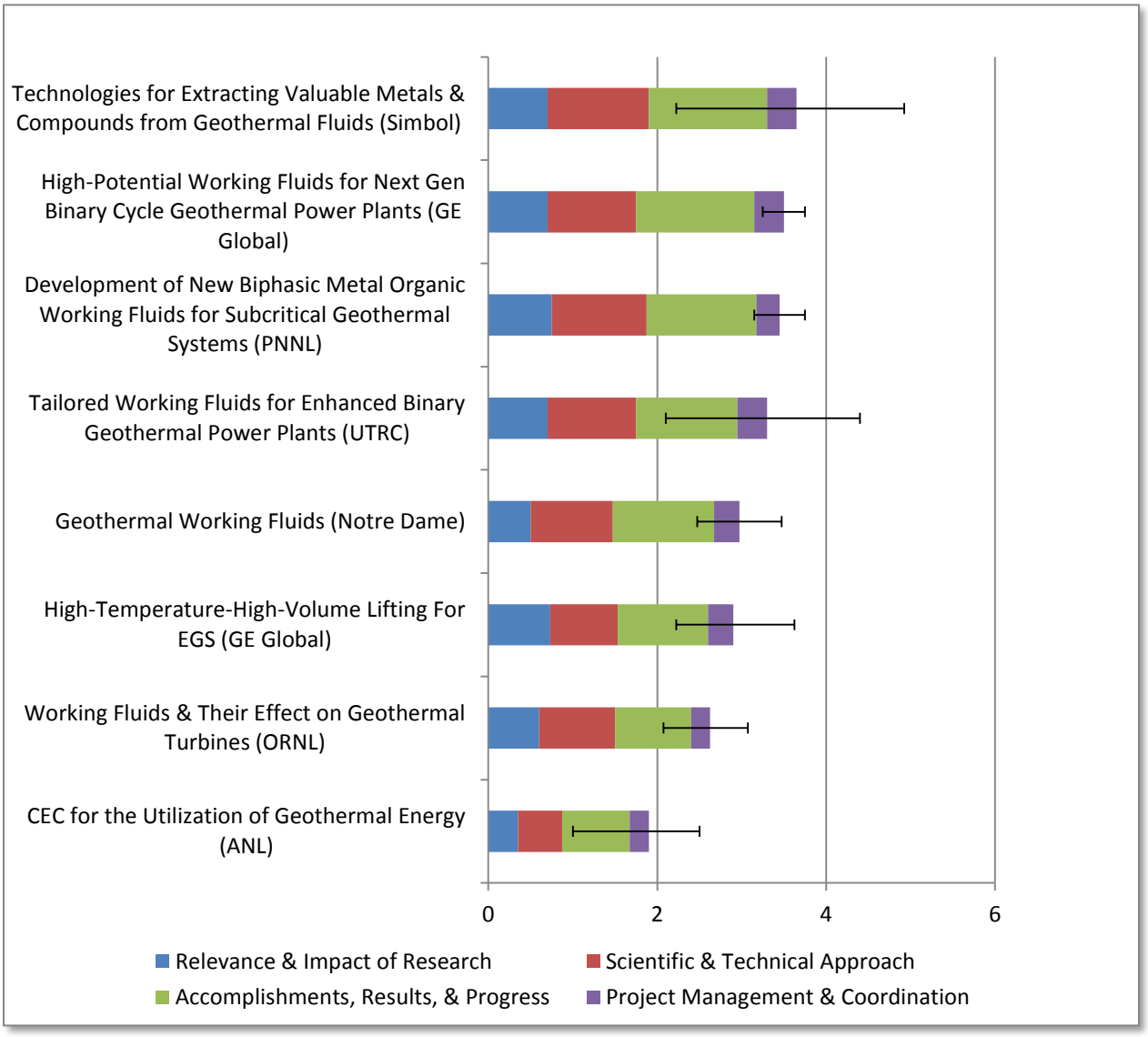


FIGURE 4.22. *Working Fluids projects*

Figure 4.22 Working Fluids projects. Shown are each scoring metric's weighted contribution to the weighted average project score for each individual project. The error bars represent the maximum and minimum weighted average score received by project from individual reviewers.

PROJECT SPOTLIGHT

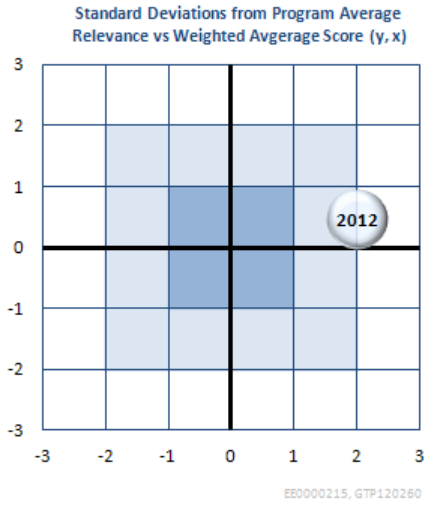
Technologies for Extracting Valuable Metals and Compounds from Geothermal Fluids, *Simbol Materials*

Scoring Summary:
This project scored exceptionally high in the Scientific and Technical Approach (4.0 out of 4.0), Relevance and Impact of Research (3.5 out of 4.0), and Accomplishments, Results, and Progress (3.5 out of 4.0) categories.

Key Reviewer Comments:
This project has added an additional revenue stream to geothermal power plants in the Salton Sea area. It is also providing a source for high quality lithium that will become more important as more cars become electrified. The vision along the progress path was outstanding as was the capturing of the lessons learned that quickly optimized the project.

Appendix A: Detailed Reviewer and PI Rebuttal Comments

ENHANCED GEOTHERMAL SYSTEMS DEMONSTRATIONS



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0000215
Project: Concept Testing and Development at the Raft River Geothermal Field, Idaho
Principal Investigator: Moore, Joseph
Organization: University of Utah
Panel: Enhanced Geothermal Systems Demonstrations

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23416

Score: 3.0

Comment: Barriers to moderate temperature resource use are addressed. Practical well-conceived project with realistically achievable goals.

PI Response:

Reviewer 23625

Score: 3.0

Comment: The project is testing a moderate temperature sequence at intermediate depth with subcommercial permeabilities. Such conditions are abundant throughout the US. If successful, it will improve significantly the nationwide geothermal potential.

PI Response:

Reviewer 23554

Score: 4.0

Comment: This is an important application in a moderate temperature environment.

PI Response:

Reviewer 23579

Score: 4.0

Comment: The score for this review item is based more on the potential impact of the project than on progress to date. The project is behind schedule and over budget due to permitting problems, apparently not the fault of the project management, and to problems with drilling equipment failure.

There are many hydrothermal systems in the USA with temperatures in the ~150C range to which the results of this project might be applicable. The project is innovative in its proposed research on the use of cooling to induce thermal fracturing prior to stimulation by hydraulic fracturing. A good database using geology, geochemistry and geophysics has been obtained to help characterize the field and the stimulation well environment. It will be useful not only in interpreting results of the stimulation, but also in judging how much of this type of work is necessary prior to stimulation in other EGS projects. Success on this project would also result in increased production from the Raft River field.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23416

Score: 4.0

Comment: Scientific methods tested successfully; approach was sound.

PI Response:

Reviewer 23625

Score: 3.0

Comment: The use of contractors from the oil & gas industry is commendable. The geothermal industry does not make enough use of reflection seismic data in general. In this particular project there are many unknowns about the nature of the heat source and the structure of the reservoir. Electromagnetic data and magnetotelluric (MT) do not provide sufficient information to understand the reservoir structure. The Proterozoic basement surface is most likely a strong seismic reflector which would allow to delineate faults that are extending deep into the basement. This would provide critical information about the heat source and may provide critical information for the site selection of future wells.

PI Response:

Reviewer 23554

Score: 4.0

Comment: Very good application of new and established methodologies.

PI Response:

Reviewer 23579

Score: 4.0

Comment: This project has a reasonably sharply focused approach and clear objectives. Execution of the project has been good, but marred somewhat by several drilling equipment failures of such a nature that it is unlikely they could have been anticipated. A team of experienced geothermal researchers and operators has been assembled for this project, and there is collaboration with several universities and national laboratories as well as with Japanese researchers developing a downhole seismic tool.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23416

Score: 2.0

Comment: Many frustrating delays (permitting related) and technical difficulties with the borehole have left the project struggling to achieve targeted time frames. But these are now largely overcome and progress should improve. The phase of scientific studies revealed complex structure with different chemistries and fracture orientations in apparently separate reservoir compartments with no obvious fault targets from basement displacements. Different source fluids are poorly mixed. Practical use of integrated gravity/magnetotelluric (MT)/ vertical seismic profiling (VSP) and petrography interpretation for targeting purposes in this setting being queried. Few background microearthquake (MEQ) events recorded. Most useful/cost effective tools apparently related directly to injectivity testing. The crucial stage of stimulation is yet to start.

PI Response:

Reviewer 23625

Score: 2.0

Comment: Due to drilling problems and various instrument failures, not all targets have been achieved. In such projects we recommend to abstain from the use of experimental tools. It is recommended to use standard equipment with a good performance record.

PI Response:

Reviewer 23554

Score: 3.0

Comment: Initial phases are complete. The results are limited by the failure of equipment; however, each failure is an opportunity to learn what to do to make it work. This EGS experiment should not be criticized for unanticipated circumstances that control what phases succeed.

PI Response:

Reviewer 23579

Score: 3.0

Comment: This project is over budget and delayed relative to the original schedule. Significant delays were caused by the lengthy process of permitting, a problem apparently with the lack of experience in this matter by the approving agencies. This problem should be lessened somewhat as the agencies gain more experience and expertise with the EGS process.

The over budget situation is the result of failures of several components of the drilling equipment. Although these things regularly happen in drilling, one wonders if enough attention was given to the quality of some of the equipment. It might also be questioned whether sufficient contingent funds were allocated for drilling problems since they seem to be the norm in geothermal projects.

Well RRG-9 ST1 is now ready for stimulation. An injection test found tight rocks in the Elba quartzite (the producing horizon in other wells) and televiewer and temperature logs have shown a fractured interval in the Elba that may be suitable for stimulation. A microseismic array has been deployed in the field by Lawrence Berkeley National Laboratory (LBNL) and is operating -- it detected some small activity during the injection test. Current work consists of finalizing design of the stimulation prior to a stage-gate review for carrying the project forward.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23416

Score: 3.0

Comment: Dealt with some frustrating delays with permitting. Planning appears sound. Coordination with other projects is excellent. Data sharing is on track.

PI Response:

Reviewer 23625

Score: 3.0

Comment: The project management team appears to be very experienced. It is difficult to assess whether the encountered drilling problems are due to insufficient planning or other reasons. The use of contractors from the oil & gas business is commendable. When using non-standard logging tools or microseismic monitoring equipment backup tools should be available on site.

PI Response:

Reviewer 23554

Score: 4.0

Comment: Good planning and execution for the preliminary phases. Again, unanticipated conditions and equipment failures do not limit the chance to learn from this experiment.

PI Response:

Reviewer 23579

Score: 3.0

Comment: Project management has been reasonably effective. The several problems with drilling equipment were handled well as evidenced by the fact that the well was successfully competed and is now ready for stimulation. Decision points are placed to allow for project review prior to each stage. The next review will be in the summer of this year and will result in a Go/No-Go decision to proceed with the actual stimulation office. The project has resulted in publications at the annual Geothermal Resources Council (GRC) and Stanford meetings. The project is also interacting with the National Geothermal Data Repository, and project results will be made public.

PI Response:

STRENGTHS

Reviewer 23416

Comment: A good EGS demonstration project. If successful, fluid circulation will be rapidly taken advantage of because of existing power plant. Good collaboration between experienced researchers in a wide range of disciplines. Project provides tests of suitability of practical methods for EGS exploration tools. Coordination with other projects allows for knowledge transfer.

PI Response:

Reviewer 23625

Comment: A successful development of a geothermal resources in a moderate temperature environment will increase the nationwide geothermal potential in the US substantially. In this respect the project has a light tower function.

The geothermal industry does not make enough use of reflection seismic data in general. In this particular project there are many unknowns about the nature of the heat source and the structure of the reservoir. Electromagnetic data and magnetotellurics (MT) do not provide sufficient information to understand the reservoir structure. The Proterozoic basement surface is most likely a strong seismic reflector which would allow to delineate faults that are extending deep into the basement. This would provide critical information about the heat source and may provide critical information for the site selection of future wells.

PI Response:

Reviewer 23554

Comment: A well managed, complex effort.

PI Response:

Reviewer 23579

Comment: Strengths of this project include:

1. This is a research and demonstration project in a different lithologic setting from that of most geothermal systems, namely the hard Elba Precambrian quartzite. The project is important simply because of this fact alone. It is also in a moderate-temperature geothermal system, and there are a number of such systems known in the USA. These include,

among many others, permeable horizons, many of them quartzite or sandstone, in sedimentary basins containing water at elevated temperatures, potentially of interest for geothermal development.

2. Success in this project would increase the output of the operating power plant at Raft River, an obvious benefit.

3. A comprehensive data base has been collected/compiled. This project will make a good case study.

PI Response:

WEAKNESSES

Reviewer 23416

Comment: Delays with permitting are a source of considerable frustration. Stimulation, flow-testing, and interconnectivity improvement have yet to commence. Seismic knowledge at depth is still lacking. Interpretation of 3-D magentotelluric (MT) model not very clear in terms of resource extent but possibly identifies inferred barrier structure from chemistry.

PI Response:

Reviewer 23625

Comment: Moderate temperatures and moderate flow rates will result in a low efficiency power conversion. It is questionable whether the set production targets will allow for an economic power production. The stated production targets of 20 kg/s at temperatures of 129°C will produce not more the 5 MW thermal resulting in a net power production of significantly less than 1 MW electric. The set target of of 5 MW electric will require more than one production and one injection well.

PI Response:

Reviewer 23554

Comment: Slow progress and too many setbacks.

PI Response:

Reviewer 23579

Comment: One minor weakness is the relative inexperience of some on the team in the areas of drilling and stimulation. This does not mean that the Raft River team is composed of novices by any means, but simply that much of the (very considerable geothermal) experience of some team members has been in research endeavors other than drilling and

fracturing. The emphasis here is on the term "relative", and there is absolutely no implication that the team is unqualified for this project.

PI Response:

IMPROVEMENTS

Reviewer 23416

Comment: Recommend post-mortem on drilling-related and logging problems (packer, bridge plug and televiewer) to avoid repetition of identifiable mistakes. Recommend ranking of geoscience endeavors on cost-benefit basis. Reconsider possible advantages of stimulation plan with thermal cycling (alternating hot/cold water injection). Suggest place more emphasis on developing/testing tools to improve injection testing and stress/fracture orientation with depth.

PI Response:

Reviewer 23625

Comment: The geothermal industry does not make enough use of reflection seismic data in general. In this particular project there are many unknowns about the nature of the heat source and the structure of the reservoir. Electromagnetic data and magnetotellurics (MT) do not provide sufficient information to understand the reservoir structure. The Proterozoic basement surface is most likely a strong seismic reflector which would allow to delineate faults that are extending deep into the basement. This would provide critical information about the heat source and may provide critical information for the site selection of future wells.

Abstain from using experimental tools, unless they are covered by research funding.

PI Response:

Reviewer 23554

Comment: Reviewer did not provide comments for this criterion.

PI Response:

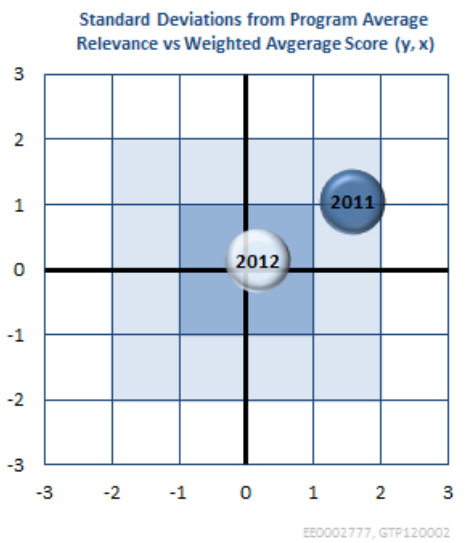
Reviewer 23579

Comment: Some suggestions are:

1. As in most projects, members of the team are working on other projects as well. This project needs to be given the very highest priority possible because a good result -- a successful project -- is needed to keep EGS moving ahead.

2. The team has on occasion sought outside help on specific matters. This is commendable, and should be continued as needed.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002777
Project: Newberry Volcano EGS Demonstration
Principal Investigator: Petty, Susan
Organization: AltaRock Energy, Inc.
Panel: Enhanced Geothermal Systems Demonstrations

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23416

Score: 4.0

Comment: Most EGS gaps and barriers are addressed. Practical, realistic and achievable demonstration project. Outstanding features are: green-field hot volcanic setting, dealing with very low permeability, and novelty of multi-depth stimulation method.

PI Response:

Thank you. That's what we were trying to do.

Reviewer 23533

Score: 1.0

Comment: Several rather interesting "new" developments (e.g. TZIM, Hydraulic Fracturing simulator) will remain proprietary!...hence, their reviews are limited and their impact non-existent. The development of high temperature logging tools might be interesting. What was the reason for developing AltaStim rather than using commercially available design software; any new capabilities? Comparisons should be carried out.

PI Response:

AltaRock is a commercial entity funded by investors, not a university or national laboratory funded by the federal government. While the methods, software and materials developed by AltaRock are proprietary they are available to operators of geothermal projects or others desiring to use these services through normal commercial channels. The data from the project will be available to the public through the National Geothermal Database. AltaStim is AltaRock's software implementation of a theoretical model originally developed by researchers in Japan to model Hijiori HDR results and published in two JGR papers (Willis-Richards et al., 1996, and Jing et al. 2000). In 2008, AltaRock evaluated existing conceptual models and codes, and determined that the theoretical basis for the Willis-Richards model best matched our own understanding and conceptual model of hydroshearing. We published a paper on the Newberry AltaStim model at the 2011 GRC Annual Meeting. We agree that comparisons to other modeling codes, including commercially available software should be carried out, particularly with the data set produced as part of this project. Code comparison is outside the scope of a field demonstration; perhaps a future DOE FOA can address this need (and this reviewer can propose his favorite commerically available design software be included).

Reviewer 23554

Score: 4.0

Comment: The research is highly relent because many of the techniques and methods could be applied in a variety of EGS geothermal projects and conventional hydrothermal settings. Unfortunately, permitting is the only thing to report for this project.

PI Response:

The fact that three federal agencies and numerous state agencies were involved and had to coordinate and agree on the induced seismicity mitigation protocol (ISMP) definitely added to the length and difficulty of the permitting process. I'm not sure why the other projects with DOE funding did not have a similar difficulty in permitting. It's possible that having an operating power plant made the process easier for others with that situation. I hope that while our experience paves the way for other projects, that all projects are not treated with equal levels of inspection and requirements for report since many of the requirements were duplicated due to lack of understanding of the first reports. We did three separate engineering studies of the structures at the Volcanic National Monument, two hydrologic studies and two separate induced seismicity hazards studies.

Reviewer 23579

Score: 4.0

Comment: Progress on this project has been slower than expected, due largely to the length of time needed for acceptance by regulating agencies of the induced-seismicity report. The score given is based less on progress to date and more on the expected impact of the research, if the project is successful.

This project will test the ability of current EGS technology to develop an enhanced geothermal system in deep, very hot igneous rocks through hydroshearing stimulation. EGS research in the Cascades volcanic/igneous environment is important due to the large amounts of heat contained in numerous volcanic centers in this province. In addition, this project is the only one of the current crop of EGS Demonstrations presented at the review that is a greenfield project, which increases its importance to the geothermal office.

Hydroshearing as a stimulation method has gained favor over massive hydraulic fracturing mainly because of its supposed ability to self-prop pre-existing fractures as they open. This idea has not been thoroughly tested, but may represent an important breakthrough in EGS technology. Moreover, the use of thermally degradable zonal-isolation materials (TZIMS) to create three separately stimulated zones is a unique feature of this project. Successful demonstration of this ability would spur EGS development by lowering the costs of creating a viable reservoir and potentially allowing a measure of control on subsurface fluid flow not now available. AltaRock has been active in TZIMS research, leading the industry in their development and patenting.

PI Response:

That is the goal. I agree that if we accomplish the stimulation of multiple zones we will help to improve the cost and risk associated with EGS power development. The fact that we have done two test stimulations and one commercial stimulation should improve our chances of a successful stimulation.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23416

Score: 4.0

Comment: Well planned scientific investigation, particularly a new stimulation method using diverter agents and planning software (AltaStim) to target several zones/well and achieve 75 kg/s (at least). Good collaborations are established. Overcoming technical challenges – lack of data at high temperature, lack of cores/geomechanical data, and lack of natural seismicity. Well-planned public outreach.

PI Response:

Thank you

Reviewer 23533

Score: 2.0

Comment: I am not convinced that "shear stimulation", as defined, will occur.
If an existing discontinuity (intersecting the borehole) needs to be stimulated, has the orientation of the borehole been optimized?
No attempts have been made to simulate a naturally fractured reservoir.
Coupled effects have been ignored
Stress shadowing due to multiple fractures planning has been completely ignored

PI Response:

Our plans are based on the designs and results of HDR and EGS project worldwide, including Fenton Hill (US), Hijiori (Japan), Soultz (France), and Basel (Switzerland). It is now well accepted that shear failure on pre-existing fractures (hydroshearing) was the primary mode of permeability enhancement at those sites. Our plans have been reviewed by many qualified geoscientists whom agree that hydroshearing is the best conceptual model for stimulation of geothermal wells (including three of the four peer reviewers here). Further, we plan to collect the data needed to distinguish the failure type caused by hydraulic stimulation and provide the geothermal community further information on this ongoing debate on hydraulic stimulation design.
The well, drilled in 2008, is a "well of opportunity" and therefore its design could not be optimized for EGS. Fortunately, the well deviates to the east, parallel to the direction of the minimum principle stress and perpendicular to the strike of a large population of fractures. No commercial operator is going to purposely drill a well that is not productive, so this well represented the best available opportunity at the time of the project conceptual development.
We agree that the simulations performed so far do neglect factors such as coupling and stress changes due to the stimulation itself. At present the stimulation model is underconstrained by a lack of some data such as the minimum principle stress magnitude and the pressure required to initiate hydroshearing. We feel that a more complex model would not change the basic stimulation design of the demonstration. The accuracy of the modeling effort that we have performed and comparison to other modelling paradigms can be evaluated after the stimulation.

Reviewer 23554

Score: 4.0

Comment: This is the best planned and researched EGS project reviewed. AltaRock has made a considerable effort to prepare and potentially execute a successful EGS stimulation in a very worthwhile geologic environment.

PI Response:

Thanks. That is indeed what we hoped for.

Reviewer 23579

Score: 3.0

Comment: The technical approach is reasonably thorough, well planned, and (so far) reasonably well executed. Most preparations are in place for the stimulation, to be carried out later this year. The microseismic network is still in the installation process, but appears to be well planned to yield good event hypocenters, with some 20 stations, half of which will be borehole installations.

The stimulation approach relies completely on hydroshearing since the research team believes that a single hydrofrac would not deliver enough heat to allow economic development. Based on the Los Alamos National Laboratory (LANL) experience at Fenton Hill, this may be so. Presumably the thermally degradable zonal isolation materials (TZIMs) would not provide sufficient blockage at pressures need for hydraulic fracturing to allow development of several hydrofracs. If this is right, some documentation should be made available by the team. If not, the team might consider hydraulic fracturing in case hydroshearing does not perform as expected. Is this a possibility given the budget and the preparation already in place?

PI Response:

The microseismic array will have 15 stations when completed (not 20 as stated by the revieer); nine borehole seismometers and six surface sites.
The TZIM materials have been tested in the laboratory at up to 1800 psi differential pressure. The TZIM particle pack-off were not tested to failure due to limitations of the laboratory equipment.
The differential pressure needed to shift hydroshearing from one zone or depth to another depends on the relative values of frictional strength and fractures orientation compared to the fractures stimulated in the prior. So it is difficult to predict the differential pressures that will be needed to stimulate multiple zones. However, it has been observed in many wells, that the crust is often near frictional failure at any depth. If this is also the case in NWG 55-29, the differential pressure required to initiate hydroshearing at a new depth will be relatively small (<100 psi), in which case the TZIMs will not need to resist high differential pressures.
The use of packers to obtain multiple tensile fractures was considered, but the pressures required, the extra equipment including a drilling rig and the additional pumping horsepower to hydrofrack in a relatively strong, igneous rock are very expensive. There would only be sufficient funds to do two tensile fractures and they would be of shorter length so that a much smaller heat exchange area would be developed between the injector and producers. We do still have this contingency in the budget. Our testing at other sites gives us the hope that we will not need to do this.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23416

Score: 3.0

Comment: Progress since last year on stimulation has been modest (less than desired). Some changes to stimulation plan resulted from information about diverter dissolution at higher temperature. Some water supply, environmental and MEQ issues were sorted out. Results to date are comprehensively reported. Good public communication- few induced seismicity concerns, but some water resource concerns. Stress orientation and magnitude at depth are still unknown, affecting reliability of stimulation modeling.

PI Response:

I'm not sure about the "diverter dissolution at higher temperature" . We do have diverter materials tested to the high temperatures at Newberry. It wasn't easy to do, but we do have them. As to stress orientation at depth, the BHT data does give us that information, so the primary issue for stimulation modeling is the unknown length of existing fractures.

Reviewer 23533

Score: 3.0

Comment: Impressive public outreach efforts
If successful, would this project be economical
Delayed by 6 months, mainly due to unexpected bureaucracy

PI Response:

The reason for the doing the demonstration project is to determine if this would be economic. We have been delayed more than 10 months.

Reviewer 23554

Score: 2.0

Comment: Procedural and permitting activities complete although behind schedule. Now that the preparation work is complete, looking forward to the project actually conducting the stimulation and seeing the results.

PI Response:

Yes, we are too.

Reviewer 23579

Score: 3.0

Comment: Progress has been slower than anticipated, due partly to events beyond the control of AltaRock. However, the progress is well commensurate with expenditures on the project to date. The stimulation phase of this project will be carried out later this year, and should prove to be very interesting.

PI Response:

Agreed

PROJECT MANAGEMENT/COORDINATION

Reviewer 23416

Score: 3.0

Comment: Dealt appropriately with some frustrating delays in permitting. Publication of results & public presentations record (2010-12) is impressive. Management of decisions was reasoned and appropriate.

PI Response:

When it became clear we would delayed on permitting, we concentrated on public outreach and publications.

Reviewer 23533

Score: 4.0

Comment: Many collaborators, well managed
Developed an accepted seismic mitigation plan
Completed the BLM environmental assessment documents
Some of these above efforts could be used by other projects; at least in the definition of the potential hurdles

PI Response:

We hope that the Induced Seismicity Mitigation Plan (ISMP) can be used as a model by others. The duplication of reporting requirements needed to develop the plan may not be needed by others after our experience. Having little to no background seismicity data was both a blessing and a curse. The area is pretty much aseismic which is good, but there is not much data for statistical analysis of the potential hazards.

Reviewer 23554

Score: 4.0

Comment: Again, the best managed and planned EGS experiment reviewed.

PI Response:

Thanks.

Reviewer 23579

Score: 4.0

Comment: This project appears to be effectively managed. The PI and top management have the necessary technical background and skills to make good decisions. The entire technical team assembled is of very high quality, and includes appropriate collaborations with national laboratories and universities. The next Go/No-go decision point is appropriately placed after the stimulation and will determine whether or not to proceed with production well drilling. The project team has done a commendable job of educating the public and other stakeholders about the project. They understand that a negative public appraisal of the project might lead not only to its cancellation, but also to damage to the image of EGS development. This is especially true after the Swiss experience. The project team has also done a commendable job of discussing the project and expected results at the annual Geothermal Resources Council (GRC) and Stanford conferences.

PI Response:

Thanks. The delays were frustrating for us to deal with but will hopefully help others.

STRENGTHS

Reviewer 23416

Comment: Promising and well-planned EGS demonstration project in a green-field area. Public outreach program and good publication record is a positive. Collaboration with reputable scientists has helped.

PI Response:

Thanks. This is really a great team of people to work with all dedicated to having a successful project.

Reviewer 23533

Comment: Strong management

Impressive list of collaborators

PI Response:

Agreed

Reviewer 23554

Comment: Completed research and seismicity phases. Continuing to install microearthquake (MEQ) monitoring network. Preparations are complete, now it is time to go to work.

PI Response:

Yes indeed.

Reviewer 23579

Comment: Strengths of this project include:

1. The project is the only greenfield project among the EGS demonstrations reviewed. Developing and demonstrating EGS technology in undeveloped areas is highly important to the long-term future and goals of EGS.

2. The Newberry EGS demonstration project is in the Cascades province, known to include a number of active volcanic centers and a great deal of heat, with very little development of these resources to date. Developing technology to utilize the geothermal resources in this area would be a significant contribution to the growth of geothermal energy utilization in the USA.

3. The project team is well experienced in geothermal technology development and in geothermal energy utilization.

4. This project has developed an extraordinarily effective program for interacting with all stakeholders, especially with the public. This is very important because of the extreme environmental sensitivity of the Newberry area and its surroundings.

PI Response:

The extra time in permitting did help with the communication effort.

WEAKNESSES

Reviewer 23416

Comment: Lack of background data is challenging. Permitting delays means progress could have been better.

PI Response:

A microseismic network was installed as soon a feasible in the summer of 2010. Last summer, the USGS has also installed a much better seismic network to monitor Newberry. Six very small events have been detected between the two networks in the past 2 years, confirming that the low level of seismicity was not related to lack of monitoring. The detection of some seismicity has been a relief, because it indicates that the differential stress is sufficient for the crust to be near failure in, at least in some locations near the EGS well.

Reviewer 23533

Comment: Need more coordination between the different parties. Would help if the Principal Investigator would listen to suggestions

PI Response:

It is not clear from the comment what parties the reviewer is referring to.
The PI has listened to many suggestions and incorporated new ideas when possible. For example, a project proposed by the National Renewable Energy Lab and Oregon State University to monitor EGS using innovative methods was funded in the last DOE FOA cycle. We have assisted this project to get an early start and loaned our own permitting expertise to the PI of that project.
AltaRock does have a vision on how to best accomplish the goals of developing and commercializiong EGS. It is true that suggestions that do not align with our vision may not be heeded.

Reviewer 23554

Comment: Time for the project to move on to stimulation and testing.

PI Response:

Yes indeed.

Reviewer 23579

Comment: Some potential weaknesses are apparent in the project:

1. The project has high visibility, especially due to the extreme environmental sensitivity of the area, as noted above. The Newberry volcano area has been a popular recreation site for many years and is well known for its beauty. If the project were to cause an environmental problem, it would likely increase the difficulty of getting geothermal projects permitted throughout the Cascades. The possibility of a felt seismic event always exists, and if one were to occur, it might end the project. Also, since the project has high visibility and is in a greenfield, failure to reach its goals would be taken among some as a black mark against EGS anywhere. However, none of this contraindicates moving ahead with or supporting this project. We must start somewhere in the Cascades with this type of research, and Newberry is a good choice.

2. The project is being undertaken at temperatures and depths near the maximum for today's technology. This necessarily increases the chances of failure. However, the high temperatures at depth certainly form an attractive target for this research.

PI Response:

It is important to remember that this project was funded not as a research project, but as a demonstration project. As such, AltaRock provides 50% of the funding. The project is certainly visible and we hope that there is enough in the budget to accomplish the goals.

IMPROVEMENTS

Reviewer 23416

Comment: Recommend full documentation of cost/time/effort in permitting/compliance issues (~80% of costs so far), to assist in streamlining/reducing these for future projects. I suspect that this effort was an outcome of earlier media attacks on an AltaRock project, and that the expenditure was designed more to influence public opinion than advance scientific knowledge. However, the public are now apparently behind the project, which is a positive outcome, despite one year delay in project execution.

The crucial phase of stimulation is about to begin. Recommend full documentation of commentary on how to plan a green-field EGS stimulation with insufficient subsurface stress information, because of limited natural seismicity and deep borehole info. Critical issues to be tested are the appropriate spacing of stimulation zones (is 100m adequate?) since induced fractures are likely to be sub-vertical, and performance of the degradable diverter. A remaining challenge is to be able to detect when diverter has dissolved downhole. It would also be desirable to obtain/improve borehole imagery at ~300 degrees C.

PI Response:

I agree that our experience should be used to help others and reduce their time and effort for this type of project. The phase I report does contain full documentation of this effort and its cost and timing.

Reviewer 23533

Comment: Have access to discrete element models to obtain a more realistic reservoir representation. Need some "Fracture Mechanics" expert on the team

PI Response:

We do not believe that anyone knows what model type (discrete element, finite element, finite difference, discrete fracture network, or hydbrid) provides the most realistic reservoir representation for an EGS reservoir. As noted above, the theoretical model that AltaStim is based on was developed to model the results of Hijiori HDR. We are not aware that any validated discrete element models of the creation of a EGS or HDR.

There are four PHD scientists on the team with expertise in fracture and rock mechanics, structural geology, and numerical modeling: Trenton Cladouhos (AltaRock), Nicholas Davatzes (Temple University), Steve Hickman, and Ahmad Ghassemi (Texas A&M). We assume that this reviewer was unaware of the participation of these individuals.

Reviewer 23554

Comment: Reviewer did not provide comments for this criterion.

PI Response:

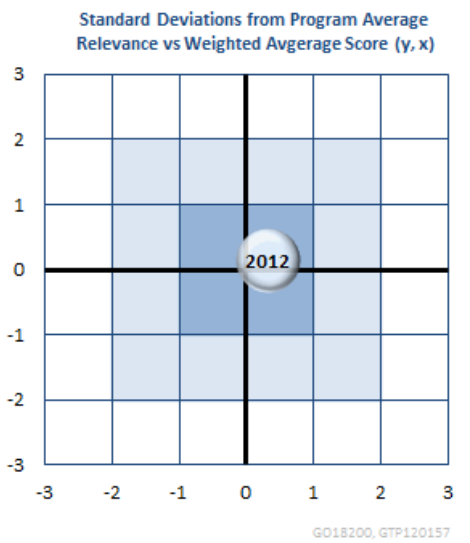
No response entered.

Reviewer 23579

Comment: It is important that this project conclude with a result that most would agree is success. Of course it would be best if the project reaches and even exceeds its goals, but falling short by some amount may not necessarily be a disaster. The team, including the researchers themselves as well as the Geothermal Technologies Office staff and their contractors helping to oversee the project, must be exhorted to give this project their very best shot. We need a winner here!

PI Response:

I totally agree. If there are things that would help to get us a winner that others want to obtain independent funding for, we would certainly support their efforts. Data from the project will be available for any further studies.



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18200
Project: Feasibility of EGS Development at Bradys Hot Springs
Principal Investigator: Drakos, Peter
Organization: Ormat Nevada, Inc.
Panel: Enhanced Geothermal Systems Demonstrations

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23416

Score: 3.0

Comment: When stimulation commences it will be a useful test of lessons learned, particularly from Desert Peak. This is a good demonstration of the current state of EGS technology with reduced risk of failure because not experimenting with untested methods. However, this project is not outstanding in terms of innovation.

PI Response:

Reviewer 23533

Score: 3.0

Comment: This project is the "twin brother" of the Desert Peak EGS demonstration project. Hence, most of the comments from Desert Peak's review will not be repeated here, unless they are more appropriate for this project
Unsure of what transpired from Desert Peak to optimize this new project.
This project has a more robust seismic monitoring area.

PI Response:

Reviewer 23579

Score: 4.0

Comment: This research addresses the problem of how to bring tight wells within operating hydrothermal fields into production as injectors or producers. Most known hydrothermal fields have wells that are neither producers nor suitable for injection because they are not well connected to the hydrothermal fracture system even though they may be located within the thermal anomaly. Testing of EGS fracturing technology to bring these wells into the system is important because of the potential for increased productivity and/or field longevity.

At present, the project is awaiting a Go/No-go decision with the stimulation planned to begin later in 2012.

PI Response:

Reviewer 23583

Score: 3.0

Comment: When successfully completed this project will improve the productivity/injectivity of a poorly performing (uneconomical) well within the Bradys Hot Springs (BHS) geothermal field while, hopefully, enhancing hydraulic connection to more productive resource areas thus making notable progress and impact toward achieving the Geothermal Technologies Office's EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment." When demonstrated, this achievement will significantly advance progress towards reducing EGS hydraulic fracturing knowledge gaps by employing “off-the-shelf” permeability-enhancement technologies. This project, if successful, will improve, significantly, understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing a strategy to deploy standard tools and techniques to improve connectivity and injectivity in non-performing wells.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23416

Score: 3.0

Comment: Good quality science. The execution and chances of success are also good, given nearby well info. Stimulation plan may be improved by adopting lessons learned from other projects. Expectations are modest (2-3 MWe).

PI Response:

Reviewer 23533

Score: 3.0

Comment: Please see previous comments on Desert Peak.
Development of a 3-D geologic model.
Attempt made to relate scratch test to logs.
Carried out Fullbore Formation MicroImager (FMI) analyses to characterize fractures.
Tried to relate type of faulting to fracture propagating pressure.

PI Response:

Reviewer 23579

Score: 4.0

Comment: The approach appears to be sound and thorough. A suite of geological, geochemical, geophysical and rock mechanics data has been gathered and interpreted to yield a subsurface structural model that has been used to design the stimulation plan. The project team represents a broad range of disciplines in geothermal energy research and development and is of high quality. The work elements as shown in the decision-tree are well designed, and are based partly on experience with a similar project at the nearby Desert Peak field.

PI Response:

Reviewer 23583

Score: 3.0

Comment: The implemented scientific/technical approach is thorough, reasonably likely to succeed and should be effective in achieving the project's objectives. The scientific rigor employed in the development of the geologic, structural, and stratigraphic models is very high and instills a feeling of confidence in the final results. The focus of the project is good, with most aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good and has room for minor improvements. However, details of how individual studies influenced the final technical decisions, such as the stimulation interval choice, were not presented nor discussed. This is a minor improvement compared to the project's technical goals but if others are to benefit from work performed, which is one of the project's goals, then it must be made clear which efforts influenced the important technical decisions.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23416
Score: 3.0

Comment: The progress slow, but careful and methodical. The first phase of laying the ground work for the stimulation phase was well thought out in terms of demonstrating EGS in a favorable setting. Proof remains to be seen with success of actual stimulation, which has yet to be achieved.

PI Response:

Reviewer 23533

Score: 3.0

Comment: Please see previous comments on Desert Peak.
Carried out 29 days of shear stimulation (@ 3 pressure tests), followed by 7 to 10 days of mixed hydro-shear and 4 days of high-rate pulse stimulation. How were days selected, and why are they different than what was done for Desert Peak?

PI Response:

Reviewer 23579

Score: 3.0

Comment: This project is behind schedule, due in part to permitting problems with the BLM, apparently not the fault of the project team. Expenditures to date appear to be in line with progress. The suite of data gathered and interpreted to construct the subsurface model and design the stimulation program appears to be thorough and well done. The critical part of the project, namely the stimulation itself, is yet to be done, and is planned for the third or fourth quarter of 2012, after a Go/No-go decision being studied at the moment.

PI Response:

Reviewer 23583

Score: 3.0

Comment: The project was initiated in June of 2009 and the end date is set for June of 2012 for a total of three years. Therefore, by calendar time (as of Jan-2012) the project should be 83% complete. However, the scope is only 50% complete and the budget is only 13% spent. Therefore, the accomplishments have been outstanding in relation to the resources expended and adequate with regard to progress towards project objectives and technical targets/goals but there is significant room for improvement regarding the schedule. This state of affairs is most likely due to difficulties in receiving BLM permits.

The quality and significance of the technical accomplishments and results is very high, however, the progress of the tasks is way behind schedule in relation to meeting project objectives. The level of productivity in work underway considering accomplishments and the value of the accomplishments compared to the costs is very admirable; lots of work for little cost. This situation is most likely due to the fact that major cost components will be in the final phase of the project.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23416

Score: 4.0

Comment: Coordination between multiple advisors, interested parties and collaborators is excellent. Delays are unfortunate but are dealt with appropriately. Data sharing on track.

PI Response:

Reviewer 23533

Score: 4.0

Comment: Please see previous comments for Desert Peak....very efficient.

PI Response:

Reviewer 23579

Score: 4.0

Comment: Planning for this project has been thorough, and the execution well done so far. Of course, the most difficult part of the project, the actual stimulation and analysis, is yet to be done. Coordination of the efforts of the rather large technical and management team has been well done. Collaborations have been established with several national laboratory and university groups. From the presentation, it is a bit unclear how all stakeholders have been brought in; however, this is a remote part of Nevada, and little effect on populations from any aspect of the project can be anticipated.

PI Response:

Reviewer 23583

Score: 3.0

Comment: So far, project management has been effectual in keeping costs down while getting the work done and plans to move forward are reasonable, logical and include needed control points. Better management is desirable to keep the project on schedule. In particular, the project management has been very effective in coordination with the fairly large number of collaborators. However, communication with the regulators has not been as effective in keeping the project on schedule.

PI Response:

STRENGTHS

Reviewer 23416

Comment: Builds on knowledge from Desert Peak experiments. Probability of success is high.

PI Response:

Reviewer 23533

Comment: There is a strong team.

Similar decision tree as established for Desert Peak, very efficient.

Nothing new, with the exception of having more data, based on previous reviews of Desert Peak.

PI Response:

Reviewer 23579

Comment: Some strengths of this project are:

1. Developing and testing technology to stimulate tight in-field wells to establish an effective connection with the rest of the hydrothermal system is an important endeavor. Many hydrothermal fields have hot but tight wells not suitable for production or injection. Isolated wells can also be anticipated in development of EGS reservoirs, and the results of projects such as this should enable a better understanding of the problems and their solutions for such wells.

2. Success in this project would increase the production from an operating geothermal field, helping to spur further geothermal development.

3. A comprehensive data base has been collected for this project, and a good case study should result from its publication.

PI Response:

Reviewer 23583

Comment: If successful this project will achieve notable progress and impact toward advancing the Geothermal Technology Office's EGS mission while significantly reducing EGS hydraulic fracturing knowledge gaps, and improving the office's understanding of how to lower current EGS reservoir creation technology barriers to reduce costs and boost performance.

The implemented scientific/technical approach is thorough, reasonably likely to succeed and should be effective in achieving the project's objectives. The focus of the project is good, with most aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good and has minor room for improvement.

The project's accomplishments have been outstanding considering the meager resources expended with adequate progress towards project objectives and technical targets/goals. In addition, the quality and significance of the technical accomplishments and results is very high.

So far, project management has been effectual in keeping costs down while getting the work done and plans to move forward are reasonable, logical and include needed control points.

PI Response:

WEAKNESSES

Reviewer 23416

Comment: Lacks innovation.

PI Response:

Reviewer 23533

Comment: This project should have produced a report on "Best Practices and Lessons Learned from Desert Peak".

PI Response:

Reviewer 23579

Comment: One minor weakness identified is the distribution of borehole microseismic stations around the stimulation well -- the NE quadrant has only one station, and it is a temporary surface station. When a reviewer asked about this, the PI responded that due to land access problems it was not possible to put a borehole MEQ station there. As a result. the locations of MEQs from the stimulation will likely be more poorly known with just the surface station to the NE since the freeway and railroad, which run through the geothermal system, can be expected to generate noise on surface stations. This problem is not seen as a major weakness in the project.

PI Response:

Reviewer 23583

Comment: Details of how individual studies influenced the final technical decisions, such as the stimulation interval choice, were not presented nor discussed. This is a minor improvement compared to the project's technical goals but if others are to benefit from successful work performed, which is one of the project's goals, then it must be made clear which efforts influenced the important technical decisions. In addition, it would seem that without more information it looks like too many studies might have been done.

There is significant room for improvement regarding the schedule and better management practices are needed to keep the project on schedule. In particular, communication with the regulators has not been as effective in keeping the project on schedule.

PI Response:

IMPROVEMENTS

Reviewer 23416

Comment: Recommend the project reconsider order and duration of pulse-shear and longer-term low-pressure shear stimulation phases, if fluid and pumps are available. The effect of cyclic cooling over time on thermal stresses might be more beneficial and cheaper than high-pressure pumping. Consider ways to test whether or not self-propped fracture failure induced by either hydro-shear or thermal stresses from longer-term cooling creates irreversible permeability improvement.

PI Response:

Reviewer 23533

Comment: Desert Peak and Brady projects are expensive and unique demonstration projects...why are we then essentially duplicating the operations rather than exploring other alternatives?

Need to consider 'reversing' the logical order; i.e. hydraulic fracturing stimulation prior to shear stimulation.

PI Response:

Reviewer 23579

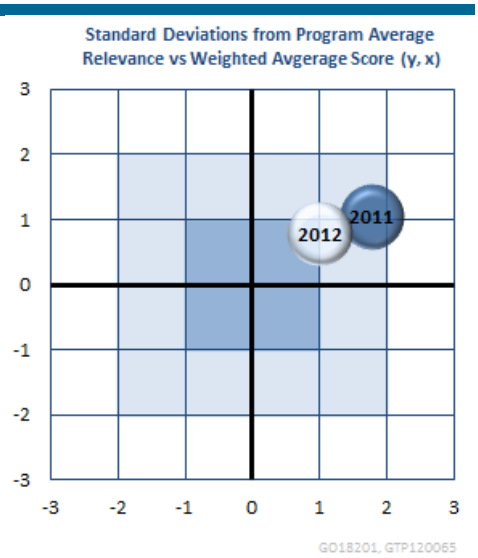
Comment: With the failure of the project at Desert Peak to reach its target injectivity (at least at this point in time), the very best effort possible should be made by the project team to ensure that the Brady project is a success. We need a winner in this part of the EGS Demo office!

PI Response:

Reviewer 23583

Comment: Provide details of how individual studies influenced the final technical decisions; better management practices are needed to keep the project on schedule, specifically communication with the regulators needs to be improved to keep the project on schedule.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18201
Project: Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field
Principal Investigator: Walters, Mark
Organization: Geysers Power Company, LLC
Panel: Enhanced Geothermal Systems Demonstrations

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23416

Score: 4.0

Comment: Tests deep permeability enhancement in high temperature roots of large conventional geothermal system. Outstanding factors include: relevance to roots of other systems from sustainability perspective; approaches the limits of corrosive chemical and high temperature settings; provides educational outreach; investigates injection cooling contraction, chemical dissolution, understanding of induced seismicity mechanisms, and brittle-ductile transition behavior.

PI Response:

No response entered.

Reviewer 23533

Score: 3.0

Comment: Definitely the highest temperature project.
Conducting a comparison with Hijori project in Japan.
Including tomography to refine 3-D geological model.
Achieving 100% mass replacement.

PI Response:

No response entered.

Reviewer 23554

Score: 4.0

Comment: An excellent experiment in a very productive geothermal system. The presenter remarked that one of his senior geologists thought this section of The Geysers would be the future production "breadbasket." This is the most relevant research to allow that speculation to come true. The Geysers is often dismissed as being unique and not representative of other geothermal settings but this is the best prospect of demonstrating the effectiveness of EGS techniques in the Geothermal Technologies Office project portfolio.

PI Response:

No response entered.

Reviewer 23579

Score: 4.0

Comment: This project has the goal of testing EGS technology in the undeveloped High Temperature Reservoir (HTR) portion of The Geysers field. The HTR is believed to result from a very young intrusion beneath the field, causing a thermal pulse that is migrating upward, and has not yet reached the Normal Temperature Reservoir (NTR). The intrusion seems not to have outgassed yet, and the HTR carries a high NCG content, including high chlorine. NCGs degrade performance of the conversion plant while the chlorine forms hydrochloric acid, which corrodes well casings and surface equipment. The objectives of the project -- to develop a fracture system in the HTR and to determine whether water injection into the HTR will significantly decrease NCGs and chlorine -- are highly pertinent to development of the HTR. If technology can be developed to utilize the heat in the HTR, the longevity, and perhaps the production capacity, of the premier geothermal field in the USA will be increased. This is, thus, an important research project.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23416

Score: 4.0

Comment: Excellent research approach by testing cost-efficient ways of accessing high-temperature, low-permeability rock for stimulation trials (low pressure, cold water) in the roots of NW Geysers. Challenges tackled include: well repairs, numerical models, understanding seismicity, chemical issues, geomechanical issues, downhole measurement issues, & NCG gases, in a field setting that is relatively well instrumented and understood. The 'roots' could be the “bread basket for the future” in terms of long-term sustainability of this and other large developed geothermal systems.

PI Response:

No response entered.

Reviewer 23533

Score: 4.0

Comment: Only EGS project investigating coupling effects (i.e. LBNL model).
Studies shear reactivation with thermal contraction and chemical dissolution.
Investigate a Hot Dry Rock (HDR) underlying a known thermal system; hence extending resource base.

PI Response:

The size of the explored but undeveloped EGS resource base in the Northwest Geysers is approximately 1100 acres. This area is sufficient for the drilling of at least 10 to 12 production and injection wells to develop this EGS resource base.

Reviewer 23554

Score: 4.0

Comment: This project is well planned and documented. Much of the background research and project documentation could serve as an operations manual for EGS projects.

PI Response:

No response entered.

Reviewer 23579

Score: 4.0

Comment: This project has been essentially completed as planned with no undue problems. A slight overrun in budget was made up by Calpine. Project results show that the technical approach and the project team were appropriate and of good quality. A significant amount of new knowledge was obtained, and based on this knowledge, Calpine should be able to move ahead with decisions about whether to develop the HTR portions of the field. The major obstacle to development appears to be in obtaining a power purchase agreement with a price that will allow economic operation -- an obstacle made worse by the very low price of natural gas at the moment.

PI Response:

Calpine recently submitted a proposal to a major utility to sell power from the EGS demonstration area in response to a request for proposals (RFP). To date, no response has been received from the utility. Calpine will continue to submit proposals for a Power Purchase Agreement (PPA) to build a power plant near the EGS as opportunities arise.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23416

Score: 3.0

Comment: Over the past year progress has been steady, except for the five month delay in stimulation. Adaptive approach allowed for changes in well utilization where justified by new information. Improvements in tasks related to seismic monitoring, super-critical temperature reservoir/geotechnical modeling, and educational outreach, are on track. Enhanced steam flow has resulted from the stimulation.

PI Response:

No response entered.

Reviewer 23533

Score: 4.0

Comment: Careful microseismic data acquisition and processing; some events were of magnitude 2.6. Project seems to be on-time and within budget; no major problems and/or difficulties encountered.

PI Response:

No response entered.

Reviewer 23554

Score: 4.0

Comment: Finally an EGS project that actually produces something! This effort deserves a gold star.

PI Response:

No response entered.

Reviewer 23579

Score: 3.0

Comment: The primary technical results include (a) a demonstration that low-volume water injection results in fracturing of the tight HTR rocks, as evidenced by microseismic observations, (b) the fact that communication with the NTR was developed, as evidenced by increase in steam from wells that can be traced through oxygen isotopes to the water injected into the HTR, and (c) the NCG content of the steam is reduced by a factor more than 10, while the chlorine content is not significantly changed. This later finding is a disappointment. The research team believes that it will take saturation of the fracture network in the HTR to reduce the chlorine content appreciably, and this was apparently not achieved. How it could be achieved in future projects in the HTR is an open question. Perhaps it's simply a matter of enough injection volume, or will the fracturing continue and the fractured volume never be saturated enough?

PI Response:

The corrosive chloride may originate from a flux (magmatic?) that is separate from the Total Noncondensible Gas source (hydrothermal) consisting mostly of carbon dioxide. Presently there is no means of determining if the concentration of chloride in steam flow from the HTR can be significantly lowered unless the HTR steam temperatures are lowered system-wide to saturated steam temperatures.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23416

Score: 4.0

Comment: This project is well managed and coordinated. It has strong industry support and there is a focus on improving modeling and measurement technology.

PI Response:

No response entered.

Reviewer 23533

Score: 2.0

Comment: Very cluttered and confusing oral presentation.
Planned to included a visitor center.
Good progress.

PI Response:

We apologize for the heavily concentrated and detailed technical information contained in a relatively few PowerPoint slides given in our oral presentation. We found that the mandated PowerPoint slide format is not conducive for presenting the technical aspects of a Phase 2 project. The mandated oral presentation format is OK for a review of the administrative and organizational aspects of a Phase 1 project. However, a Phase 2 (or Phase 3) EGS project is primarily technical in nature and much more space should be allowed for this information. We look forward to a better mandatory Peer Review format in 2013 when most of the GTO EGS projects have reached a Phase 2 level.

Reviewer 23554

Score: 4.0

Comment: This project is well planned, executed and managed. A prime example of how to do things right.

PI Response:

No response entered.

Reviewer 23579

Score: 4.0

Comment: This project has been well managed. It was completed on time and a bit over budget, but no additional money was needed from DOE. The project team is outstanding in its qualifications for this work. Especially close collaboration was established with the LBNL for microseismic monitoring and reservoir modeling. This knowledge resource at LBNL is potentially available to others and for publication, so this collaboration has importance. The publication of information that will result from this project will represent a valuable addition to current technology. The very sensitive matter of inducing felt earthquakes did not occur during the project.

PI Response:

Both LBNL and Calpine have published several papers as shown during our oral presentation. The knowledge resource (provided by Calpine) at LBNL is already available to others and is being published by others. Since the Peer Review two papers have been submitted for publication (e.g., Lutz, S., et al, June 2012, New Insights into the High-Temperature Reservoir, Northwest Geysers, in press: GRC Transactions to be published in October 2012).

STRENGTHS

Reviewer 23416

Comment: Returns from this project will be significant, and the knowledge gained will help guide development strategies for the roots of many other high temperature geothermal systems. Strengths are in the areas of high temperature instrumentation, modeling, public outreach, understanding induced seismicity, mitigation of NCG, and cold water stimulation methods.

PI Response:

No response entered.

Reviewer 23533

Comment: Complete approach with all scientific aspects covered. Contains a portion of research-oriented aspects. Probably the most probable successful EGS project.

PI Response:

No response entered.

Reviewer 23554

Comment: Exceptionally well planned and executed.

PI Response:

No response entered.

Reviewer 23579

Comment: Strengths of this project include:

1. The high-temperature reservoir (HTR) that underlies parts of The Geysers field represents a very large thermal resource. Developing technology to ensure its utilization is very important for this premier geothermal field, and for application to other very high temperature fields.

2. The project team has extensive experience in The Geysers area, were eminently qualified to carry out this project, and are equally qualified to continue work to develop the HTR.

3. Calpine is a large enough company to have the financial and human resources and the infrastructure to carry a project such as this forward in the face of most difficulties that might be encountered. This may be an important consideration for DOE in considering future projects to support.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23416

Comment: Weaknesses are the potential for problems with discharging fluid and gas chemistry, and with longevity of re-completed old well bores, to cause premature failure.

PI Response:

No response entered.

Reviewer 23533

Comment: Very poor presentation; this reviewer was lost in details and I needed to review the slides afterwards for clarification.

PI Response:

We believe that the mandated oral presentation format should generally follow the required written Project Summary outline. This year's written Project Summary outline and mandated oral presentation PowerPoint slides were entirely different which makes the presentation of the project difficult to review.

Reviewer 23554

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23579

Comment: None identified.

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23416

Comment: Recommend continue exploring novel tracer test methods to understand flows. I also suggest the PI further investigate ways of mitigating high CL (HCL) in produced steam from these stimulated roots. Further research into the issue of coinciding ductility and brittle failure -induced microearthquakes (MEQ)-could be very enlightening and assist with resource potential assessments for deeper high temperature resources. Such research may uncover implications, in

terms of ductile versus stick-slip strain relief, and MEQ behavior, of long and short term changes in temperature and pressure arising from utilization of these deeper resources.

PI Response:

No response entered.

Reviewer 23533

Comment: Reduce the review to the most salient points.

PI Response:

We felt that we needed to "force fit" the guts of our project's progress into the clumsey structure of the mandatory PowerPoint slides. We will welcome the opportunity to reduce our 2013 Peer Review presentation to its salient points assuming the DOE reduces the mandatory slides to a minimum consistent with the Phase of a particular project (see comments above in Project Management coordination).

Reviewer 23554

Comment: Continue to power production phase. Regrettably, power purchase agreements limit the project.

PI Response:

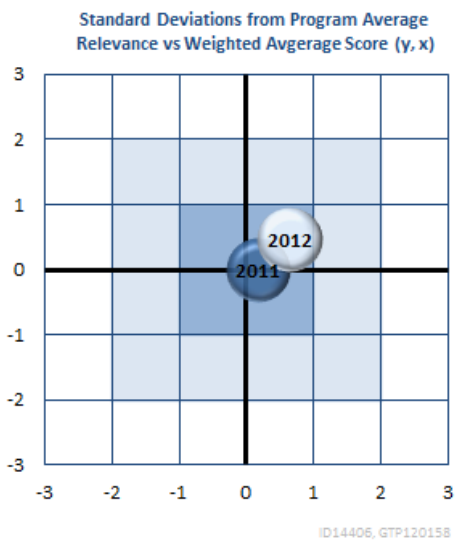
No response entered.

Reviewer 23579

Comment: None suggested.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: ID14406
Project: Desert Peak East EGS Project
Principal Investigator: Drakos, Peter
Organization: Ormat Nevada, Inc.
Panel: Enhanced Geothermal Systems Demonstrations

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23416

Score: 3.0

Comment: This project tested different stimulation approaches in a softer rock setting; research successfully addresses issues around creation and testing of stimulated permeability. Lessons learned will be transferable to other similar projects.

PI Response:

Reviewer 23533

Score: 3.0

Comment: This project attempts several stimulation types: shear, chemical, controlled hydraulic fracturing, and pulsation. Fit for operation optimization.
Borehole stability problems in abandoned well 23-1 should be back analyzed.

PI Response:

Reviewer 23579

Score: 4.0

Comment: This research addresses the problem of how to bring tight wells within operating hydrothermal fields into production as injectors or producers. Most known hydrothermal fields have wells that are neither producers nor suitable for injection because they are not well connected to the hydrothermal fracture system even though they may be located within the thermal anomaly. Testing of EGS fracturing technology to bring these wells into the system is important because of the potential for increased field productivity and/or longevity.

The project is essentially complete as originally designed, and nearly achieved its target injectivity, but fell a bit short. An interesting and worthwhile case history should result from this work, especially in view of the large amount of pre-stimulation information collected. Release of data to the public through the Geothermal Data Repository is part of the project, with the exception of data Ormat considers to be proprietary. The impact and value to the geothermal community

of the data and interpretations generated will be maximized if a minimum of proprietary data is retained by Ormat. The score for this element is based on the assumption that this will happen.

PI Response:

Reviewer 23583

Score: 4.0

Comment: This project has been going on for a long time (almost 10 years!) but is almost completed (workover and 2nd pulsed stimulation planned) and on the plus side it has met its technical goals of: increasing the injectivity of well 27-15 to commercial levels (to ~0.8 gpm/psi), improving the hydraulic connection to the producing geothermal field (reduced break-through time to producer 74-21 by a factor of 7X), and demonstrating enhanced power generation through successful stimulation (+1.5 MWe, personal communication with Ezra Zemach). It is clear that these successes have made notable progress and impact toward achieving the Geothermal Technologies Office's EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment." However, the “reduce costs” part of the mission remains undecided and the question remains, “Would the PI have done this stimulation without Geothermal Technology Office funds?”

That being said, these achievements have made a significant advancement towards reducing EGS hydraulic fracturing knowledge gaps by showing that if used correctly, “off-the-shelf” permeability-enhancement technologies can improve injectivity. This project, has improved, significantly, the understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing a strategy to deploy standard tools and techniques to improve connectivity and injectivity in non-performing wells. This project has already had a significant impact on the geothermal industry.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23416
Score: 4.0

Comment: Scientific and technical approach was sound. An adaptive strategy allowed for plan changes, and evaluation of different technology options. The project was designed to test the technique of self-propping shear-failure to enhance permeability.

PI Response:

Reviewer 23533

Score: 3.0

Comment: This project developed a reservoir model based on rigorous mechanics.

PI Response:

Reviewer 23579

Score: 3.0

Comment: A thorough and well designed approach has been taken for this project. Pre-stimulation data collection and interpretation to characterize the field and help plan the stimulation program was thorough. The work elements appeared to be well designed even though the target objectives were not realized by execution of the planned program. The project is staffed with a wide variety of experienced geothermal experts and is of high quality.

PI Response:

Reviewer 23583

Score: 4.0

Comment: The scientific/technical approach was well-planned, straightforwardly implemented and effective in achieving the project's objectives. That is not to say that challenges did not occur, they did, like the well instability issues cause by the chemical stimulation. The scientific rigor employed in the development of the geologic model, core/cuttings analysis, well field correlation & mapping, and seismic reflection survey was commendable. Overall the focus of the project was good, with most aspects contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach was good but has room for productivity improvements (10 years!). However, details of how individual studies influenced the final technical decisions, such as the stimulation interval choice, were neglected. This is a major issue if others are to benefit from work performed, which is one of the project's goals. It must be made clear which efforts influenced the important technical decisions and which did not.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23416

Score: 3.0

Comment: Progress was delayed by technology issues, equipment availability, and permitting issues related to seismicity protocol compliance. Some issues developed in managing well condition, due to formation instability and chemical stimulation, leading to extra cost of well cleanout. Ongoing work to achieve success still required.

PI Response:

Reviewer 23533

Score: 4.0

Comment: This project achieved 113 days of shear stimulation, followed by 10 days of chemical stimulation (type?), and then 3 days of pulse stimulation to reach an injectivity of 8 gpm; questioning the success of such a logic.
Was pulse stimulation efficient?
Good seismic analysis, revealing moments ranging from 0.1 to 0.74.
Controlled hydraulic fracturing stimulation of hundreds of gpm induced 45 seismic events.

PI Response:

Reviewer 23579

Score: 3.0

Comment: Although the stimulation program was well carried out, and the injectivity of well 27-15 was increased by a factor of about 60 to 0.8 gpm/psi as a result of stimulation, the target of 1 gpm/psi was not reached, and the well is deemed not to be commercially useable. Whereas the hydroshearing, hydraulic fracturing and pulse stimulation were successful, the chemical stimulation caused wellbore damage that required workover. The instability continues to persist and further workover will be required before stimulation to reach the target injectivity can be carried out. This will require further funding, some of which is presumably being requested from DOE.

A wealth of geoscientific data was generated by this project and it will contribute significantly to the growth of knowledge in the geothermal community. This will be especially true with a thorough examination of the problems generated by the chemical stimulation.

PI Response:

Reviewer 23583

Score: 3.0

Comment: The Geothermal Technologies Office-funded portion of the project is completed. Other work (workover and 2nd pulsed stimulation) is planned outside of the initial project scope and budget. It was initiated in September of 2002 and the end date was last year Q4 2011 for a total of 9.3 years. The project's budget is 100% spent and accomplishments have met the targets/goals within the resources expended.

The quality and significance of the technical accomplishments and results is high (increasing the injectivity of well 27-15 from 0.012 to 0.8 gpm/psi, improving the hydraulic connection to the producing geothermal field by a factor of 7X, and demonstrating enhanced power generation by +1.5 MWe). However, the level of productivity considering the length of

the project and the accomplishments was low. The value of the accomplishments compared to the costs is questionable and will need to be looked at very carefully; increased injectivity for considerable cost ~$8M.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23416

Score: 3.0

Comment: Stimulation work program and plan reasonably comprehensive and well managed. Technology evaluation is competent. Delays unfortunate but mostly managed appropriately.

PI Response:

Reviewer 23533

Score: 4.0

Comment: The Principal Investigator is totally 'in control' of an impressive team of experts.
There have been numerous reports and technical papers to disseminate results in a timely fashion.
There is fast decision making, very efficient operation.
This project has good coordination with plant operations.

PI Response:

Reviewer 23579

Score: 4.0

Comment: The project appears to have been well managed, especially in view of the large number of participants. The project team is well experienced and of high quality. The use of a well constructed decision tree to help with quick project decisions is noted. The project team has produced a large number of publications at the annual GRC and Stanford workshops.

PI Response:

Reviewer 23583

Score: 4.0

Comment: Because the project is completed and the goals were met or exceeded within the agreed-to budget, retrospectively, one has say that project management was successful; i.e., effectual in keeping costs down while getting the work done. However, it is clear that better project management could have kept the project on schedule. That being said, project management was very effective in coordinating with the fairly large number of collaborators.

PI Response:

STRENGTHS

Reviewer 23416

Comment: A mature project, Desert Peak has encountered its share of problems in the past, but is now showing promising indications of success. Stimulation activities were generally sound. Lessons were learned in terms of the causes of well instability issues, and the benefits of perseverance with various stimulation techniques, and choice of favorable structural settings. The need for deep borehole seismometers to characterize very small magnitude events to track the progress of an expanding stimulated reservoir volume was identified.

PI Response:

Reviewer 23533

Comment: This is a strong team, working together.

Project results readily available.

PI Response:

Reviewer 23579

Comment: Some strengths of this project are:

1. Developing and testing technology to stimulate tight in-field wells to establish an effective connection with the rest of the hydrothermal system is an important endeavor. Many hydrothermal fields have hot but tight wells not suitable for production or injection. Isolated wells can also be anticipated in development of EGS reservoirs, and the results of projects such as this should enable a better understanding of the problems and their solutions for such wells.

2. Success in this project would increase the production from an operating geothermal field, helping to spur further geothermal development.

3. A comprehensive data base has been collected for this project, and a good case study should result from its publication.

PI Response:

Reviewer 23583

Comment: This project has achieved notable progress and impact toward advancing the Geothermal Technologies Office's EGS mission while significantly reducing EGS hydraulic fracturing knowledge gaps, and improving the office's understanding of how to lower current EGS reservoir creation technology barriers to boost performance.

The implemented scientific/technical approach was thorough, successful and effective in achieving the project's objectives. The focus of the project was good, with most aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach was good with some room for improvement.

The project's accomplishments are outstanding with outstanding progress towards project objectives and technical targets/goals. In addition, the quality and significance of the technical accomplishments and results are very high.

Project management was highly effectual in getting the work done and reaching the goals but the project took way too long to complete.

PI Response:

WEAKNESSES

Reviewer 23416

Comment: Additional stimulation is still needed to improve injectivity and make the project completely successful. Also, the need to maintain high pressure stimulation pumping continuously for a week or more requires attention to maintenance schedules and water supply.

PI Response:

Reviewer 23533

Comment: Should carry out a post-mortem analysis on well 23-1.

In light of the presence of soft shale, was the chemical compatibility checked?

PI Response:

Reviewer 23579

Comment: It might be argued that the wellbore damage resulting from the chemical stimulation could have been anticipated, and this may or may not be true.

PI Response:

Reviewer 23583

Comment: Details of how individual studies influenced the final technical decisions, such as the stimulation interval choice, were missing. In addition, it would seem that without more information about the specific influence of each study, it might look like too many studies were done.

There is significant room for improvement regarding the schedule and better management practices were needed to keep the project on schedule.

PI Response:

IMPROVEMENTS

Reviewer 23416

Comment: Recommend a post-mortem on successes/failures. For example, documenting of the problems caused by geological and tectonic setting (soft rock, high clay content), and utilization of chemical stimulation (after sufficient near wellbore permeability has been created to disperse chemicals away from wellbore and avoid damage). Recommend document lessons learned: benefits of low pressure shear and high pressure pulsed stimulation; the value of borehole seismometers to detect smaller events; being cautious about stimulating old wells with possible stability issues.

Recommend consider the possible long term benefits in terms of gradual but permanent permeability increase caused by cooling contraction (and thermal stimulation of self-propped shear-failure) through low-pressure injection. Compare with modeling studies and overseas injection experience (e.g. Mokai, Kawerau and Rotokawa).

PI Response:

Reviewer 23533

Comment: I recommend that a summary be published clearly outlining the satisfactory technology transfer to the Brady project....and what to avoid (e.g. is pulse stimulation efficient?)

Was there any microseismicity resulting from the shear stimulation?

Is it possible to improve the definition of the stimulated volume?

PI Response:

Reviewer 23579

Comment: A thorough analysis of project results, with emphasis on why the various stimulations fell short of achieving their goals, is needed for this project. Some emphasis should be placed on why the chemical stimulation caused wellbore instability and how this can be anticipated and/or prevented in future projects. Results of this analysis should be published.

PI Response:

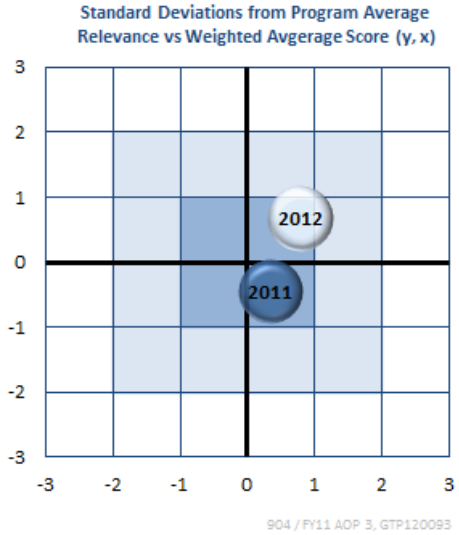
Reviewer 23583

Comment: Details of how individual studies influenced the final technical decisions are needed; an analysis of why the project took so long is suggested in hopes of providing helpful suggestions to other projects of what not to do.

PI Response:

EXPLORATION VALIDATION

Review: 2012 Geothermal Technologies Office Peer Review
ID: 904 FY11 AOP 3
Project: Integrated Chemical Geothermometry System for Geothermal Exploration
Principal Investigator: Spycher, Nicolas
Organization: Lawrence Berkeley National Laboratory
Panel: Exploration Validation



RELEVANCE/IMPACT OF RESEARCH

Reviewer 23554

Score: 4.0

Comment: Highly relevant and an important step in making sense of geochemistry and geothermometry. Release of the software may be the best advance in geochemistry since Werner Giggenbach.

PI Response:

Reviewer 23552

Score: 3.5

Comment: The research by Spycher and his team is important and should be of wide interest as different geothermometers are widely applied in geothermal exploration and resource evaluation. Their approach attempts to create a practical thermodynamic method to optimize geothermometry results and identify and minimize the effects of gas loss and dilution. Their synthetic, numerical, and case study approach is innovative and the results of significant importance. Furthermore, their multi-component geothermometer approach should be less susceptible to disequilibrium processes and time-dependent changes. In detail, their laboratory benchmarking experiments and sensitivity tests give the novel approach credibility and promote a more fundamental understanding of processes and chemical components influencing resulting compositions and possible erroneous results. My concerns are mainly related to (1) a necessary better treatment of time-dependent transient signals and re-equilibration during ascent, outflow, or storage; (2) a more robust Monte-Carlo based approach to better understand realistic uncertainties (compared to the controller approach); and (3) the uncertainty or lack of plan in regards to code/software dissemination and making it available to the community. Making the data (not the product?) available through the National Geothermal Data System platform appears inadequate. Despite, these minor points, the research by Spycher and colleagues is extremely important and systematic and should lead to a fundamentally improved and more robust approach to geochemical geothermometry in geothermal research and exploration.

PI Response:

Reviewer 23532

Score: 3.0

Comment: This project may have limited application to exploration of hidden geothermal systems since it relies on the availability of fluid samples. However, once temperature gradient wells are available, fluid samples may be available. The project should have significant application to exploration in geothermal areas where springs are available for sampling.

Proper interpretation of geochemical thermometers should have a major impact on selecting drill sites that reach adequate temperatures for economic geothermal production. This project should have an important impact on accurate determination of subsurface temperatures without drilling if applied to areas where adequate samples are available for inverse modeling.

This project is well worth continued funding to improve and test the potential and limitations of the methodology

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23554

Score: 3.0

Comment: Very good progression from controlled experimental phase to applied practical phase. Still early in evaluating field results and limited to one field example (Dixie Valley).

PI Response:

Reviewer 23552

Score: 3.5

Comment: The scientific, and technical approach by Spycher and his team and the pursued methodology is flawless and based on a deep and comprehensive understanding of the problem and the applications and shortcomings of chemical thermometry of geothermal fluids. The project takes a multifaceted approach to improved and automated geothermometry using complete geothermal water analysis and multi-component thermometry. The approach consists of optimization of multi-component analysis of synthetic and "real-life" examples from several collaborative case studies, experimental bench-marking, and integration into available reactive transport models. In particular, laboratory-based sensitivity analysis of multi-component systems and the exploration of the parameter space in terms of deviation from "true value" due to specifications (e.g. Al), gas loss dilution, etc. The approach is very solid and promising, however, also somewhat simplistic. While this might make the proposed widely applicable and easy to use in an automated fashion that only depends on complete water analysis and a series of assumptions. The project would benefit from a more critical review of these assumptions. For example, their employed optimization approach assumes that the system is in equilibrium and that all chemical thermometers record the same temperature and all are in thermodynamic equilibrium. Storage, ascent re-

equilibration, and the influence of lithologies the fluids percolate through makes that assumption questionable. Is it possible that the optimization (i.e. finding a common minimum) combines a more complicated signal that might in fact record more information? The laboratory based approach might allow a test of this assumption, but varying the bulk chemistry, not just Al content. As mentioned above, the Monte-Carlo based approach developed by Spycher and his team should also allow for a better estimation of temperature uncertainties. While people might just want a number, it would be very useful of the automated approach would also allow an estimation of confidence. Certainly not all complete water analysis thermometry results are created equal. Overall excellent and very useful research.

PI Response:

Reviewer 23532

Score: 4.0

Comment: The project appears to be making outstanding progress in developing the technology to utilize inverse modeling and geochemistry to determine subsurface temperatures while taking into account boiling, mineralogy, mixing, etc. So far the project has focused on the important parameters.

The PI is aware of problems and limitation of the method such as compartmentalized fluid and rock.

There are some restrictions on its use that the PI seems to understand but that future users will need to be aware of. Hopefully any manual will carefully provide this information. As mentioned during the talk, highly saline waters will cause problems as well as compartmentalized systems of different base temperature, geochemistry and rock type.

Re-equilibration of fluids during transport to the surface will mask deeper temperatures as well as the effects of boiling and mixing which are already being considered by the PI.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23554

Score: 3.0

Comment: The Dixie Valley results are a prime illustration of how this software can work and how relevant this research is to quickly and realistically evaluating geothermometer results.

PI Response:

Reviewer 23552

Score: 3.5

Comment: The project has successfully automated the multi-component chemical geothermometer developed previously, taking into account reservoir mineralogy, gas composition, gas loss, and dilutions, while assuming a reservoir temperature that is record by equilibrium conditions of multiple geothermometers. The team has applied this approach to several case studies (e.g., Dixie Valley) in collaboration with a large number of industry and academic collaborators. The completed research has also evaluated the important effects of gas loss and dilution and co-existing mineralogy through by thermodynamic models and laboratory-based experiments. The project appears to be on track despite initial personnel-related delays (hiring of post-doc). The project is currently in the process of implementing an optimization-based approach, input from multiple locations, integration with existing software packages, and reactive transport modeling of real and synthetic data. The last point that is mentioned in progress is the integration into a practical software tool. However, Spycher was not clear or didn't articulate a plan on how to make this the Geothermal Technologies office-sponsored tool available to the community and how to disseminate the knowledge and lessons learned. I would rate this as a significant shortcoming, despite the substantial progress and valuable research outcome to date. Along the same lines, the "data" sharing plan is inadequate. How about calling is "product" sharing (and software is a product; THE product of this project).

PI Response:

Reviewer 23532

Score: 3.0

Comment: There was some delay in getting staff for the project so progress has not been outstanding. However, progress, results and accomplishments have been outstanding since the project was fully staffed.

The progress so far has shown that the method works under some circumstances. To the PIs credit he seems to have realized most, if not all, of the constraints on the accurate application of the model. Hence progress and future direction should continue to be outstanding.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23554

Score: 4.0

Comment: Proceeding to target date for release.

PI Response:

Reviewer 23552

Score: 4.0

Comment: The team assembled by Spycher is very qualified and well-coordinated and managed as one would expect from a successful National Laboratory team. What is particularly noteworthy is how the team is piggy-backing very successfully onto existing projects for the case studies. I find this to be excellent use of collaborative contacts and illustrate the well managed and coordinated project. Of course, unlike many other more complex project that involved a wide spectrum of geological, geophysical, etc exploration tools as well as drilling and exploration efforts, this project is significantly more straightforward and manageable. This, however, does not and should not detract from a nicely coordinated and productive project.

PI Response:

Reviewer 23532

Score: 3.0

Comment: The technical team is well qualified to undertake this work and successfully complete it. Geochemists at Lawrence Berkeley National Laboratory (LBNL) with strong experience in geochemistry of geothermal systems are part of the LBNL project team.

PI Response:

STRENGTHS

Reviewer 23554

Comment: Excellent experimental work and software development.

PI Response:

Reviewer 23552

Comment: I consider this an excellent project with a number of significant project-oriented, scientific, and "user-community" strengths. As discussed above on the scientific, and technical strength of the project by Spycher and his team this is a flawlessly executed project that builds on a well-developed understanding of the chemical problems as hand. The team of experts of international caliber is a true strength with all their expertise, experience, and know-how that they bring

to the table. The science plan is well formulated and conceived and promises success and significant results with wide-ranging applicability and impact in terms of the improved and more robust application of chemical thermometry to geothermal fluids in order to characterize reservoir temperatures. The improved and automated geothermometry using complete geothermal water analysis and multi-component thermometry will be useful for a large audience of industrial and academic users. Spycher's team's approach utilizes an interesting and powerful optimization approach for calculating refined reservoir temperatures based on of multi-component analysis of complete water analyses. Another strength of the project lies in the system strategic devised by the team, integrating synthetic and "real-life" examples from several collaborative efforts, experimental laboratory-based insights into effects of various parameters, and integration into available reactive transport models. As previously stated, the laboratory-based sensitivity analysis of multi-component systems and the exploration of the parameter space in terms of deviation from "true value" due to specifications (e.g. Al), gas loss dilution, etc. is clearly powerful and will shed real light on the validity of the various assumptions and misconceptions of widely-used and -abused chemical thermometry.

PI Response:

Reviewer 23532

Comment: The scientific objectives of this project are well thought out and the science is very interesting. This could be a very important new tool for determining geochemically derived temperatures for geothermal systems where an adequate number of chemical samples are available from hot springs and wells.

I hope that the Geothermal Technologies Office will continue to fund this project in order to fully validate its usefulness. There are some restrictions on its use that the PI seems to understand and that future users will need to be aware of. Hopefully any manual will carefully provide this information. As mentioned during the talk, highly saline waters will cause problems as well as compartmentalized systems of different base temperature, geochemistry and rock type.

Re-equilibration of fluids during transport to the surface will mask deeper temperatures as well as the effects of boiling and mixing which are already being considered by the PI.

Its use will be limited in hidden systems but once even shallow or intermediate depth temperature data becomes available the method may be useful.

PI Response:

WEAKNESSES

Reviewer 23554

Comment: Expand to other areas and other geothermal systems.

PI Response:

Reviewer 23552

Comment: While the overall project is very strong as detailed in the "Strength" section and while the approach is very solid and promising, some aspects are maybe somewhat simplistic and would benefit from a more realistic fluid-rock interaction concept. The project could make a bigger effort to explore some of the fundamental assumptions and discuss the limitations and pitfalls. As stated before, the project would benefit from a more critical review of the assumptions, the likelihood of equilibrium in the reservoir, re-equilibration with rocks during percolation and ascent, the possible kinetic effects on results. The employed optimization approach assumes that the complete system, as characterized by complete fluid chemical analysis, is in equilibrium and that all chemical thermometers record the same temperature and all are in thermodynamic equilibrium. Storage, ascent re-equilibration, and the influence of lithologies the fluids percolate through makes that assumption questionable. Is it possible that the optimization (i.e. finding a common minimum) forces a more complicated signal into a common artificial minimum that might in fact record a more complicated and time-transgressive information? The laboratory-based approach might in fact allow a test of this assumption, but varying the bulk chemistry, not just Al content. As mentioned above, the Monte-Carlo based approach developed by Spycher and his team should also allow for a better estimation of temperature uncertainties. While people might just want a number, it would be very useful of the automated approach would also allow an estimation of confidence. These points are not necessarily weaknesses of the project, but rather cautionary suggestions.

PI Response:

Reviewer 23532

Comment: There are some restrictions on this inverse modeling approach that the PI seems to understand and that future users will need to be aware of. Hopefully any manual will carefully provide this information. As mentioned during the talk, highly saline waters will cause problems as well as compartmentalized systems of different base temperature, geochemistry and rock type.

Re-equilibration of fluids during transport to the surface may mask deeper temperatures.

The effects of boiling and mixing may make analysis more difficult but the PI is already considering these aspects of the technique.

The technique maybe limited in hidden systems but once shallow or intermediate depth fluid samples are available, the method will be useful.

The system may also have limited applicability in exploration for EGS which are lacking sufficient fluid for near surface sampling.

PI Response:

IMPROVEMENTS

Reviewer 23554

Comment: Deploy in volcanic environment where the majority of geothermal systems occur worldwide.

PI Response:

Reviewer 23552

Comment: Without wanting to sound repetitive, as I summarized much of this in the previous section, the project could benefit from the following improvements and adjustments of future directions:

(1) a more careful evaluation and exploration the basic assumptions and their validity

(2) an improved treatment of uncertainties during optimization (temperature estimate and +/-)

(3) explorations of geological pitfall both in applied and laboratory-based studies (what could influence or potentially invalidate results)

(4) a better defined and articulated software distribution and dissemination strategy and plan (the main weakness at this point)

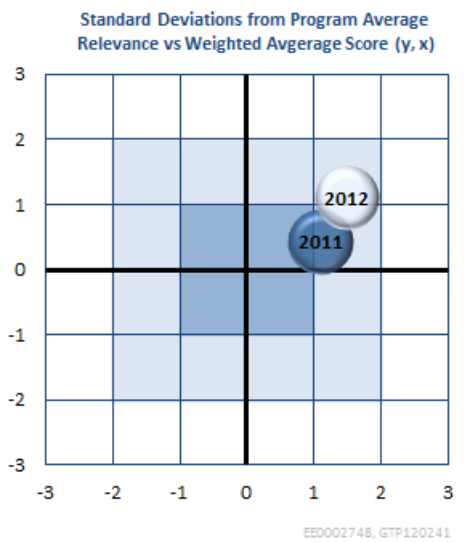
PI Response:

Reviewer 23532

Comment: Continue to work on solutions to the weaknesses noted.

Testing of the system at the Raft River geothermal field might provide a good test of a system in which the fluids appear to be strongly compartmentalized.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002748
Project: Characterizing Structural Controls of EGS-Candidate and Conventional Geothermal Reservoirs in the Great Basin: Developing Successful Exploration Strategies in Extended Terranes
Principal Investigator: Faulds, James
Organization: University of Nevada, Reno
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23427

Score: 4.0

Comment: The research addresses EGS site selection and characterization barriers. This work will augment the discovery of new conventional geothermal systems, as well as enhancement of known systems, by providing qualitative and quantitative data on the most favorable structural settings for geothermal activity.
Better characterization of known geothermal systems is critical for new discoveries, targeting drilling sites, and EGS development. This is especially important in the Great Basin, where the bulk of geothermal resources may have no surface expression. The project is assessing the structural controls of geothermal systems in the Great Basin and adjacent regions in close collaboration with industry.
The project end date is 1/31/2013.

PI Response:

I agree.

Reviewer 23530

Score: 4.0

Comment: This is an important project as it will help with structural predictions of reservoirs to reduce the risk of drilling. The oil and gas industry has greatly benefited from such characterizations and predictions and this project will promote the same for geothermal exploration and development. Many of the systems in the Basin are blind so this project will pave the way to the development of better conceptual models to predict reservoirs in this area. The project has similar applications to EGS reservoirs as well.
The educational influence of this work in drawing students and young professionals into the geothermal industry is to be especially commended.

PI Response:

I agree. It is indeed imperative to involve the next generation of geoscientists in such research.

Reviewer 23627

Score: 3.5

Comment: The idea of systematic analysis of site-tectonic conditions to find out where within a geothermal field the upflow zone is likely to be or where conditions for a blind field might be favorable is very interesting and could have high impact in the future works.

PI Response:

Agree.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23427

Score: 4.0

Comment: The project is systematically assessing the structural controls of geothermal systems in the Great Basin and adjacent regions. Phase I (Year 1) involved a broad inventory of structural settings of geothermal systems, with the aim of developing conceptual structural models and a structural catalogue of the most favorable environments. This overview permitted selection of representative sites for more detailed studies in Phases II and III (Years 2, 3). Sites were selected based on quality of exposure, potential for development, and general type of system. The detailed investigations include geologic mapping, kinematic analysis, and stress
This project expands upon previous research efforts through an inventory of known systems in the Great Basin, detailed investigations of several additional but representative sites, and comparative analysis of systems in different tectonic provinces or settings (e.g., magmatic vs. non?magmatic). In addition, we have incorporated a more quantitative approach through analysis of the slip dilation tendency of faults and 3-D modeling of geothermal systems, thus facilitating the selection of drilling sites and well paths.

PI Response:

Agree.

Reviewer 23530

Score: 4.0

Comment: The project has a comprehensive approach as the PI has analyzed 300 geothermal systems to develop categorizations. As the presenter said, there is “no geothermal field of dreams;” the project approach will make the most of existing data to develop a comprehensive characterization of geothermal structures based upon existing data.

The project has a logical approach to develop categorization of all structures and subsequently test the approach via detailed evaluation of a smaller number (5-6; maybe 9-10) of resources.

Development of three dimensional models will help with an understanding of the complexity of geothermal structures.

PI Response:

Agree.

Reviewer 23627

Score: 4.0

Comment: Systematic analysis of existing date from numerous sites is an excellent way to proceed.

PI Response:

Agree.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23427

Score: 4.0

Comment: The primary goals of Year 2 were to finalize selection of representative sites for detailed study, conduct the detailed studies, embellish the structural catalogue, and initiate 3-D modeling and slip dilation tendency analysis.
Major field excursions were undertaken to analyze geothermal systems in eastern California, northern Nevada, and southern Oregon.
Structural controls of over 300 geothermal systems have been analyzed either with literature research or field reviews (200 additional systems this year). Eleven representative geothermal fields were selected for detailed study.
The project has defined a spectrum of favorable structural settings for geothermal systems in the Great Basin region. The project also completed a catalogue that interprets the structural setting of most of the geothermal systems in the region. This work will augment the discovery of new conventional geothermal systems, as well as enhancement of known systems, by providing qualitative and quantitative data on favorable settings. Specifically, it will help to focus regional exploration programs, target productive well sites in individual geothermal fields, and select the best sites for EGS experiments.

PI Response:

Agree.

Reviewer 23530

Score: 4.0

Comment: Progress to date has been very good. Database development is aggressive. The PI and team have produced many publications and presentations on their work. The development of categorization of geothermal structures allows similarities to be evaluated across the industry. Use of data to evaluate the five or six systems has shown good progress towards defending structure categorizations. This project has shown good progress in categorization of blind systems based upon existing geophysical data.

PI Response:

Agree.

Reviewer 23627

Score: 4.0

Comment: Excellent.

PI Response:

None needed.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23427

Score: 4.0

Comment: The greatest challenges involved changes in the time commitments of two original co-principal investigators. These were overcome by adding additional personnel to the project.
This project is progressing well, with completion of nearly all Years 1 and 2 milestones.

PI Response:

The additional personnel, including one post-doctoral scholar, are contributing enormously to the project.

Reviewer 23530

Score: 4.0

Comment: Project has successfully backfilled positions created by vacancies. The PI has done well to draw in so much industry participation. Project is progressing well; milestone progress is clearly evident.

PI Response:

Industry collaborations have greatly benefited this project and facilitated the 3D modeling with substantial subsurface data.

Reviewer 23627

Score: 4.0

Comment: The project management seems very good.

PI Response:

None needed.

STRENGTHS

Reviewer 23427

Comment: The strength of this project is that it is systematically carrying out evaluations in an area (the Great Basin) that is critical to EGS exploitation.

PI Response:

The Great Basin is one of the premier regions of the world for geothermal activity. Systematic studies here will provide critical data for EGS exploitation world-wide.

Reviewer 23530

Comment: Project is creating foundational work that will lead to successful exploration on future geothermal projects and categorization of structures within geothermal reservoirs to facilitate communication throughout the industry. Training of next generation of researchers is commendable.

PI Response:

Agree.

Reviewer 23627

Comment: The strength of this project lies in a very clear vision on the objectives and well-defined tasks.

PI Response:

None needed.

WEAKNESSES

Reviewer 23427

Comment: A weakness is that of the 300 systems selected, there was insufficient data on 100 of them. This isn't a near-term problem, because there appear to be more characterized sites than there are geothermal prospectors.

PI Response:

We have found that many so-called "geothermal systems" in the Great Basin correspond to nothing more than warm wells within basins. Such systems are difficult to characterize unless substantial geophysical data are available for the basin, which is not common. Furthermore, we are currently in the midst of reviewing our interpretations of the designated structural setting of all systems, including those that we could not initially categorize. This process is reducing the number of "undetermined" systems.

Reviewer 23530

Comment: None noted.

PI Response:

None needed.

Reviewer 23627

Comment: This project has no obvious weaknesses.

PI Response:

None needed.

IMPROVEMENTS

Reviewer 23427

Comment: I don't think that I came up with any weaknesses or strengths that everyone isn't pretty much aware of already; however, I think there needs to be a proactive approach to ensuring that data/information generated in Geothermal Technologies Office projects is not only archived, but actively used in advancing the goals of the office.

Specifically, this project has made the following statements as to how its results will be made public.

• In addition to providing the required quarterly and annual reports, results will be presented at various meetings and workshops.
•A course in geothermal exploration was taught in Spring 2011, as described above. In addition to transferring knowledge to the next generation of geothermal geoscientists, some of those taking the course were professionals currently holding positions in industry.

•Papers and presentations were presented at national meetings and workshops.

•Multiple publications addressing structural controls of geothermal activity will result from this project, including a comprehensive catalogue detailing favorable settings.

•Results were presented at the 2011 GSA and GRC annual meetings (Year 2, Milestone 5).

•And this project is integrated with other projects in Geothermal Technologies Office portfolio.

PI Response:

We will work toward achiving all of our products, including those listed above.

Reviewer 23530

Comment: Reviewer did not provide comments for this criterion.

PI Response:

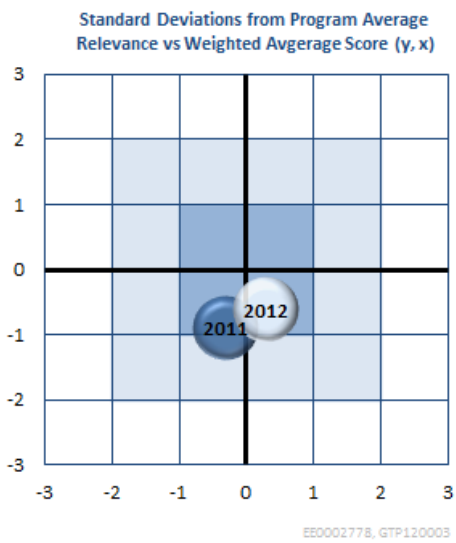
None needed.

Reviewer 23627

Comment: No suggestion – the project is excellent.

PI Response:

None needed.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002778
Project: Development of Exploration Methods for Engineered Geothermal Systems through Integrated Geophysical, Geologic and Geochemical Interpretation
Principal Investigator: Iovenitti, Joe
Organization: AltaRock Energy, Inc.
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23537

Score: 2.0

Comment: While not explicitly stated in the slides or presentation, the objective appears to be to develop a statistically defensible EGS exploration methodology. This project presents a robust analysis of the geological indicators for a geothermal system in Dixie Valley. It is unclear whether this methodology is transportable anywhere beyond Dixie Valley. EGS has not been demonstrated to be commercially sustainable anywhere. The applicability of this project as an exploration tool that is not portable beyond the valley limits its value. The application of this methodology to another district that contains a producing geothermal system would be valuable (e.g., Imperial Valley) and would demonstrate its portability.

PI Response:

Portability of the findings in the current EGS Exploration Methodology is very important. The present study was designed to start with an area that has a large amount of available data with similar geologic conditions over a wide area and determine whether a calibrated EGS exploration methodology could be developed and how defensible could the calibrated model be. Dixie Valley was chosen because it has a large amount of existing data and is in the Basin and Range province where similar temperature at depth and geologic conditions extend over a very large area. It appears based on the baseline data analysis that a defensible, calibrated model can be developed.To answer the portability issue beyond the Basin and Range, the methodology needs to be applied at other producing geothermal areas as stated by the reviewer above. Ideally this should be conducted in a systematic fashion with the first test being in another Basin and Range geothermal field of comparable setting analyzed, and with success exporting the methodology to a comparable Basin and Range geothermal field, then the methodology would need to be tested at other geothermal provinces such as the example cited above, the Imperial Valley.

In summary, while I agree with the reviewers comments, at this stage of developing the method, Dixie Valley is acting as a proxy for the Basin and Range. Further testing is needed to understand the applicability of the method to other areas. The PI can report that parts of the methodology developed have been previously applied to other geothermal areas both within and outside of the Basin and Range.

Reviewer 23427

Score: 3.0

Comment: The Geothermal Technologies Office's mission is to accelerate the growth of geothermal energy in the US. That will require discovering and exploiting the EGS resources of this country. This project addresses that goal by developing methodologies that can be applied in greenfield areas and reduce the need for drilling and thereby lower exploration costs. The project has made significant progress in addressing knowledge gaps and barriers. A calibrated EGS exploration strategy will be developed (based on Dixie Valley). This strategy should increase drilling success and thereby decrease exploration costs.

The rating would have been 'Outstanding'; however, the usefulness of the methodologies in finding new EGS sites or even an EGS area within Dixie Valley has not yet been demonstrated. The current project, developing a calibrated exploration methodology for EGS through integrated geoscience interpretation, is designed to attempt to meet the objective of lowering the cost of EGS by reducing exploration and development risks. More specifically, this project supports the goals of demonstrating 5 MW reservoir creation by 2020; and lowering EGS levelized cost to 6 cents/kWh by 2030.

End date September 2012.

PI Response:

I, on behalf of the project team, thank the reviewer for the comments.

Evaluating the validity of the EGS exploration methodology findings is one of the critical next steps in being able to validate that the project findings can be used to reduce exploration and development risks.

It is critical to recognize that developing the methodology for defining EGS drilling targets is different from conducting a project to delinate EGS driling targets. The current project accomplishes the former. Additional work (not a significant amount but a critical amount) is needed to select EGS drillling targets.

Reviewer 23530

Score: 3.0

Comment: The focus of this project is on the Dixie Valley Geothermal System. The team is developing trends via statistical analysis of the available data. These trends will reduce exploration risks and accelerate the development of both EGS and hydrothermal resources.

The project has proposed an EGS exploration methodology that allows for a system engineering approach to exploration.

PI Response:

Thanks, that's what we intended.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23537

Score: 3.0

Comment: The techniques employed in this project were of very high quality and consistent with the project's objectives. A next step would be to apply these criteria to another, well-studied region deemed through alternate methods to have a high EGS potential and see whether this potential EGS site is identified.

PI Response:

Thank you. We completely agree with the next step identified above.

Reviewer 23427

Score: 4.0

Comment: The approach is clearly stated, excellent in design and addresses the technical barriers to achieving project objectives. As evident in the accomplishments to date the approach is Outstanding. The technical challenges are clearly stated and a program has been carried out to meet those challenges. What is missing, at least from the summary, is a clear delineation of the path(s) to meeting the Geothermal Technologies Office goal regarding creating a reservoir capable of 5 MW. There needs to be a clear statement of how this project supports that objective. This is particularly important, because this approach involves spending more money upfront to save a lot more money later in reservoir development (drilling). Also, it should be made clear that this is meant to be a generalized approach, applicable to different EGS regimes.

PI Response:

I, on the behalf of the project team, thank the reviewer for the comments. The issue of defining the path(s) to meeting the Geothermal Technologies Office goal of creating a reservoir of 5 MWs will be addressed in the next Peer Review from the prespective of potential drill site locations. It is important to note that this project cannot, in and of itself, create an EGS reservoir capable of generating 5 MWs. All that this project can do is define where to drill for a potential EGS reservoir.

Reviewer 23530

Score: 3.0

Comment: The PI makes the point that decisions are based upon available data and trust maps are being developed based upon these data. Trends should be peer reviewed by the industry for concurrence.

PI Response:

I agree.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23537

Score: 3.0

Comment: Most tasks have been successfully completed on time and appear to be of the highest quality. It was unclear, however, whether the observed T- vs. P-wave velocity relationships is a real phenomenon or an artifact of the limited available data. To "discover" a relationship like this through this project is expected. To demonstrate that this relationship is real and applicable elsewhere would be significant. This relationship is not yet significant. Like other relationships identified in this project, their relevance is in their portability.

PI Response:

I concur with the review on the validity of the T vs P-wave relationship based on the baseline data presented. The first step in evaluating the validity of the observation is to determine if the relationship exists using the enhanced seismic data (to be presented in the next Peer Review). If the relationship using the higher resolution seismic data is supportive, then the issue of portability comes into play. Given this potential outcome, a "path forward" to evaluate the portability of the identified relationship will be presented in the next Peer Review and in the project's final report.

Reviewer 23427

Score: 4.0

Comment: All of the existing, available extensive geological, geophysical, geochemical, and hydrological data at Dixie Valley was reviewed and assessed. Then a fully integrated baseline conceptual model was developed which included re-interpretation of some of the structural setting and stress conditions. It was recognized that the existing geophysical data did not have sufficient resolution and new gravity, magnetotelluric (MT), and seismic data were collected along with developing a 3-D conductive and thermal model. These data will be integrated as appropriate with the baseline data to develop a fully-integrated enhanced conceptual model.

From my viewpoint, the most innovative aspects of the project consisted of developing an interdisciplinary method for synthesizing, integrating, and evaluating geoscience data, demonstrating new seismic techniques based on ambient noise, and discovering a previously unrecognized relationship between temperature and P-wave velocity (Vp) using well data and modeled Vp data.. T vs P wave, if validated, allow non-invasive subsurface thermal mapping through seismic tomography. (Validate at other sites).

The project expects results to be integrated into other program by the EGS exploration area in the future to develop a fully integrated EGS exploration process. And future activities should be the application of the methodology developed to other Basin and Range geothermal systems and other geothermal geologic provinces. But those activities are not part of this project.

PI Response:

Thank you for the comment.

Reviewer 23530

Score: 3.0

Comment: The PI affirms that the project spend plan is on track in the respective technical tasks. The project has identified an interesting correlation between formation temperature and P-wave velocity. This is very innovative but should be validated by additional research before industry acceptance. The exploration methodology is justified by presentation of available data. Data is relevant to the Dixie Valley system and generalized application to other resources is cautioned.

PI Response:

I concur. A previous reviewer (above) raised the issue of portability of the finding and the reader is referred to the PI comments on that issue.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23537

Score: 3.0

Comment: Given the ambitious plans and regional requirements (i.e., BLM delays), the managers of this work and the many collaborators stayed on top of the schedule.

PI Response:

Thank you for your comment.

Reviewer 23427

Score: 4.0

Comment: Program management has been outstanding in coordinating a diverse virtual team of university professors/researchers and independent consultants to maintain project schedule, and obtaining permits in a timely fashion. The lessons learned here have applicability to other projects.

I would like to have seen more regarding the path forward with the steps laid out to the ultimate goal of a 5 MW reservoir at a greenfield site by 2020. I think that laying out that logic would help build support for follow-on projects.

It is stated that this project is fully integrated with other projects. I have no idea what this means.

PI Response:

Thank you for the comment. We will address the "path forward" in next year's Peer Review, published papers, and in the final project project. With respect to the comment, "…this project is fully integrated with other projects.", the PI calls the reviewer's attention to the Peer Review presentation Slide 3 that states, "We expect project results to be integrated into other programs in the EGS exploration area in the future to develop a fully integrated EGS exploration process." On Slide 10 of the presentation we report that as a project accomplishment we have a "fully integrated geoscience baseline conceptual model…".

Reviewer 23530

Score: 3.0

Comment: The project has engaged three universities and one national laboratory to develop project team. Project management appears to be on track with accomplishments, publications and milestone completions demonstrated.

PI Response:

Thank you for your comment.

STRENGTHS

Reviewer 23537

Comment: Solid team established. Excellent planning and management. Solid peer review presentation.

PI Response:

Thank you for your comment.

Reviewer 23427

Comment: Program management has been outstanding in coordinating a diverse virtual team of university professors/researchers and independent consultants to maintain project schedule, and obtaining permits in a timely fashion.

Strengths include the development of an interdisciplinary method for synthesizing, integrating, and evaluating geoscience data, and demonstrating new seismic techniques based on ambient noise.

PI Response:

Thank you for your comment.

Reviewer 23530

Comment: This project is making strides in interpretation of the Dixie Valley geothermal system and development of statistical methods to guide future explorations. Generalized trends should be broadly communicated to operators in the region to develop trust in predictions resulting from this work. Overall project management, technical approach and results to date appear to be satisfactory

Project is making good use of available data to establish trends

PI Response:

Thank you for your comment.

WEAKNESSES

Reviewer 23537

Comment: Premise: Given that there are no commercially sustainable EGS systems on earth, how does one gauge the value of an EGS exploration methodology?

Interim findings: Several of the correlations (3-D convective thermal model, T- vs. P-wave relationship, ambient noise) are intriguing but have not been applied in a robust fashion such that they hold any value to others.

PI Response:

I concur. However, the PI believes that this project is the first of its kind and the process of making EGS commercially successful begins with demostration projects such as AltaRock/DOE's Newberry Project. It is anticipated that EGS projects will be commercially successful and with the large EGS resource identified by other investigators we need a process to explore for it. This project is designed to make a contribution to the latter objective.

Reviewer 23427

Comment: From the summary, I see no significant weaknesses.

PI Response:

Thank you for your comment.

Reviewer 23530

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23537

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23427

Comment: Under ‘Plans for the Future’, there could be an outline of the steps leading to reservoir creation by 2020. From previous discussions, I know that such a scenario exists. Also there could be a discussion of lessons learned in coordinating a diverse virtual team be applied to future and different challenges.

It is not clear to me how this methodology is meant to be applied at a completely new site. Moving down the road to Coso is not much of a stretch. Does the methodology require input data in a specific format or can existing data, if available, be used? This isn't exploration in the sense of finding a site, but confirming before drilling. Is it therefore a companion to EE0002748, 'Characterizing Structural Controls ...'?

Therefore, application of the methodology should be discussed at length.

PI Response:

The project scope of work is to essentially develop a calibrated EGS exploration methodology. The Dixie Valley site was chosen because of the large amount of existing data that could be used to calibrate the methodology. We have taken that data, processed it, integrated and interpreted the data into an internally consistent conceptual model. The approach is applicable to other sites irrespective of the amount of existing data that exists for an individual project site. One of the principal differences that will manifest itself as a function of the amount of viable data available is degree of uncertainty associated with the favorability/trust maps.

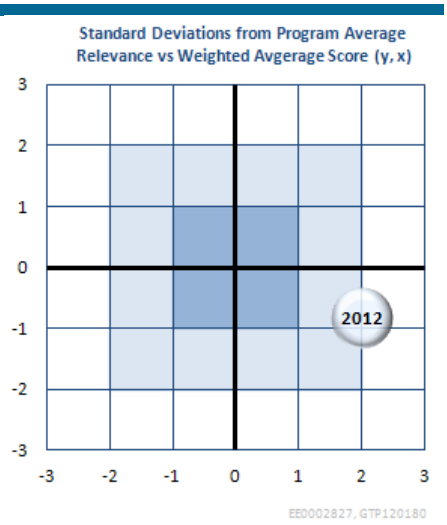
We would plan to discuss the methodology developed at the next Peer Review, within published papers and in the final report.

Reviewer 23530

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002827
Project: El Paso County Geothermal Electric Generation Project: Innovative Research Technologies Applied to the Geothermal Resource Potential at Ft. Bliss
Principal Investigator: Lear, Jon
Organization: Ruby Mountain, Inc
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23577

Score: 2.0

Comment: Marginal impacts to broader office mission and goals. It appears that most of the accomplishments have used conventional geothermal exploration tools and models. I cannot understand the role of the Chem Stratigraphic analyzer and the Heli-lite Drill Rig within the project. With that being said, the project is nicely laid out and managed well it may lead to results relevant to the local area.

PI Response:

Reviewer 23404

Score: 3.0

Comment: The success of this project will provide, perhaps, the necessary information to determine if there is a useful geothermal resource for a military base. The two innovative methods were evaluated in the presence of other data/information; these represent objectives which appear to have been demonstrated.

PI Response:

Reviewer 23537

Score: 3.0

Comment: Determining if a low temperature geothermal resource exists at Ft. Bliss (or anywhere with geothermal potential) is a worthwhile endeavor and relevant as is determining the source of fluids and the best location for a “resource well.” Some of the gaps or key issues (as identified in the presentation) such as the minimum depth and expected temperatures weren't really issues. The T’s determined during this program, so far, were similar to the T’s determined by Sandia 15 years ago. And resource volumes and “limitations” do not appear to have been addressed yet.

PI Response:

Reviewer 23485

Score: 2.0

Comment: This project has two goals that can have a positive impact on the goals of the Geothermal Technologies Office. The first is demonstrate an approach to assessing a low temperature geothermal prospect, whose existence had been demonstrated by earlier work. Success would lead to more utilization of low temperature resources, increasing the use of geothermal energy by a modest amount. It remains to be seen whether the temperatures at this site are hot enough to be useful.

The second is to assess the value of two innovative assessment methods: Heli-lite, an environmentally sensitive impact drilling method and QEMSCAN, a commercially available system that automatically produces images of the spatial distribution of minerals on the surface of a sample from cuttings or core.

The impact of this work will not be known until the project progresses further.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23577

Score: 3.0

Comment: Solid exploration approach. The methods employed may have greater applicability when folded into an exploration package for low temperature resources in general.

PI Response:

Reviewer 23404

Score: 2.0

Comment: The approach taken was rather straightforward with a variety of lab and field activities in this difficult access area; Go/No-Go decisions were incorporated into the process. The team evaluated the methods they used, this is important on its own--perhaps it will inform others what to try first. There is nothing innovative about the work presented in this project.

PI Response:

Reviewer 23537

Score: 2.0

Comment: The "regional flow" model, chemostratigraphy and confirmation of temperatures (originally determined in the late 1990s) is somewhat additive. Given the temperatures encountered, the (muddy) presentation attesting to poor permeability, and no flow testing, it is unclear exactly how this approach adds to the understanding of whether or not a direct use or even low temperature binary resource exists at Camp McGregor. Clearly the isothermal temperature profiles (in 1997 and in 2012) suggest heat and lateral flow of some kind. But the work presented did not. Furthermore, it is totally unclear where this next well should be drilled and why.

PI Response:

Reviewer 23485

Score: 2.0

Comment: The overall scientific approach is very good. The team is collecting and reviewing a variety of appropriate geological and geophysical information, and taking full advantage of pre-existing datasets and using slimholes both for samples and testing. All this information should allow the siting of a confirmation well that will reveal a lot of information about the system. The quality of some of the scientific and technical details is harder to assess based on the information presented, which raises some questions. For example, how reasonable is the geological/structural model that they have determined? On page 9 of the presentation shows unrelated several families of faults determined from different methods all plotted on the same map. Are they related? Which ones might be young and open? Which ones are favorably oriented given the stress conditions? How constrained is the flow model they present? More information would be needed to assess the scientific approach with confidence.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23577
Score: 2.0

Comment: The accomplishments of the project are behind schedule due to permitting issues. Most of the major results that focus on the project objectives are still to come. I may have scored higher if some of the more important results had been accomplished.

PI Response:

Reviewer 23404

Score: 2.0

Comment: This project appears to be somewhat on track in terms of meeting the stated goals, but is behind schedule due to permitting issues. They did not drill the slimholes but rather found that such wells had already been drilled - it is unclear why they took credit for completing this goal?

PI Response:

Reviewer 23537

Score: 2.0

Comment: Some very solid work has been performed. However, the accomplishments are marginal especially if a Low Temperature resource is to be developed. A question to the presenters about the marginal T's and poor permeability resulted in an answer 100% foreign to all of the presentation material. The answer provided was that the future of this project and Camp McGregor is to develop these fluids as a solar thermal resource. This may someday prove to be the case but solar thermal is mentioned nowhere in any of the material provided.

PI Response:

Reviewer 23485

Score: 3.0

Comment: The project is moving through its planned tasks on schedule, and this work has lead to a choice for a site to drill a confirmation well. They demonstrated that the Heli-lite system did not work well in this application, but then discovered some pre-existing thermal gradient holes, and are using the QEMSCAN system on available core from an earlier well. These activities have all contributed to their goal of siting a well to confirm this resource. However, from the presentation it is not possible to assess how much these methods have contributed, and how different the model of the system is now compared to when they started.

Is this appropriate progress based on the expenditures to date? This cannot be determined from the information presented. The presentation does not provide the total expenditures, but indicates that almost 40% of the DOE funds have been spent. If that same ratio applies to the matching funds, then, compared to other demo projects, this project has spent a larger than average fraction of its funding before drilling.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23577

Score: 2.0

Comment: Project management is fair to good. Being behind in schedule is never a good thing, especially if it is driven by circumstances outside of their control (permitting). Next year will really tell the tale with respect to this project. I am optimistic that the project can recover lost time on the schedule.

PI Response:

Reviewer 23404

Score: 2.0

Comment: This project gives the appearance of being well run and coordinated. Collaborations with the military, the local government, and universities are all good things. Future consideration of industry collaboration was mentioned.

PI Response:

Reviewer 23537

Score: 3.0

Comment: In terms of technical, policy, schedule, business and staffing plans, as well as spend plans, Project Management seems to be solid. The seemingly unscripted reference to solar thermal at the Peer Review was either indicative of internal dissent or an out of scope direction that the project is taking. Neither is a positive attribute nor a great reflection on PM.

PI Response:

Reviewer 23485

Score: 3.0

Comment: This project is well defined and is moving systematically through its planned tasks. There is a slight delay now due to permitting, but until now the project is on or ahead of schedule. While pushing towards a site-specific system confirmation, the team is also considering the wider applicability of what has been learned. Efforts have been made to explicitly describe the decision processes and to perform a preliminary assessment of the value of different methods.

PI Response:

STRENGTHS

Reviewer 23577

Comment: The project has a good team pulled together. This is an interesting problem and needs to be finalized.

PI Response:

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23537

Comment: University Utah provides skills an credibility in any such geothermal exploration program. The subject area is worthy of further investigations and the specific objectives of this office are strong.

PI Response:

Reviewer 23485

Comment: The project is well defined and well organized. If they continue their efforts to explicitly evaluate the different methods, the project will have benefits beyond their particular site.

PI Response:

WEAKNESSES

Reviewer 23577

Comment: Schedule variance and lack of scope are a concern. It is not possible for me to determine if the delays are all driving by permitting issues. The delays need to be addressed very quickly and the project put back on track.

PI Response:

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23537

Comment: The presentation was unclear, the presentation material is confusing (and the Geothermal Technologies Office boilerplate material about jobs etc. really needs to be removed for a technical review with a time limit) , and I am uncertain where or why a well should be drilled (other than the fact that money is available).

PI Response:

Reviewer 23485

Comment: I do not see a convincing argument that the confirmation well is in the best place. It appears that the rationale is to drill into faults contained in the highest temperature zone of the shallow temperature gradient (TG) survey. Based on page 9, the well is sited in a lobe of the 120 degree temperature contour. Looking at the location of the actual data, the well is sited equidistant from 4 TG wells with a large range of temperatures, from >120F to about 110F. Consequently, the uncertainty about the temperature at that location is fairly high. Why not place the well close to the TG holes with the highest temperature? That would have a high expected temperature with lower uncertainty.

Of course, the flow model must be taken into account. The arrows on page 14 indicate that the model consists of rising hot fluid flowing (generally) to the west, and presumably cooling as it flows. Since flowlines don't make right-angle turns, in this simple model, the upflow zone zone would be upstream (to the east) of this highest near-surface temperatures.

Strengthening the geological model and the flow model would make it clearer where the confirmation well should be.

PI Response:

IMPROVEMENTS

Reviewer 23577

Comment: Other than the geophysical well logs, the presentation didn't show any seismic, gravity, magnetics, or other geophysical data. Perhaps the data are available but not presented. I would like to ensure that a comprehensive analysis

has been done using all the available datasets and that if additional traditional datasets are not available that recommendations be made to collect these data.

PI Response:

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23537

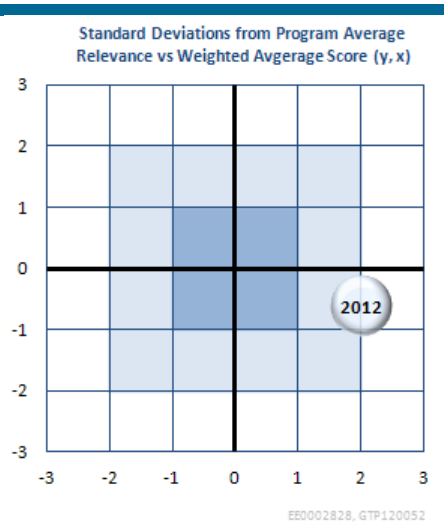
Comment: This project is screaming out for a thorough repackaging, rewriting, and re-presentation of the salient data and interpreted results. If such an event occurs, then perhaps it would be obvious that a model for whether or not a resource might exist has actually been developed. This model can include specific flow paths, projected permeabilities/flow rates, volumes and other attributes central to a direct use or Low Temperature binary operation. Only then can a defensible drilling target be sited. None of this is clear right now and it is very unclear exactly where or why a well should be drilled. Only then should money be made available to drill. And if this repackaging results in an argument for enhancing fluid temperatures via solar troughs or some other secondary heating application, the presentation should explicitly describe how this will work.

PI Response:

Reviewer 23485

Comment: As stated in other sections, the geological model and flow models could be improved, or, if they are more rigorous, be explained better in the presentation.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002828
Project: Direct Confirmation of Commercial Geothermal Resources in Colorado using Remote Sensing and On-Site Exploration, Testing and Analysis
Principal Investigator: Robinson, Lee
Organization: Flint Geothermal LLC
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23404

Score: 2.0

Comment: This project attempts to do a statewide evaluation of geothermal resources in CO. Successful evaluations like this are important to developing an understanding of the geothermal resource within the US. There is nothing innovative about the work done in this project.

PI Response:

Reviewer 23577

Score: 2.0

Comment: Landsat thematic mapper (TM) or enhanced thematic mapper (ETM) has been used in the past and is focused into this approach. Although the project claims the use of integrated remote sensed data, as a reviewer, I am left wondering what is new or unique about this approach. I think the project does have value in creating a data set for Colorado and the drilled data will be useful for future studies. I was baffled with how the use of remote sensed data could be used to infer geothermal sources and flow paths, etc. but I think ETM was also used from an on the ground survey. Obviously the relevance and impact would go way up if a new geothermal field had been discovered, however, the project is behind schedule and the drilling has not started yet.

PI Response:

Reviewer 23627

Score: 3.5

Comment: Innovative project that is able with low cost to detect geothermal fields that are reflected by elevated temperature at the surface.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23404

Score: 1.0

Comment: The approach taken by the researchers was to try many different methods, I believe 15+ were listed to evaluate resource potential in CO. The researchers down selected to areas/sites but it was not clear what criteria were used to make this decision. It is unclear from the work presented and written how the researcher valued one method, or a group of methods in arriving at the down selection. This project has the potential to offer the geothermal community value by evaluation of technology prioritization but this was not done. Also, it is unclear how the researcher was connecting ASTER (surface) based technology to subsurface hydrothermal flow. This is a shortcoming.

PI Response:

Reviewer 23577

Score: 2.0

Comment: Only 10% of budget has been spent. 38 sites were visited for ground confirmation. After running down a dead end and having to redirect the project in another direction they seem to be making good progress. I almost gave them a three on the technical approach because it does take a lot of discipline to realize you need to change directions. However, more progress should have been made. On-the-ground temperature and geophysical surveys are critically important and not being done has hurt this review.

PI Response:

Reviewer 23627

Score: 4.0

Comment: The utilization of Aster data allow a rapid scanning for possible geothermal fields over of huge areas. This methodology is well justified and the scientists are well aware of the limitation of the methods applied.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23404

Score: 2.0

Comment: The project has completed its stated goals for Phase 1 for reasons that are unclear as the decision basis for local area selections is not stated. Therefore there is nothing remarkable to state for the accomplishments and results.

PI Response:

Reviewer 23577

Score: 2.0

Comment: As mentioned previously, the project is underspent and behind schedule, which is better than overspent and behind schedule. Nevertheless, progress has been made and reasonable explanations were given for the delays.

PI Response:

Reviewer 23627

Score: 3.0

Comment: The project was delayed due to the researchers underestimating the real effect of the solar radiation that masked the underlying surface thermal anomalies. This was corrected and the project seems to produce promising results.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23404

Score: 2.0

Comment: Although the goal of this work was to assess the entire state of CO, it would have been more advantageous to downsize and perhaps focus on doing a better job in half of the state. This may represent insufficient management abilities since the PI failed to recognize that the original scope was too overwhelming. In this case, maybe less would be more?

PI Response:

Reviewer 23577

Score: 2.0

Comment: Asked for a no cost time extension. Not clear how project management is performing with only 10% having been spent. Behind on schedule due to reassessment of methodology. Established five lease areas out of 29. Difficult to assess project management success due to little progress.

PI Response:

Reviewer 23627

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

STRENGTHS

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23577

Comment: Multi-component data set approach. Good collaborations. PI seems to have relevant experience.

PI Response:

Reviewer 23627

Comment: If successful, this methodology might lead to fast discoveries of numerous geothermal fields. The method involves the scanning of large areas and narrows down prospective areas for further conventional exploration on local scale. It is however obvious that the method applied in Phase I will lead to many false-positive results caused by local disturbances of the surface temperature (outflow zones, etc.) that has to be sorted out with the on-site exploration.

PI Response:

WEAKNESSES

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23577

Comment: Project management appears to be suffering a bit. More involvement by collaborators should be occurring to get on the ground for Phase II and III.

PI Response:

Reviewer 23627

Comment: It is necessary to bear in mind that blind geothermal systems will not be detected by this method.

PI Response:

IMPROVEMENTS

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23577

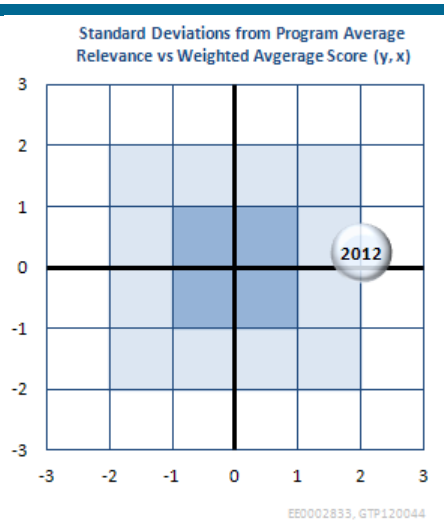
Comment: As presented the Landsat TM or ETM was sort of a black box to this reviewer. Of the 16 criteria listed in the presentation, it was only listed on one item. How useful is it and how does it correlate to the other 15 criteria listed? Project would benefit by clearly ranking and weighting criteria for discovery.

PI Response:

Reviewer 23627

Comment: The project seems to be very well constructed with clear targets. I see no need for major improvements

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002833
Project: Validation of Innovative Exploration Technologies for Newberry Volcano
Principal Investigator: Waibel, Albert
Organization: Davenport Power, LLC
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23530

Score: 3.0

Comment: This project is taking a number of technologies and blending them together for improved geothermal exploration. Newberry is a blind resource so this research has broad industry application. The developer has indicated the results of this work will be beneficial to identification of future targets.

PI Response:

The Davenport team agrees with the Reviewer's comment. In addtion to the technical tools, the Davenport team has developed a more coordinated and collaborative process of intergrating the various technical specialists to evaluate the Newberry resource and locate potential geothermal targets.

Reviewer 23537

Score: 3.0

Comment: The project's stated objective of locating "hundreds of megawatts of potential geothermal resources" has great value and is extremely important. It is unclear to date whether this objective will be achieved through this work. Certainly it has not be achieved yet.

This project incorporates the following technologies: gravity, magnetotellurics (MT), LIDAR, drilling and 4-D seismic analysis and passive seismic. Passive seismic is a "technology" not typically incorporated in other geothermal exploration projects; however, the value of passive seismic to date, if any, is unclear. It can be argued that the "knowledge gap" is the gap between the acquisition and interpretation of field data (including potential field data) results in an understanding of where best to drill to identify a resource. This "gap" has not yet been bridged via this work.

If the integration of these technologies results in the location of a productive well (i.e., locating "hundreds of megawatts of potential geothermal resources") then this project will have had a great impact. To date, no such claim can be made.

PI Response:

The Reviewer's comments are correct. The integration of all data collected to date addresses the cumulative volcanic structure underlying the western flank of the volcano. The goal is to identify structures that are favorable to hosting geothermal cells. Data from the final phase of this effort and the temperature gradient well completion, will add a critical

overlay, showing a more complete picture of the distribution of heat within this structurally complex area. To date, less than 20% of the budget has been spent.

The data processing phase of the first half of the passive microseismic monitoring is going slower than anticipated, in large part because the collaborative process has resulted in technical specialists rethinking and revising some of their traditional evaluation approaches. Also, the Apex HiPoint passive microseismic survey is their first attempt to adapt this oil and gas tool to geothermal exploration and volcanic terrain. Davenport has been in regular communication with Apex HiPoint as they are working to develop the methods to understand and evaluate the extremely large amount of data (far more than originally aniticpated) that their monitoring recorded. The result is that this evaluation is taking a considerable amount of time, and may not be fully finalized until the northern passive microseismic survey is completed late this year. The second survey will include an area with an exploration well with known noncondensable gas releases.

Reviewer 23485

Score: 4.0

Comment: This project has objectives that can potentially have a significant impact on the Geothermal Technologies Office's mission -to determine how effective a set of exploration tools can be in detecting and characterizing blind hot plutons and geothermal targets. If successful, this effort could increase the probability that a large resource will be exploited at Newberry, and could lead to improved chances of success at a number of similar areas. A well-documented case study of the integrated use of multiple exploration methods could lead to better understanding of exploration strategies for volcanic systems. The inclusion of several moderate depth (3500') thermal gradient holes should provide valuable information about how effective the geophysics is at getting through the near-surface volcanic deposits which are assumed to be masking the deeper heat. Although most of the methods being used are traditional, one (possibly) innovative technology is being studied: the APEX Hi-Point seismic noise/event location approach. If the performance of this approach is documented and compared to more traditional microearthquake (MEQ) methods, then others could use this method do reduce their resource characterization risks.

To date, the activities have not realized this impact, as the project is ongoing.

PI Response:

The Davenport team agrees with the Reviewer’s comment.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23530

Score: 3.0

Comment: The PI is using new and traditional techniques to identify and target blind resources. The researchers used 700 ft. – 1000 ft. wells for APEX survey.

PI Response:

The Davenport team agrees with the Reviewer’s comment.

Reviewer 23537

Score: 3.0

Comment: A high quality team was assembled for this work. The instrumentation and technical approach were appropriate for the desired tasks. The technical approach was sound. It is difficult to assess whether these methods achieve the project's outcomes because the intended outcomes, at least per the slides and presentation, are to assist Davenport in locating "hundreds of MW of potential geothermal power." While this effort is assisting Davenport, they have yet to discover/drill into any potential geothermal resources. In the presenter's defense, however, they have only spent 18% of their total funds.

PI Response:

The Davenport team agrees with the Reviewer's comment, but notes that this program alone will not fully locate the targets for all of the the hundreds of MW's that Newberry may yield over time. We are hopeful that we will locate some of the targets to utilize the Newberry resource for power production, while developing the tools and process for continued evaluation and location of more targets for future resource utilization. Portions of the program are proceeding slower than anticipated.

Reviewer 23485

Score: 2.0

Comment: The project is collecting exploration data using a variety of techniques that appear to be of high quality. The project is integrating extensive previous work with new LIDAR, gravity, magentotelluric (MT), temperature, chemistry and seismic noise/event location. (The presentation says eight methods, so there must be others.) The rationale for choosing these techniques was not described. The scientific/technical approach could be more accurately assessed if the presentation had described a conceptual model for the area, and indicated what different measurements may tell us about uncertainties of that model. What are they looking for? The project team may have a well-thought-out rationale for their approach, but it was not apparent from the presentation.

PI Response:

The scientific process is broadly split into two logic paths. "A priori" is a method of starting the investigation with a pre-conceived conclusion (a conceptual model), followed by data collection. "A posteriori" is a method whereby data are collected and conclusions are drawn from the data.

The process of developing and testing models is both time consuming and expensive and we would have difficulty meeting the restraints of the program, but more importantly the Davenport technical team does not believe a detailed conceptual model would be the most appropriate approach in designing this early stage exploration program. The team choose to approach the program with a posteriori logic, as opposed to a priori logic, by collecting data and drawing conclusions from those data (creating an "integrated model" based on the data) which we believe is the most time and cost efficent approach at this stage of the Newberry resource exploration. The scientific team is lead by the data obtained from past and ongoing studies, and adjusts the methodology as new data arrive. The scientific team began with what is known, and develops a list of questions that need to be resolved in order to address the end-point question "Where do we drill our deep exploration test wells?". As with all forensic science programs, there are a number of issues to address. The first team issue is to separate out relevant data from irrelevant data. The second issue is to identify which gaps in knowledge need to be filled in order to reach the final project goal.

With regard to exploration for geothermal resources on the flank of Newberry Volcano, it is a true blind exploration area with no surface thermal features, and recent volcanic tephra obscuring potential structural evidence. Earlier geographically constrained geothermal exploration produced a very limited, though very enticing, block of data. The western flank of the volcano was shown to be underlain by hot rock, at least a portion of which consisted of young granitic plutonic rock. Two very hot deep exploration wells were drilled by Davenport, one showing fractures containing geothermal fluid and the other showing abundant though isolated fractures without geothermal fluid. The challenge has been to identify and implement a set of exploration techniques that could locate deep blind geothermal cells. The key question for Davenport Newberry is: "What structural conditions resulted in one hot well having connective hydrothermal-hosting fractures and the other having abundant though individually isolated fractures?" The resolution of this question leads into the question: "Which other area(s) underlying the broad flanks of Newberry Volcano host hydrothermal cells?"

A century of data generated by the minerals exploration industry have provided the Davenport Newberry exploration team with a good understanding of the various tectonic/geologic settings that have potential for hosting geothermal systems in volcanic terrain. The exploration challenge is to try to identify the location(s) of such structures under the "blind geothermal" flank of Newberry Volcano. This DOE-coupled program is designed to accumulate structural and geological data, using a combination of traditional and untested innovative exploration techniques that can lead to the identification of potential structures and test the results with deep exploration driling. To date the program has reached the 20% budget expenditure level.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23530

Score: 3.0

Comment: To date: the gravity is complete, the magnetotellurics (MT) is complete, and they had LIDAR data dropped in their lap. A number of shallow temperature holes have been drilled. The data suggests the rim collapsed and filled with ash.

PI Response:

To date, only the shallow upper portions of the temperature gradient wells have been drilled and cased to accommodate the microseismic monitoring program. These holes will need to be deepened for the acquisition of temperature gradient data.

The recognition of older explosive volcanic craters on the upper west flank of the volcano, along with the chaotic lack of stratigraphic correlation among close-proximity drill holes and the trail of plutons under the western flank of the volcano enabled the team to recognize that the volcanic activity has been sauntering eastward. This really changes the understanding of the geological and structural complexity underlying the west flank. The surface features observed within the current caldera are likely variations of the complexity buried under the west flank. This strongly affects geophysical data processing and modeling from one of simple layering to one of complex 3-D structures.

Reviewer 23537

Score: 2.0

Comment: The technical plans and results to date seem straightforward. There are no results yet from the "innovative" portions of this works - 4-D passive seismic. Results from the other work include an interpreted offset of the caldera rim and hot (?) plutons on the basis of gravity data. It is difficult to tell from the graphics what the geothermal project (lease?) boundaries are vs. the "monument" boundaries. Therefore it is difficult to tell whether the previously drilled hot hole actually syncs up with the presented model of available structures (from LIDAR and mapping), potential heat source (hot plutons) and potentially altered zones (magnetotelluric (MT) anomalies).

If the stated objective is to "assist", then the objective will have been accomplished upon completion of this work. If the objective is to assess 4-D seismic, then that too will have been achieved regardless of the results. If the objective is to "locate" producible geothermal resources, then it is too early in the project to rigorously assess.

Recommend:
A restatement or refinement of the objective ("relevance of research") would add considerably to the ultimate assessment of this research. Specifically, if a model or geothermal occurrence concept were advanced, and this work was designed to test that mode, then the objectives could be accomplished even if "hundreds of MW" are not developed.

Graphics for review purposes that include scales, lat-longs, etc. would be extremely helpful. Otherwise it is very unclear how these geophysical anomalies vs. previously drilled holes vs. your model for development are related in space.

PI Response:

The Reviewer's comments are appreciated, and point out the need to clarify ambiguities in the presentation.

The basis for concluding plutons underlie the western flank of the volcano, and that those plutons underlying the upper western flank are hot, is based on temperature data from both temperature gradient and deep exploration wells, intrusive lithology encountered in deep exploration wells, the occurrence and ages of silicic volcanic outcrops on the western flank, and detailed gravity data across the area.

The stated object for this program is to assemble a set of exploration tools, traditional and innovative, to deploy over a truly blind geothermal volcanic location, and to assess the ability of these combined tools to identify hydrothermal structures within the area underlain by and adjacent to hot plutonic rock. An incidental side product of this effort will be identifying areas with no indication of hydrothermal structures within the thermal area (prime EGS sites). In addtion to the technical tools, an objective for the Davenport team is to develop and successfully utilize a more coordinated and collaborative process of intergrating these various technical specialists to evaluate the Newberry resource. The Phase 1 goal is to produce an integrated geological and geophysical model of the west flank of Newberry Volcano that can be used to define Phase 2 drilling locations and targets.

The purpose of this program is not to propose and test a conceptual geothermal model. The purpose of this program is to conclude with a model, to try to advance functional exploration methodology.

The problem: An area covering many square miles is known to be underlain by hot rock. This area has no surface thermal features and recent volcanism has obscured surface structural evidence. The southern and western boundaries of the thermal area are poorly constrained.

The question: Which combination of exploration tools can identify areas in volcanic terrain underlain by young hot plutonic rock? A follow-up question is which techniques can identify potential hydrothermal structures at depth in this blind thermal area?

The program: Apply a combination of exploration tools to better constrain the boundaries of the thermal anomaly; identify potential hydrothermal targets at depth; and evaluate the practical contribution of each of the techniques in a final integrated model.

The Reviewer's comment regarding graphics is well taken. Clarity to the viewer would be improved greatly if each graph would have shown both the Monument boundary and the lease boundary.

Reviewer 23485

Score: 2.0

Comment: There has been progress on a number of exploration methods, but their significance towards meeting the project goals cannot be assessed with the information provided. Previous results have been reviewed, and a number of new measurements taken. New measurements include gravity, magentotellurics (MT), LIDAR and 4-D seismic noise/event detection. Thermal and chemical studies have been delayed due to permitting issues and drilling difficulties. Although the speaker is enthusiastic about the gravity, MT and LIDAR results, it is not clear from the presentation what is being learned from them about potential targets. The gravity shows high densities to the west, the MT shows a "shallow" conductor whose existence has been known for some time, and the LIDAR shows an area with little erosion. The seismic data is currently being processed. It seems to have identified a linear feature. The presenter asserts that new processing of the MT data will lead to extremely valuable results, but did not justify. These results may be providing improved understanding for the project team, but for the results to have value beyond the project, they will have to be integrated into a comprehensive conceptual model in order to guide site selection for a deeper hole, and to assess the contribution of various methods.

PI Response:

The Reviewer comments focused on details of the MT observations and a conceptual model.

MT studies at Newberry, published as far back as the 1988 Journal Geophysical Research - Newberry Volcano issue, show a general high resistivity at depth and a standard shallow low resistivity layer, both interpreted as thermal artifacts. MT modeling produces a non-unique result. That is, multiple models are equally valid. The Davenport team worked together to successfully utilize a more coordinated and collaborative process of intergrating the various technical specialists. An example of the results was that other technical specialists contributed insight as to how to constrain the MT modeling. After a number of iterations, the product looked markedly different from the early versions, particularly with regard to the shallow conductive areas. The density of MT stations allow for some certainty with regard to the data set.

The deployment of MT for geothermal exploration has been standard for decades, and the "conceptual model" for interpreting MT has changed little over time, while both the equipment and data processing has advance greatly. The standard model for MT in volcanic terrain has been one of showing a deep highly electrically resistive stem overlain by a highly electrically conductive alteration cap. The observations at Newberry are markedly different from the standard MT interpretation model. There is no empirical correlation between the intense shallow electrical conductor areas and hydrothermal activity. The one location of known hydrothermal activity is located in a very weak shallow electrical conductive area. Well 55-29, shown to be in rock that does not and has not hosted hydrothermal activity, is located in an area with an extremely strong shallow electrical conductive zone. The recent MT results now show marked vertical structural off-sets within the shallow conductive area that did not show up in the standard geothermal MT modeling of the data. At this early stage there is a tentative correlation between shallow conductive intensity and geometry, and volcanic structures. There is clearly no empirical correlation between areas of shallow highly electrically conductive zones and areas overlying hydrothermal systems.

Currently the MT sub-contractor is discussing the possible collaboration with the other Davenport team members to completely re-address the data acquisition, processing and interpreting of MT in geothermal exploration.

The goal of the Davenport project is to address an exploration problem, assemble data from a variety of venues, and produce a concluding model based on the integration of all data. The Davenport scientific team is lead by the data, and adjusts the methodology as new data arrive. The scientific team begins with what is known, and develops a list of questions that need to be resolved in order to generate a concluding model that will facilitate answering the endpoint exploration question "Where do we drill our deep exploration test wells?".

PROJECT MANAGEMENT/COORDINATION

Reviewer 23530

Score: 3.0

Comment: The project team experienced delays with permitting. They have issued a drilling contract for low temperature wells.

PI Response:

Delays unfortunately are too common in projects of this type. As the Reviewer noted, permitting has been challenging but management continues to work closely with the various regulators to keep the project moving forward.

Reviewer 23537

Score: 3.0

Comment: Management of this project and schedules seem to be as good as can be expected when relying on select federal agencies (BLM) for permits.

PI Response:

See previous comment

Reviewer 23485

Score: 2.0

Comment: There is very little hard information to use to assess the quality of the project management. The presenter has a lot of enthusiasm for the project, and a good understanding of the geology and the exploration methods, all of which is essential for a successful project. There have been delays due to permitting and drilling problems, but those issues impact most projects. It is possible that there is not much collaboration, as most of the listed participants are sub-contractors.

PI Response:

Part of the objective of this project, in addtion to the technical aspects, is to develop and successfully utilize a more coordinated and collaborative process of intergrating the various technical specialists to evaluate the Newberry resource and locate potential geothermal targets. To date, the collaborative process has been a cornerstone of this project as the geophysical and geological members have formed an integrated team. Multiple joint working meetings have already been

held where each team member lays out their body of data and interim results of data processing. Each team member provides insights and constraints for processing data. The MT portion of the program has benefited the most from this team approach. The Davenport Peer Review presentation did not illustrate the "back-room" collaboration between the team and various other groups who are not compensated by the grant, including AltaRock Energy (Davenport's EGS partner at Newberry Volcano), faculty at various universities, DOE national labs and U.S.G.S. scientists.

STRENGTHS

Reviewer 23530

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Response not required

Reviewer 23537

Comment: Strong team and great potential resource.

PI Response:

The Davenport team agrees with Reviewer's comment

Reviewer 23485

Comment: This project is addressing an important problem - how to find hot plutons in a blind volcanic environment, and utilizing a broad range of technologies to try to answer it. The presenter has a lot of enthusiasm for the project, and a good understanding of the geology and the exploration methods. If the efficacy of the Apex HiPoint seismic method is demonstrated, it could be used in other geothermal sites.

PI Response:

The Davenport team agrees with Reviewer's comment. In fairness, it should be pointed out that the enthusiasm of the presenter is merely a reflection of the enthusiasm of the entire team

WEAKNESSES

Reviewer 23530

Comment: The lack of a project write-up makes one question project leadership and accountability to project sponsorship.

PI Response:

The Davenport team was not aware that a "Project write-up" was required at this stage of the project. A paper on the status of the exploration to date was submitted to the GRC for publication later this year. The project is still in an early

stage and data continues to be analyzed. Additional testing and studies are ongoing. Davenport intends to include its findings in a comprehensive project write up at the end of Phase I of this project.

Reviewer 23537

Comment: Not very solid presentation material. Benefits of "innovative" portions of this work are not at all clear yet. An integration of work accomplished to date is not innovative although it is very valuable/useful, especially given the locality.

PI Response:

The exploration process at Newberry is in the early stages. Data continues to be processes from MT, passive microseismic and LIDAR studies. Unfortunately the processing is taking considerable time so Davenport was not able to present the results as the data integration has not been completed.

Reviewer 23485

Comment: As is discussed under the Scientific/Technical Approach criterion, the presentation does not communicate the logic behind the choice of exploration methods and their utilization. Assuming that there is an underlying logic, this weakness can be dealt with if, as the project progresses, subsequent presentations and reports communicate the hypotheses being tested and how successfully the methods reduced uncertainty in the conceptual model being used to make choices.

One single innovative technique is being used, the APEX HiPoint 4-D seismic noise and microearthquake (MEQ) detection method. The technique is not described in the presentation. If my description is not correct, then my questions are not very useful! Based on other reading, strings of seismometers are placed in several drillholes. Traditional MEQ detection searches the recordings for discrete events, and uses the picked travel times to estimate the locations and the seismic velocity structure. This approach appears to assume a seismic velocity model, and, cycling through all possibilities, assumes an event took place at a location and time. The waveforms are then summed based on when the signals would arrive at the recorders, and locations and time that provide high correlations among the recordings are likely spots for events. (Apparently, the seismic recordings are then screened to look for false alarms.)

Figure 11 shows preliminary data from this method. The locations that produce highly correlated events define a plane, which would be an interesting result. The detected events are as deep as 10,000' (presumably from the surface) and the plane appears to be vertical. The presentation does not indicate the vertical extent of the seismometer arrays. If that extent is small, then it is possible that the vertical array of points is an artifact caused by poor depth resolution. If the array is in the upper 1000 to 2000 feet, and the velocity increases with depth, then the seismic energy will be traveling nearly vertically as it passes through the seismometer strings. In that case, placing the event at a greater depth and an earlier time would not reduce the correlation.

PI Response:

The presentation and peer review process format includes a set number of topics required to be addressed within the allotted time. A discussion of just the passive microseismic monitoring portion of the project could require a 45 minute presentation. Due to the large number of presentations, the peer review meeting is not the appropriate venue for detailed discussions of each technology applied.

The first of two passive microseismic surveys was conducted involving multiple-well seismic monitoring. . This survey will provide two categories of data. First, monitoring for seismic events related to possible local faulting could identify structural exploration targets. Second, monitoring for low-amplitude seismic waves generated by fluid moving through

fractured rock could locate geothermal drilling targets in a 3-dimentional format. The second category represents an innovation to geothermal exploration for "blind" systems by adapting cutting-edge oil-field technology to frontier geothermal exploration. Geophones will be placed in multiple wells to greatly improve monitoring results. Placing geophones in multiple wells will greatly reduce surface-generated noise, and it will eliminate the problem of signal attenuation due to shallow non-compacted volcaniclastic layers

A set of ten to thirteen 3-component digital geophone sondes are placed in the upper portion of the temperature gradient wells for a period of 7 days. This test is used to locate areas of anomalously high levels of seismic energy that could be indicative of hydrothermal fluid movement. Apex HiPoint processes this data using proprietary "Low Amplitude Seismic Emission Analysis ("LASEA") software (previously known as "Fluid Flow Analysis)." The seismic monitoring is conducted during the interim between the rotary drilling and the second drilling stage of drilling the temperature gradient wells. This dual-use of temperature gradient wells will reduce the time, cost and surface disturbance associated with separate wells drilled solely for seismic monitoring. We are coordinating activities between this project and the EGS Demonstration project. As a result of this and the plan to drill two more wells now in permitting, we expect that we will wait until after the EGS stimulation before the second seismic test will be performed.

The first microseismic monitoring was conducted in 4 wells located south of Paulina Creek. These 4 wells encompassed approximately 4 square acres. The data thus far analyzed has been encouraging and Davenport will perform a similar test north of Paulina Creek. This second monitoring will encompass a larger area and use up to 6 wells that will surround well 46-16.

The geophones sondes are placed in each of the wells involved in the test. Measurements for each sonde is collected every .5 millisecond for a period of approximately 7 days. This resulting tremendous amount of data takes a considerable amount of time to process and analyze.

IMPROVEMENTS

Reviewer 23530

Comment: A write-up was not available for this project which made it difficult to understand project intent, technical approach and accomplishments. Based upon the slides and presentation, the project appears to be on track relative to programmatic objectives.

PI Response:

The Davenport team was not aware that a "Project write-up" was required at this stage of the project. A paper on the status of the exploration to date was just submitted to the GRC for publication later this year. The project is still in an early stage and data continues to be analyzed. Additional testing and studies is ongoing. Davenport intends to include its findings in a comprehensive project write up at the end of Phase I of this project.

Reviewer 23537

Comment: Stated earlier:

A restatement or refinement of the objective ("relevance of research") would add considerably to the ultimate assessment of this research. Specifically, if a model or geothermal occurrence concept were advanced, and this work was designed to test that mode, then the objectives could be accomplished even if "hundreds of MW" are not developed.

Graphics for review purposes that include scales, lat-longs, etc. would be extremely helpful. Otherwise it is very unclear how these geophysical anomalies vs. previously drilled holes vs. your model for development are related in space.

PI Response:

The Reviewer's comments regarding refinement to the project objectives have been addressed above.

Latitudes and longitudes were not superimposed on graphs given the general purpose of the slides. However, the Monument and lease boundaries on some of the slides would have improved the presentation for the viewers. In future presentations or at least in more detailed project write-ups, Davenport will consider including location reference data to more clearly describe the area being discussed

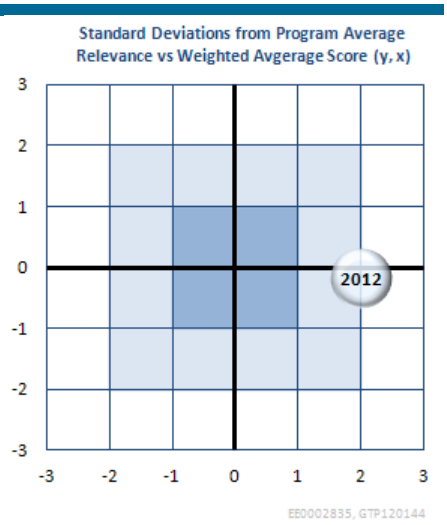
Reviewer 23485

Comment: As is discussed elsewhere, as this project progresses, an explicit discussion of the conceptual models that lead to the choice and interpretation of exploration methods would enhance the value of this demonstration to the geothermal community. Special attention should be given to analysis of the innovative seismic method. The value of project would be increased if the same data were processed by standard first-break detection algorithms, so that the benefits from this method could be clearly quantified.

PI Response:

Refer to Conceptual model question above in response to first comment

The Davenport team will be publishing a paper outlining in detail the acquisition, data processing, and deduction metholologies when the program has been completed. Davenport feels that its is premature at this point to attempt to input this data into a conceptual model as the data from the intial passive microseismic studies continues to be processed by the Apex HiPoint team. This process has taken longer than expected, but this is an innovative process to the geothermal industry and thus it can be expected that appling a new technique will have some time hurdles to overcome.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002835
Project: High Precision Geophysics & Detailed Structural Exploration & Slim Well Drilling
Principal Investigator: Casteel, John
Organization: Nevada Geothermal Power Inc.
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23537

Score: 3.0

Comment: This project's objectives are ambitious but reasonable. It is difficult to reconcile all objectives with work conducted to date because one of the "innovative" tasks (e.g., flowing differential SP) has not been completed. The other exploration techniques are solid undertakings for companies with exploration budgets.

PI Response:

Reviewer 23485

Score: 2.0

Comment: This project has several technical objectives that potentially could contribute to meeting the Geothermal Technologies Office's objectives. However, most of that impact has not yet been realized.
1). Although it was not discussed in the presentation, demonstrating that they were able to use sumpless drilling in an environmentally sensitive area may impact a lot of projects.
2) . If they bring new power on line, or if they are able to characterize the geothermal system at this site well enough to guide future exploration elsewhere, then this work could support expansion of geothermal development. The project does not define what significant technical knowledge gaps need to be filled to characterize this system, so it is not clear that they are choosing the most effective approach to this problem. In addition, the work is in progress, so its impact is not yet realized, and is hard to evaluate. However, it is clear that they are learning a lot about this system, and that knowledge will help others.
3). A general objective is to demonstrate the application of high precision geophysics for well targeting. The geophysics they have applied is relatively routine, and they have not yet documented whether it is successful for finding faults. In fact, the wells they targeted had low flow rates. Unless they can develop an understanding of why the geophysics did not locate a permeable fault, this work will have little impact. They also plan to demonstrate an innovative approach, Flowing Differential Self-Potential (FDSP), and combine it with electrical resistivity studies demonstrate its usefulness. Well documented results from these efforts could be of value to other post-drilling exploration and development projects. Because they do not yet have a flowing well, study has not occurred.
PI Response:

Reviewer 23427

Score: 3.0

Comment: The rating of 'Good' is really based on advancements to date. If the project is completed successfully, it would have a significant impact on the Geothermal Technologies Office's goals and have a large impact on geothermal energy development.
The purposes of this project are to evaluate an innovative geophysical approach to geothermal exploration and progress toward developing additional MWe of production for the state of Oregon. The techniques and methods employed here and lessons learned from results can then be applied at other prospects, with the end goal to reduce exploration and development costs/risks.

What is the innovative geophysical approach which partially justifies this project? It may partially be the flowing differential self potential (FDSP), which they haven't gotten to yet, since they don't have flowing wells. The integration of different tools; geophysics, geologic mapping, etc. also could be considered innovative.

End date of September 2012: Most of these projects have a near-term completion date. Because of that, the utility of comments specific to each individual project is debatable. What then might be useful to the Geothermal Technologies Office; perhaps lessons learned and what should happen to the research results?

PI Response:

Reviewer 23627

Score: 3.5

Comment: The material that the reviewer has access to is too limited to allow serious review. The phase I of the project has been reported and approved. The present material covers only phase II which is the drilling, acoustic televiewer logging and seismic reprocessing.

The major objectives of the project are:

1. Discover new 260F and 300F geothermal reservoirs in Oregon.
2. To demonstrate the application of high precision geophysics for well targeting.
3. Demonstrate a combined testing approach to Flowing Differential Self Potential (FDSP) and electrical tomography resistivity as a guide to exploration and development.
4. Demonstrate utility and benefits of sump-less drilling for a low environmental impact.
5. Create both short and long term employment through exploration, accelerated development timeline and operation.

There is very little or no information given about the results from items 2, 3 and 4. How has the "high precision geophysics been applied for well targeting? How has FDSP and electrical tomography served as a guide to the exploration? And what about the demonstration of the benefits of sump-less drilling? These major items are neither covered in the project nor in the summary which makes my review meaningless.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23537

Score: 3.0

Comment: The geophysics, direct push and drilling are all solid exploration tools. The companies should strongly consider integrating fundamental structural mapping into this program before moving much further ahead. This would allow the excellent data generated to date to be put into some overall geological, Basin and Range-centric geothermal occurrence model context. There is nothing innovative about drilling range bounding faults or hot spots. Developing a model on the basis of the integration of ALL of these tools and then drilling...that is innovative, useful and valuable to the overall community. Furthermore, the “gap” that exists in any exploration project is an understanding of the resource (assuming a resource exists).

On the basis of the presented material it is difficult to tell why holes were drilled where they were drilled. A short presentation does not really give the presenter or reviewer the benefit of the doubt but it appeared that the good exploration.

PI Response:

Reviewer 23485

Score: 2.0

Comment: Some of the work that has been done is of good quality. The acoustic log images are clear, and the reprocessed seismic section provides a lot of subsurface information. The shallow heat-flow data appear reasonable, and the fault model may be accurate. The approach appears to have been to locate the range-bounding fault in this area of high heat flow, and target it with wells. To date there is no indication of how the "high precision" geophysics contributed to the inferred fault location and characteristics. The rationale for moving successive wells to the north was not clearly spelled out. The presentation indicated that development of a 3-D model is ongoing, so this question might be addressed in the future.

However, I think that the geological model is lacking elements that should be useful in siting wells. The first is what mechanisms are there for maintaining permeability in the fracture zone? Since (apparently) there is not much seismicity on the faults, I encourage them to look at the relationship between the faults and the regional and perhaps local stress fields. Which set of faults would you expect to be optimally oriented at this site? The second element is to develop a conceptual model of the geometry of fluid flow. They have identified an "outflow" zone using the shallow and deep temperature data. The challenge is to move backwards along the flow paths to reach a drilling target that might be both hot and permeable. The rationale for the location of 35-34 seems to be based on an idea of the flow:
"Core well which again stepped north of 38-34, with the goal of getting out of the zone of out-flow rollovers seen in the previous well". If the model is that the flow comes up the fracture and then has outflow to the east, then it seems to me that this well should have been to the west of 38-34.

Their current models leaves questions to be answered. Is the range-front fault a single planar feature, or a complex set of faults? Is the flow along the range-front fracture current and ubiquitous, or does it occur in localized vertical zones within the fault? Or is it in other faults completely? How can questions like these be addressed?

PI Response:

Reviewer 23427

Score: 3.0

Comment: The approach is well thought out and effective in achieving the project's objectives. The technical approach is to apply high-precision geophysics to define fault offsets. This includes ground and airborne magnetics, Bouguer gravity, shallow seismic reflection/refraction and electrical resistivity tomography. Slimholes are then used to discover and test the reservoir. A flowing differential self potential (FDSP) survey will be used to observe fluid flow patterns. The FDSP survey will hopefully provide a low-cost solution for mapping fluid flow paths in lower temperature settings, and shallower hydrothermal systems

PI Response:

Reviewer 23627

Score: 3.5

Comment: The scientific/technical approach seems to be strong.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23537
Score: 3.0

Comment: I don't recall whether or not a fracture and stress analysis was done with all of these excellent downhole image data. This in concert with the detailed structural mapping (that I trust this work will be integrated) would provide a big advantage to you as well as the community the Geothermal Technologies Office serves with this funding.

PI Response:

Reviewer 23485

Score: 3.0

Comment: The project has successfully demonstrated sumpless drilling; has collected valuable seismic and temperature data; and has made progress in understanding the geothermal system at Crump Geyser. The fact that the permeability is not high at this intersection of the range-front fault is frustrating to the project, but probably valuable information for future projects. The project has not yet documented the value of the high precision geophysics that has been carried out, and, in fact, it is not clear how much the data influenced their model of the system. If the project moves forward and if they encounter an area with higher flow rates, their technical objectives could be accomplished in the future. I rated this progress as good because it is appropriate for this stage of the project, although I recognize the possibility that the project might be terminated without much tangible progress towards objectives.

PI Response:

Reviewer 23427

Score: 3.0

Comment: The accomplishments to date are given as; geophysical data sets collected and interpreted, created 3-D geologic model, drilled exploration well, drilled first slim wells. It is stated that the completed tasks are consistent with project milestones and support moving into Phase II drilling. The flowing differential self potential (FDSP) survey will come later when they have flowing wells. Their major issue is that their two core wells had low injectivity (low permeability).

PI Response:

Reviewer 23627

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23537

Score: 3.0

Comment: Solid team and management.

PI Response:

Reviewer 23485

Score: 3.0

Comment: It is difficult to assess the quality of the project management. Project is moving ahead in an orderly manner, and has good control over any permitting and other barriers to moving ahead. Was on schedule until low permeability was observed, and that lead to an appropriate re-evaluation of the next step. Obviously, progress on the project was disrupted more than necessary because it took a long time to learn that the slimholes had low permeability. I cannot evaluate whether there were good practical reasons for delaying the testing until just before the planned (and now postponed) round of drilling.

PI Response:

Reviewer 23427

Score: 4.0

Comment: Management challenges listed include regulatory approvals, and coordination of an increasing number of participants, How these challenges were overcome should be discussed with a view toward applying lessons learned to other projects. This score is based upon the statement that Phase I has been completed with its objectives met and they have defined a way forward.

PI Response:

Reviewer 23627

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

STRENGTHS

Reviewer 23537

Comment: Solid team and plans.

PI Response:

Reviewer 23485

Comment: The strength of this project is that it is providing case study information about a poorly explored geothermal system. In addition, should the project get that far, the tests of the "Self-potential while flowing" could identify a new well-evaluation strategy.

PI Response:

Reviewer 23427

Comment: Up to this point the project has been carried out on schedule and consistent with what was promised.

It was impossible to do justice to this area based on pre-Peer Review materials. (However, it came out during the presentation that there is a hold to re-evaluate strategy because of low injectivity.)

PI Response:

Reviewer 23627

Comment: See comment under Relevance above.

PI Response:

WEAKNESSES

Reviewer 23537

Comment: Need to better integrate geologic mapping into the analysis in order to create a framework from which to develop and then test (i.e., drill) a geothermal occurrence/geothermal system model. The PI stated "innovative...approach...designed to aide in development of detailed reservoir model." No such model exists yet.

PI Response:

Reviewer 23485

Comment: As is discussed in another section, it appears that drilling is targeted based on a conceptual model that is not explicitly discussed, that may be too simplistic to describe flow patterns usefully, and that does not seem to account for the stress field and its influence on the permeability of faults. (It is possible that these weaknesses were addressed in the Phase I Report, which was not available to the reviewers.)

PI Response:

Reviewer 23427

Comment: I was unable to define significant weaknesses based upon pre-Peer Review materials.

PI Response:

Reviewer 23627

Comment: See comment under Relevance above.

PI Response:

IMPROVEMENTS:

Reviewer 23537
Comment: See earlier comments

PI Response:

Reviewer 23485

Comment: As is discussed in other sections, I think the project would benefit from explicit discussions about the conceptual model, and the possible complexities and controls of the fluid flow field. If a flowing well is not found at this site, could the project be redirected to test the Flowing Differential Self-Potential (FDSP) concept elsewhere?

PI Response:

Reviewer 23427

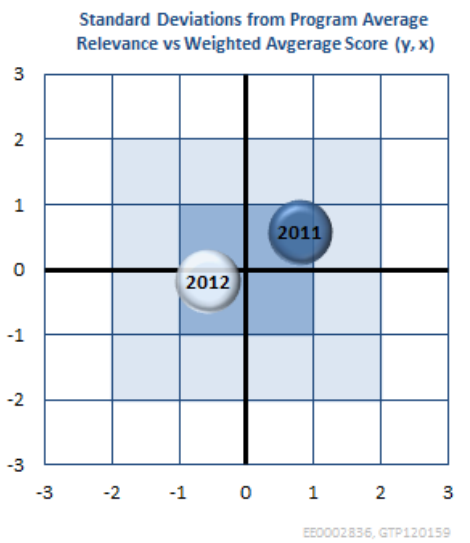
Comment: Management accomplishments include regulatory approvals, and coordination of an increasing number of participants. How these challenges were overcome should be discussed with a view toward transfer to other projects.

PI Response:

Reviewer 23627

Comment: See comment under Relevance above.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002836
Project: Merging High Resolution Geophysical and Geochemical Surveys to Reduce Exploration Risk at Glass Buttes, Oregon
Principal Investigator: Walsh, Patrick
Organization: Ormat Technologies Inc.
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23577

Score: 3.0

Comment: Generally this approach serves industry and the Geothermal Technologies Office. It is focused on a real world problem and using a combination of data sets in a complementary manner. Permitting delays are unfortunate. Successful results would greatly increase the project relevance and impact however, if the data can be put into the public domain then any results would benefit the industry as a whole.

PI Response:

Reviewer 23427

Score: 3.0

Comment: This project supports the Geothermal Technologies Office goal of lowering the risks and cost of development of near term hydrothermal by combining high-resolution geophysical and geochemical techniques including surveys which have not been used for geothermal exploration previously.
The project scope and goals do not support the criteria required for an ‘Outstanding’ score as defined by the Geothermal Technologies Office.

PI Response:

Reviewer 23627

Score: 2.5

Comment: The project seems to have very little innovation and only a small impact in research. It is supposed to "combine high resolution geophysical and geochemical techniques to reduce exploration risk, including surveys that have not been used specifically for geothermal exploration previously." It is not clear which are the methods that have not been applied previously in geothermal exploration and how the methodology leads to reduction of exploration risk compared to conventional exploration procedures.

The impact of the project might mainly be to identify a commercially producible geothermal energy in Oregon and help speed up further activities if successful.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23577

Score: 2.0

Comment: Good geophysical basis for selection sites. Geologic map a big part of the approach. It was difficult to evaluate approach based on a lack of temperatures in the presentation. A little more technical discussion would have helped elevate this score.

PI Response:

Reviewer 23427

Score: 3.0

Comment: I can do no better than to edit/repeat the guidance for a 'Good' score; "the approach is well thought out and effective in achieving the project's objectives. The project has good focus, with all aspects of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good".
I don't think the scope of the project lends itself to the Geothermal Technologies Office's requirements for 'Outstanding'. However, the project has clearly stated its objectives and how they were carried out.

PI Response:

Reviewer 23627

Score: 2.5

Comment: This seems to be rather standard geothermal exploration project.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23577

Score: 3.0

Comment: Accomplishments lag due to permitting issues. The locations still look good, smart to permit so many locations (17), but it may have led to delays in the project. Progress is slow, but these types of drilling projects take a lot of time.

PI Response:

Reviewer 23427

Score: 3.0

Comment: The accomplishments, results, and outcomes have been good in relation to the resources expended and progress towards project objectives and technical targets/goals. The technical accomplishments are stated and appear to meet the requirements of the project.
Long BLM permitting process has delayed drilling. Permits are anticipated Summer 2012, but apparently there is no assurance this will happen.
Software purchased by the project utilized for all Geothermal Technologies Office projects. Some details on what this software and how it has been utilized would have been useful.

PI Response:

Reviewer 23627

Score: 2.0

Comment: The objective of the project is to "combine high resolution geophysical and geochemical techniques to reduce exploration risk". No attempts are made to use the high resolution geochemical techniques until now and it is not suggested in the future plans. It is hard to see that any "high-resolution geophysical methods have been applied, for example, the magnetotelluric (MT) data used in the 3-D visualization is only 1-D. It is not obvious that enough high-resolution data are already available to justify the testing of the model by drilling.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23577

Score: 3.0

Comment: Project management seems appropriate. Project appears to be behind due to sage grouse and artifacts. Not enough data to tell if funds track schedule. The PM seems to value open communication with stakeholders which in my opinion is critically import for these sorts of endeavors.

PI Response:

Reviewer 23427

Score: 3.0

Comment: Management of this project appears to have been effective in meeting the objectives to date and plans for future management are succinctly stated. No deviations from original plans were stated, but it was noted that well permitting was challenging and has delayed the project. This could be elaborated on as a lesson learned.

PI Response:

Reviewer 23627

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

STRENGTHS

Reviewer 23577

Comment: Good graphical presentation of geophysical results. LIDAR images were interesting and potentially useful. Use of traditional exploration tools and new tools is well integrated and PI seems very capable.

PI Response:

Reviewer 23427

Comment: It appears that the project is being carried out consistent with what was promised. I felt that the materials provided were not sufficiently definitive in this area. A discussion of strengths should be in the context of the overall goals of the Geothermal Technologies Office. However, the summary and the presentation do not really provide the logic by which to judge the potential contributions of this project.

PI Response:

Reviewer 23627

Comment: It is difficult to see any special strengths of this projects.

PI Response:

WEAKNESSES

Reviewer 23577

Comment: More use of geochemistry would make this a more useful. But this is information should be coming later from the drilling.

PI Response:

Reviewer 23427

Comment: Were potential permitting difficulties adequately addressed in the original proposal and scheduling?

PI Response:

Reviewer 23627

Comment: The methodology applied is not innovative but rather standard. The objective of the project is to "combine high resolution geophysical and geochemical techniques to reduce exploration risk". No attempts are made to use the high-resolution geochemical techniques until now and it is not suggested.

Apart from the Light Detection And Ranging (LIDAR) and possibly the magnetics there are no high-resolution geophysical data collected or used to underpin the location of the slim wells.

To make a 3-D model of available data is of course an excellent presentation of the data, but it is very dangerous if the data behind the 3-D model is poor as is in the case of the magnetotelluric (MT) data used here.

PI Response:

IMPROVEMENTS

Reviewer 23577

Comment: Use of chemistry data is critical. A better description of the conceptual model, water source, flow etc. must be done but was not presented. Perhaps this is proprietary? Overall, I think this is a solid project and that other than delays seems to be progressing nicely.

PI Response:

Reviewer 23427

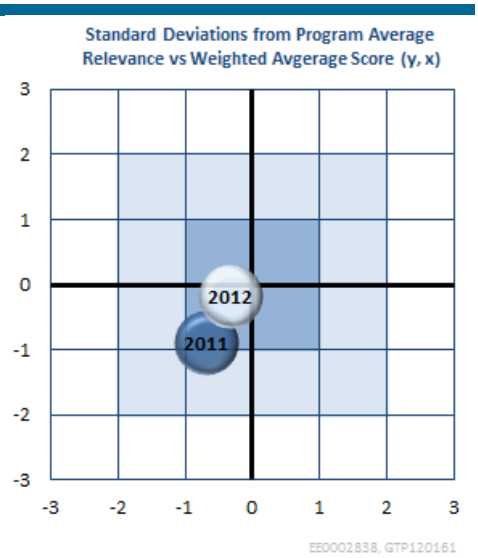
Comment: Permitting issues have come up in several projects. Insights as to how to deal with issue would be applicable to other projects.

It is stated that software purchased by the project has been utilized for all Geothermal Technologies Office projects. If so, this should be discussed further.

PI Response:

Reviewer 23627
Comment: In order to make reliable 3-D models as intended, it is necessary to use 3-D data and processing. It is strongly recommended to collect magentotelluric (MT) data for 3-D interpretation.
Geophysical logging of existing well is also desirable.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002838
Project: Conducting a 3D Converted Shear Wave Project to reduce exploration risk at Wister, CA
Principal Investigator: Walsh, Patrick
Organization: Ormat Technologies Inc.
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23577

Score: 2.0

Comment: This project uses shear wave seismic survey to reduce exploration risk for a blind geothermal resource. The use of shear wave data appears to be a bust, at least in this location. It is not clear if this is a site specific limit on the use of S-waves or if the PI thinks that S-wave use at other sites may have better results. It would be nice if every test hole came back positive but they usually don't. The results are useful in adding to the collective body of knowledge, not just in this area but in the application of this particular geophysical technique to other sites.

PI Response:

Reviewer 23537

Score: 3.0

Comment: Conducting a 3-D 3-C seismic survey to potentially reduce exploration costs was a worthwhile undertaking. Knowledge "gaps" were identified and addressed through this research.

PI Response:

Reviewer 23627

Score: 3.5

Comment: The challenges to "conduct a 3-D 3-C (converted shear wave) seismic survey to reduce exploration risk by characterizing fault and fracture geometries" is a very ambitious one. If the technology would prove successful it could have high-replication potential.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23577

Score: 3.0

Comment: Approach seems to be sound, but it is hard to see how the S-wave seismic analysis would have contributed to the project. P-wave data seemed to work fine. Use of standard approaches was appropriate and positive.

PI Response:

Reviewer 23537

Score: 4.0

Comment: The approach is solid especially given the nature of potential resources in the Imperial Valley.

PI Response:

Reviewer 23627

Score: 3.0

Comment: The scientific content of this project is innovative and can, if successful, be applied elsewhere.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23577

Score: 3.0

Comment: Good progress. The seismic 3-D survey results lead to a very nice interpretive package in conjunction with the data from two deep holes and calibration.
PI Response:

Reviewer 23537

Score: 2.0

Comment: Unfortunately, data were acquired and drilling was conducted but "open fractures" were not encountered.

PI Response:

Reviewer 23627

Score: 3.0

Comment: The results from the innovative approach of using 3-D converted S-waves were disappointing and reported unsuccessful. This changes the continuation of the project from an innovative project to a standard exploration project. It is not clear why the S-wave processing failed but this was from the beginning a very difficult task but worthwhile to try. It is important to report the results even though they were negative.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23577

Score: 3.0

Comment: Project management appears to be good. The Geothermal Technologies Office is getting a good value with this project.

PI Response:

Reviewer 23537

Score: 3.0

Comment: Solid team and management.

PI Response:

Reviewer 23627

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

STRENGTHS

Reviewer 23577

Comment: Excellent combination of standard drilling data with geophysics. Classic exploration approach, unfortunately it didn't result in a viable project. With the data collected it may be possible to re-interpret the prospect area and find additional targets.

PI Response:

Reviewer 23537

Comment: Strong team. Solid concept. Great test bed area for this work.

PI Response:

Reviewer 23627

Comment: This seems to be a very sound and technically well-prepared and performed project. Despite the fact that the innovative part did not lead to success, the secondary goals of the projects are likely to be reached.

PI Response:

WEAKNESSES

Reviewer 23577

Comment: It seems like the use of geochemistry data in advance may have shed light on the low permeability area in prior to drilling. A retroactive re-interpretation of the 3-D seismic is warranted. Is it still possible to get a VSP or sonic log done to help with S-wave processing?

PI Response:

Reviewer 23537

Comment: Poor results.

PI Response:

Reviewer 23627

Comment: This project has no obvious weaknesses.

PI Response:

IMPROVEMENTS

Reviewer 23577

Comment: Another well is warranted after a reassessment of the data because indications of a resource in the Unocal hole are still there. Perhaps another look at the structural aspects based on the fault location as now known would illuminate another drill location.

PI Response:

Reviewer 23537

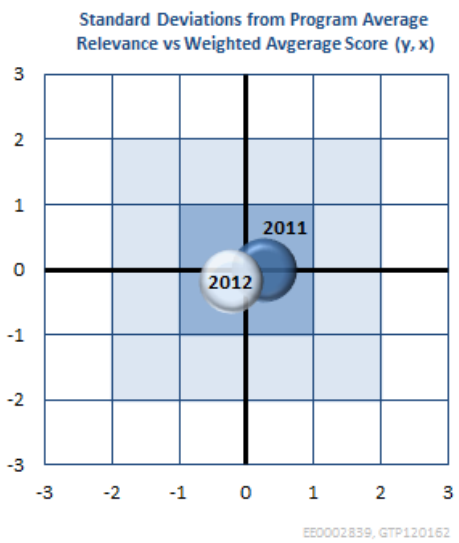
Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23627

Comment: Nothing special.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002839
Project: Advanced Seismic data Analysis Program (The "Hot Pot Project")
Principal Investigator: De Rocher, Theodore
Organization: Oski Energy, LLC
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23530

Score: 4.0

Comment: This project is using advanced techniques to interpret seismic survey data to improve geothermal site selection and reduce drilling risk. This is innovative as seismic is relatively new to geothermal exploration. There are two parts to this: seismic reflection survey and confirmation wells. The team is using reflection seismic to develop good quality drilling targets early in the process. They noted it is better to make cheaper mistakes earlier than expensive ones later. The overall objective is to refine models early to get power online faster. The team spends very little project time in time domain evaluations; alternatively go early to velocity domain for analysis and interpretation.

They are using this to site intermediate depth temperature wells and use the well data to confirm the conceptual model.

PI Response:

Reviewer 23537

Score: 2.0

Comment: Many have already used Optim's seismic reflection processing algorithms but it is always worthwhile to have more of these data sets interpreted and made available to the entire geothermal industry.

Improving the quality of drilling targets via geophysics is valuable and useful but hardly innovative. Testing structures determined from Satish's analysis (and whether or not they carry hydrothermal fluids) by shallow to intermediate depth drilling is a reasonable approach. However, a 500 ft thermal gradient holes (TGH) campaign has already been conducted. Didn't these results drive the location of the survey lines in the first place?

The Hot Spot location is a reasonable exploration target. Optim's algorithms provide an alternative processing approach although they have been used already (albeit not extensively) in the Basin and Range. If money is not considered a factor, then staged drilling reduces risk. However, if the 500 TGH campaign and the processed seismic data are compatible, why not drill to the target depth(s) with a few deep slim holes directly?

PI Response:

Reviewer 23485

Score: 3.0

Comment: This project has an important and relevant objective: to improve aspects of exploration strategy to learn more before drilling begins, and thereby improving the success rate for drillholes. The project focuses on seismic reflection surveying, which is a very powerful method in the oil patch, but one that has had limited use in geothermal fields.

Traditional seismic reflection surveying uses maximization of summed reflections from continuous, flat-lying layers to determine the seismic velocity throughout the model. Most geothermal applications are in complex geological situations without the simple structures found in undisturbed sedimentary sections. This project is using a somewhat new seismic method that allows determination of seismic velocities before the reflections are summed, allowing the detection of complex geological structures. This "innovative' method has been applied in some geothermal areas with some success, but it still needs more successful case studies before it would be used regularly. To that the extent that this project demonstrates how that success rate could be increased, it will have a modest but useful impact on the Geothermal Technologies Office (GTO) objectives of lowering exploration costs.

This project also has the potential to lead to a geothermal development, another positive for GTO goals.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23530

Score: 3.0

Comment: The researchers are using formation velocities as the baseline approach. They use geologic data to adjust the velocity model. PI noted that geophone spacing is key to pick up all the features. Seismic processing has been around 12-14 years; this is innovative for geothermal.

PI Response:

Reviewer 23537

Score: 3.0

Comment: It is not clear from the presentation material how the PI intends to bridge the gap, if at all, between results from intermediate depth drilling and desire to drill deeper. Is there a unique temperature profile being sought from the ~2,500 ft holes not seen in the thermal gradient hole (TGH) wells? It was not stated that the PI was going to sample fluids for geothermometry. I assume this is the case.

PI Response:

Reviewer 23485

Score: 3.0

Comment: The plan was to collect the seismic surveys on a grid of crossing lines. The project used a systematic approach to siting the seismic surveys, reviewing past information and filling data gaps with detailed gravity and thermal gradient data. These data sets were used to plan the orientation and extent of the seismic survey. The planned approach was to use the seismic survey to choose sites for intermediate depth temperature holes and an exploratory hole. The overall project would benefit from considering the interaction of faults with the regional stress field.

The researchers recognized that the seismic results we not useful, and figured out how to utilize some well data that was fortuitously available to improve the velocity models, leading to their current choice of drill sites. This serendipitous result indicated that, despite a careful choice of station spacing and survey design, the method was not able to learn enough about shallow velocities to successfully image the subsurface without additional information. If properly analyzed and communicated, that result could improve the future use of this approach to seismic reflection surveying in geothermal areas.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23530

Score: 3.0

Comment: Background data has been collected; the seismic survey completed; the seismic data has been integrated with pre-existing geological information; and the hole locations have been selected. Interpretable data have been obtained regarding geologic structures. Hole locations have been selected to obtain specific reservoir information.

PI Response:

Reviewer 23537

Score: 3.0

Comment: Much of the field data have been collected and analyzed. The seismic data were acquired, interpreted and pending permitting and remaining clearances, intermediate drilling will occur.

PI Response:

Reviewer 23485

Score: 2.0

Comment: The project has collected some data, and spent effort to site and permit drillholes. Given the high cost of seismic surveys, and the effort on logistical issues, this is probably appropriate progress for the approximately $1M spent to date, but the project is clearly behind its proposed time schedule. The level of accomplishment for the project will ultimately depend on how well those holes confirm the inferences from the seismic data, and how well the project analyzes and communicates the strengths and weaknesses of the method. Because they learned what additional information had to be added to the method to make it work, there is a potential for a very worthwhile analysis.

The staff has experienced geologists, but I am uncertain about the how much experience one of the investigators has with interpreting seismic reflection data. In order to evaluate and demonstrate the method provided by Optim, the project should have someone with experience in interpreting seismic reflection data.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23530

Score: 3.0

Comment: Phase 2 consists of drilling wells. This will consume funding. Team has had frequent project meetings.

PI Response:

Reviewer 23537

Score: 3.0

Comment: Appears to be reasonable.

PI Response:

Reviewer 23485

Score: 3.0

Comment: The plan makes sense, and there appears to be a strong geological interpretation component. It is understandable why the project is delayed. The project may need more seismic reflection interpretation experience on team.
PI Response:

STRENGTHS

Reviewer 23530

Comment: Phase I work on this project has been successful and future work plans are underway to validate the overall modeling approach.

PI Response:

Reviewer 23537

Comment: Good field area. Interesting data processing algorithms.

PI Response:

Reviewer 23485

Comment: Well defined and narrow objective (with possible "bonus" of more geothermal)

Willingness to go back an reanalyze seismic when it did not work.

PI Response:

WEAKNESSES

Reviewer 23530

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23537

Comment: Not innovative.
PI Response:

Reviewer 23485

Comment: I am concerned (perhaps through ignorance) about the knowledge the PI's might have to evaluate the seismic results. One concern is raised by the figure on page 9 of their presentation. Here, fault B is extended down to be nearly vertical at more than 7 km depth. I am concerned that no reflected energy could reach this fault and return to the stations shown on the figure. Provided that there is a careful and credible analysis of the effectiveness of the seismic data, this project could have a positive outcome even if the wells are never drilled and the seismic data are not confirmed.

I am guessing based on many other sites that the effect of the regional stress field on faults may be the causing factor for permeability maintenance this subject was not discussed.

PI Response:

IMPROVEMENTS

Reviewer 23530

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23537

Comment: Reviewer did not provide comments for this criterion.

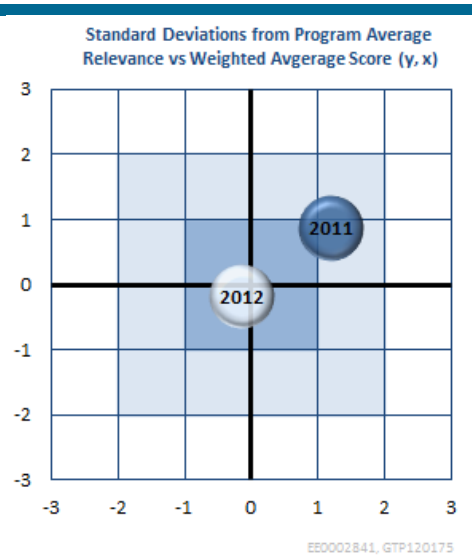
PI Response:

Reviewer 23485

Comment: I suggest that the project provide enough analysis of the seismic data to meet its stated objective. This would be very valuable, and a detailed report on this subject would be used by many people. How do you make certain that you have enough shallow velocity data? What kind of velocity structures make this method ineffective? How much can you learn from the measured velocity structure, as opposed to the reflections. Are the nearly horizontal reflectors in the melange meaningful or noise? These are useful and interesting questions that could be discussed.

The project should be given extra time, if needed, to compensate for the seismic interpretation uncertainty and permitting issues.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002841
Project: Innovative Exploration Techniques for Geothermal Assessment at Jemez Pueblo, New Mexico
Principal Investigator: Kaufman, Greg
Organization: Pueblo of Jemez
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23530

Score: 4.0

Comment: This is one of two tribal lands projects. It is the first revenue generating project for the Jemez Tribe; the Jemez tribe is actually developing the project. It is the main geothermal project in NM. The project has developed full-time employment for several people. They are expecting temperatures of 250F; the exact properties of the reservoir remains to be seen pending completion of the drilling phase of the project. It is a relevant and potentially highly visible project due to its proximity to the original Hot Dry Rock Project in New Mexico.

PI Response:

Indeed. Thank you.

Reviewer 23404

Score: 2.0

Comment: This project seeks to assess the cold and hot water resource on Native American lands and has the potential for commercial power generation. This could represent an important contribution to this pueblo. The innovativeness of the methods applied to this project are nonexistent.

PI Response:

The innovative nature of some methods applied in this project has been well accepted by the international geothermal community. Especially the details of the seismic data acquisition and processing lead to many positive remarks and inquiries.

Reviewer 23577

Score: 3.0

Comment: A lot of time was spent on the background related to the project, very interesting but not very informative with respect to impact of research. The impacts seem to be significant for the tribe and state. Difficult to access how useful this project will be for the geothermal industry. If the 10 MWe power is proven then impacts will be very significant.

PI Response:

Maybe we could have given a better presentation and outlook with respect to impact of research. It is certain that this project triggered a very interesting discussion about the use of seismic in geothermal projects in the U.S. In Europe seismic is already a standard method applied to geothermal projects. We hope to demonstrate the utility of seismic to the geothermal community through our seismic work which did not follow general mining or oil & gas standards but was designed for our specific purposes. The structural information obtained by this method alone is unmatched. We feel that drilling planning and drilling with proper structural exploration through correctly applied seismic surveying provides the best chance of success.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23530

Score: 3.0

Comment: Although the original project plan was to drill two 3000 ft. wells, the drilling plan has been modified in consideration of available data. The drilling location has been selected based upon data analysis. The location has been selected with the best probability of encountering high temperatures.

PI Response:

Indeed. Thank you. We tried to do our best to be objective and fact based in all of our decisions to maintain a high probability for success.

Reviewer 23404

Score: 2.0

Comment: This project has assembled a good team of technical individuals to work on it. However, it is unclear as to the role of each individual, but certainly there exists a great deal of knowledge in the group.
The nature of completing the drilling program as indicated for the budget is questionable. The project proposes to drill a vertical well near a fault and then to possible kick over to the fault. It is unclear why the location of the well, was chosen where it is, especially given the funds available. It may make more sense to drill the vertical well closer to the fault, and then not worry about the potential for a side kick. The funds do not appear sufficient to complete the well.

PI Response:

Understood. We will provide more detail on the slides regarding personnel and their respective input to the project for the next peer review. Essentially, we have used experts in each scientific descipline relevant to this project, e.g., the seismic scientist does seismic imaging, the hydrogechemist does hydrogeochemistry, the geologist does geology, the tracer experienced scientist does tracer testing, etc. This is a competency-based team environment managed by the technical project manager who glues the team together and manages the decision making process as delegated by the PI. Most of the team live and work in the region we are exploring so we feel that, in addition to academic credentials, we are capitalizing on the team members' knowledge of the area from personnal, scientific experience. In regards to the drilling related comments, we provided all of the supporting documents that included all scientific findings resulting in the conceptional model of the resource to the Technical Monitoring Team which reviewed them extensively. We had a series of phone conferences and a few in-person meetings to review and refine the drilling plan. In the end, after we

incorporated some notable changes to the original plan, the TMT approved it. The plan was then approved by the DOE project officer and his chain of command in the Geothermal Program. Thus, we feel that we have a consensus within the DOE geothermal community that we can complete the drilling plan within the budget and with a decent chance for success. One detail to note: we have been allowed to consider the 3rd phase of this project (well testing and associated mesurements) as optional. If we exceed the Phase 2 drilling budget, we will be able to reduce the more optional elements in the scope of work for Phase 3 and apply those funds to the drilling budget. This provides us with a substantial safety margin. That said, we are doing everything within our power to ensure that we do not exceed the drilling budget. This includes decreasing the drill risk and drilling costs by drilling through several faults as perpendicular as possible (directional drilling) rather than hitting them at an oblique angle from a verticle bore, and exploring the cross cut zone between the two major fault zones that might host the source mechanism for the large MT anomaly observed. The cross cut zone is an essential exploratory target for this project.

Reviewer 23577

Score: 3.0

Comment: Very sound technical approach. Good data collected so far. Great work. Deviated drilling looks good.

PI Response:

Thank you.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23530

Score: 3.0

Comment: The project is showing good progress and has advanced to the planning part of drilling (Phase 2). Work in the exploration phase has provided significant data that will contribute to identification of the preferred drilling location. The probability remains high for power production. A detailed conceptual model of the resource has been developed that is a significant improvement over the pre-project geologic cross-section. Advanced processing capabilities from Los Alamos National Laboratory (LANL) have helped with this development. A seismic monitoring network has been setup and has been validated with known seismic events. The team is moving towards developing a permanent processing station. Proposals have been received from drilling companies indicating the validity of the revised drilling plan. Up flows of fluids from the Valles Caldera have been suggested making the resource attractive.

Overall the project is showing measurable progress toward attaining programmatic objectives.

PI Response:

Thank you.

Reviewer 23404

Score: 2.0

Comment: The team has put together the requisite and available information to develop a geologic model. This is a geologically and structurally complex area, unraveling the structural geology was not simple. The innovativeness of the approaches applied is not clear.

PI Response:

The innovative nature of some methods applied in this project has been well accepted by the international geothermal community. Specifically, the details of the seismic data acquisition and processing lead to many positive remarks and inquiries.

Reviewer 23577

Score: 4.0

Comment: Looks like a lot of very nice work has been performed so far. This project is a nice story for the Geothermal Technologies Office particularly in light of the effort made by the project team to bring in all the stakeholders. The use of traditional methods combined with enhanced seismic and 3-D magnetotellurics is particularly appropriate for this problem. Developing a site conceptual model based on existing and new data is especially well done. The 3-D seismic acquisition and processing appears to be especially well done.

PI Response:

Indeed. Thank you.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23530

Score: 3.0

Comment: Project management is sensitive to environmental regulations even though the project falls outside typical state/federal jurisdictions. Due diligence is evident in that they are moving forward with the drilling plan. The drilling plan will allow the deviated portion of the well to occur higher in the well if necessary to control drilling costs. Although the original project plan was very aggressive, the team has revised it to make it more realistic. The team is keeping DOE in the loop for approval of project changes. The team is maintaining contingency in the drilling budget to ensure they can handle uncertainties in the overall drilling plan. Lost circulation may be a particular concern since it was at Fenton Hill. Project management has done a good job of re-scoping drilling plan based upon available data.

PI Response:

Thank you.

Reviewer 23404

Score: 2.0

Comment: In terms of meeting project goals, the management and coordination of this project is well poised. Being able to accommodate cultural needs and issues into the work plan is a challenge which the management has been able

successfully achieve. It appears that the Geothermal Technologies Office was consulted in the decision to switch from two exploratory well to a single deep well; the merits of this decision remains to be determined.

PI Response:

No comment.

Reviewer 23577

Score: 4.0

Comment: Good management. Some rough going has led to delays; nine month delay for Los Alamos National Laboratory (LANL) partners, teaming with drilling project is a good move. I am impressed with how this project has advanced in light of all the various components that needed to be managed.

PI Response:

Thank you.

STRENGTHS

Reviewer 23530

Comment: This is an exciting project that is near the foundations of the US geothermal industry. Successful completion of this project will be extremely beneficial to New Mexico and the geothermal industry at large.

PI Response:

Thank you.

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23577

Comment: Coupled geophysical exploration methods with drilling, innovative flowing electrical conductivity logging and tracer testing may be useful for providing insight into the nature of the resource. Technical team approach is outstanding. Being the largest geothermal project in New Mexico since Fenton Hill helps to promote geothermal exploration in this area.

PI Response:

Thank you.

WEAKNESSES

Reviewer 23530

Comment: Unclear if the overall drilling plan has sufficient contingency to handle unanticipated trouble during the drilling phase of the project.

PI Response:

The risk management workshop will allow us to identify any unanticipated troubles not yet sufficiently addressed. This management approach leads to a higher probability in handling unanticipated troubles successfully. Also, we have been allowed to consider the 3rd phase of this project (well testing and associated mesurements) as optional. If we exceed the Phase 2 drilling budget, we will be able to reduce the more optional elements in the scope of work for Phase 3 and apply those funds to the drilling budget. This provides us with a substantial safety margin. That said, we are doing everything within our power to ensure that we do not exceed the drilling budget.

Reviewer 23404

Comment: The location, cost, and depth expectations of the well to be drilled are unrealistic and should be re-evaluated.

PI Response:

The reviewer does not give any specifics or references for his general remarks. It is not possible to formulate a sufficient response. It would be more beneficial to the geothermal program if the reviewer would give more detailed and specific remarks in order for us to process those as a critical but constructive input to our work.

Reviewer 23577

Comment: A bit behind on schedule due to unforeseen permitting and contraction issues.

PI Response:

Yes.

IMPROVEMENTS

Reviewer 23530

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23404

Comment: The project should be more realistic in well construction expectations.

PI Response:

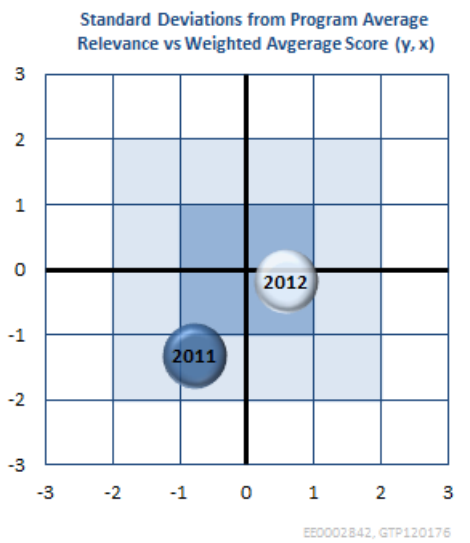
The reviewer does not give any specifics or references for his general remarks. As stated above, we worked in close collaboration with the TMT, the DOE project officer for this project, and his chain of command to develop the drilling plan. Over the course of months, the drilling plan was evaluated, revised, and re-evaluated. The consensus is this is a solid drilling plan, based on sound data that was also peer reviewed, that can be completed successfully with the budget at hand.

Reviewer 23577

Comment: Merging of Laboratory and Tribe seismic network is important for the success of the project..

PI Response:

We agree. Also, the merger is improtant to develop best practices and lessons learned for the geothermal industry in the U.S. Two non-DOE grant applications have been submitted recently by the New Mexico Institute of Mining and Technology to join the seismic network developed for our project by TBA Power, Inc, and the network of the Los Alamos National Laboratory. Contrary to the general commercial industry approach in the U.S., this project used a pro-active approach in implementing its seismic network and we feel it would be beneficial for future geothermal projects if the geothermal industry followed this approach.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002842
Project: Comprehensive Evaluation of the Geothermal Resource Potential within the Pyramid Lake Paiute Reservation
Principal Investigator: Noel, Donna
Organization: Pyramid Lake Paiute Tribe
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23537

Score: 3.0

Comment: Project absolutely conforms with broader Geothermal Technologies Office mission and goals.

The only blemish in this remarkable program is the value of reservoir modeling. To date, no production wells have been drilled and certainly nothing has been flow tested. No production wells or even slim wells with rig tests are scheduled for this program either. Given that a resource might be inferred from exploration data, it is still unclear what is going to be modeled. More importantly what is the value of an assumption-based reservoir model in an "innovative" exploration program? Reservoir modeling in productive fields is often questioned by stakeholders because of the rarely supported and often disputed input variables, costs, and the never-ending engineering vs. operations interpretations of the reservoir. It is unclear how modeling at this point in an exploration project offers any value (other than to the modeler). If the Pyramid Lake-DRI-UNR-others team feels that this task is additive, then they need to explain what exactly they plan to model, what the anticipated results will be and what the results of such modeling offers at this pre-discovery stage of the program.

PI Response:

Clearly the reviewer didn't read the supporting material or the project proposal. Given the limited amount of time allotted for the presentation we had to focus on Phase III of the project and as such didn't review previous work. Recall that in Phase II we drilled two wells, one of which is a production well and we flow tested for a 30 day period. During this testing we collected temperature and pressure data at multiple locations within the reservoir. We also disagree with the value of the reservoir model. Prelimary economic analysis of the reservoir indicates that the project viaaiblity is highly dependent on production capacity and temperatures, both of which will be predicted accurately with the model. Therefore, we respectively disagree with the reviewer's position.

Reviewer 23485

Score: 2.0

Comment: The objective of this project is to identify geothermal target sites on the Pyramid Pauite Tribe Reservation, and specifically evaluate the site at Astor Pass. This work has the potential to impact the Geothermal Technologies Office's goals of more power on line, however, its potential contribution is not large because the geothermal potential of the Reservation is not large. The experience gained here may also help exploration at other sites, but that has not been a central focus of this program.

PI Response:

The geothermal potential at Astor Pass may be relatively small, but given the broader scope of the project we are likely to increase the geothermal potential within the Reservation. The entire Reservation, the focus of our Phase III work, is a huge area with complex faulting, voluminous high-temperature springs, and active seismicity. So we disagree with this reviewer that "the geothermal potential of the Reservation is not large. In terms of the broader impacts of the project, the integration of multiple novel techniques has proven valuable to the project and hopefully to the geothermal industry as a whole.

Reviewer 23427

Score: 3.0

Comment: This project supports the hydrothermal goals of the Geothermal Technologies Office. The project now has two overarching objectives; characterize the geothermal reservoir at Astor Pass using innovative technologies and exploration to locate blind geothermal reservoirs at other sites in the reservation. The innovative technologies are apparently the 3-D geologic and reservoir model and the use of SeisOpt seismic data analysis to create fault plane images, to mitigate risks and development costs the 3-D reservoir model will be used to predict long term efficacy of the reservoir. The innovative characterization and simulation techniques will be validated.

PI Response:

We agree with this comment.

Reviewer 23627

Score: 3.5

Comment: The relevance/impact of research for this project is high.

PI Response:

We agree with this comment.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23537

Score: 4.0

Comment: The integration of geologic mapping, geophysical data (e.g., seismic reflection) and processing, drilling and analysis and structural modeling is the best possible approach to take for geothermal exploration.

PI Response:

We agree that that geologic mapping, geophysical data processing, drilling, and structural modeling are important components of a geothermal investigation, but one must also develop a detailed geologic and reservoir model to validate

the conceptualization. If one omits the quantitative analysis, then the study becomes an exercise in hypothesis building without fully understanding the system.

Reviewer 23485

Score: 3.0

Comment: The team is reviewing and collecting a large number of datasets, incorporating them into a 3-D geological/structural model with information about the stress field and response to it, and then planning to develop a 3-D reservoir model of the behavior of Astor Pass. In addition, they are using a wide range of data to assess the potential at other sites on the Reservation. Although there is not enough information presented to allow an assessment of many of the exploration methods, the activity looks very thorough and it is carried out by a strong team.

PI Response:

We agree with this comment and unfortunately couldn't provide a more detailed presentation to show how all of the components fit together. This information will be provided in the final report.

Reviewer 23427

Score: 3.0

Comment: The key issues that are currently being addressed include: Understanding the key geologic features as identified in the three dimensional geologic model and how these drive fluid and heat flow in the reservoir.
The project summary illustrates the Technical Approach by listing the 13 tasks along with their titles. From these you can discern that the technical approach includes permitting, shallow temperature survey, seismic data collection and analysis, fracture stress modeling and slip tendency analysis, drilling, borehole geophysics, well testing and geophysical analysis, etc

PI Response:

We agree with this comment that the project tasks are appropriate to understand the geothermal potential within the Pyramid Lake Paiute Reservation.

Reviewer 23627

Score: 3.5

Comment: There was a reasonable selection of methods to achieve the project's objectives. Scientifically and technically, a very strong team.

PI Response:

We agree with this comment.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23537

Score: 4.0

Comment: The technical accomplishments, results, and progress of the tasks are on point.

PI Response:

We agree with this comment.

Reviewer 23485

Score: 3.0

Comment: Many datasets have been collected and processed. The structural model is "complete" for Astor Pass, but we were informed that a drilled well did not flow, making it impossible to test the model at this time. The wider assessment has started.

PI Response:

The reviewer may have misunderstood our response because we focused on Phase III of the project.. Two new wells were drilled and we conducted a 30-day well test to gain critical pressure and temperature data within the reservoir. These data are being used in combination with the 3D geologic model to construct, calibrate, and validate a 3D reservoir model to determine the long term efficacy of the reservoir.

Reviewer 23427

Score: 3.0

Comment: First two project phases are complete. The list of technical accomplishments almost mirrors the task list headings.
Reservoir temperatures were found to be a few degrees less than anticipated (95 versus 100 degrees C) but a preliminary economic analysis indicates that the Astor Pass Geothermal Site is a viable resource. Using a conservative production estimate of 500 gpm, the site would produce 539 kW with a simple pay back of 5.8 years. Although the economics are marginal at such a low production rate, the results of the well testing suggest that fluid production could be much larger than 500 gpm.
The project team felt strongly that a reservoir model was needed to ascertain sustainable production rates both in terms of fluid flow and temperature and apparently this was added to the project. Also, at the request of the Geothermal Technologies Office and to reduce overall project risk the project was modified to also include a reservation-wide geothermal assessment.

PI Response:

We generally agree with this comment, but the reservoir model was planned from the outset of the project, and the reservation-wide assessment was the primary change made following the 2011 review meeting.

Reviewer 23627

Score: 3.5

Comment: This project is in line with expectations.

PI Response:

We agree with this comment.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23537

Score: 4.0

Comment: This appears to be the ideal team to tackle this type of project. Oversight of the work to date seems to be on point.

PI Response:

We agree with this comment.

Reviewer 23485

Score: 3.0

Comment: The project has good coordination, and appears to be getting many researchers to contribute to the final model and decisions. The addition of the Reservation-wide assessment was a good idea, and the resulting experience may be useful at other places as well.

PI Response:

We agree with this comment.

Reviewer 23427

Score: 3.0

Comment: Project is stated as being on schedule and within budget.

PI Response:

We agree with this comment.

Reviewer 23627

Score: 3.5

Comment: Looks good but hard to judge from the presentation.

PI Response:

We agree with this comment, and again only had limited time to present. All of the project detailed will be provided in the final report.

STRENGTHS

Reviewer 23537

Comment: Team. Approach. Accomplishments to date. Future plans.

PI Response:

We agree with this comment.

Reviewer 23485

Comment: Varied team integrating wide range of information. The Reservation-wide assessment reduces the chances of "failure" if Astor Pass does not turn out to be a viable site.

PI Response:

We agree with this comment.

Reviewer 23427

Comment: It is stated that the project in on schedule and within budget. Those have to be strengths.
It also appears that the project has been modified to reflect changing needs such as the development of a reservoir model and a reservation-wide geothermal assessment.

PI Response:

We agree with this comment.

Reviewer 23627

Comment: There is a clear multidisciplinary approach to build a 3-D model of the area. Methodology might be relevant in other projects.

PI Response:

We agree with this comment.

WEAKNESSES

Reviewer 23537

Comment: Other than plans to perform reservoir modeling, none.

PI Response:

Again, we disagree with the assessment that reservoir modeling is not needed. See first comment response.

Reviewer 23485

Comment: Quality of work cannot be assessed from a short presentation. Need to make certain that techniques and results are described in adequate detail so that the value of the work and the contributions of the techniques to the understanding can be assessed.

PI Response:

We agree with this comment, and again only had limited time to present. All of the project detailed will be provided in the final report.

Reviewer 23427

Comment: Opening up the project to the whole reservation raises the potential for impacting sacred sites.

PI Response:

To some degree this is true, but we are very aware of this fact and working with Tribal leaders to ensure that our characterization activities are in areas that are not deemed sacred.

Reviewer 23627

Comment: The results from resistivity data is not used in the 3-D model. The reason is not obvious since resistivity is in general one of the most prognostic parameters for geothermal fields.

PI Response:

Although the resistivity wasn't used directly to build the 3D geologic model it was used to help identify well locations, to develop a conceptual understanding of the reservoir, and to constrain the 3D geologic model. The resistivity data will also be used in the development of the 3D reservoir model to identify zones of high permeability that are generally associated with low resistivity.

IMPROVEMENTS

Reviewer 23537

Comment: Strongly recommend the PI remove the modeling phase and either return that money to the Geothermal Technologies Office or use that money to further augment exploration work.

PI Response:

Again, we strongly disagree with the reviewer's position. Since the reviewer didn't review all material provided, fully understand the critical nature of the modeling task, and is clearly biased against modeling, his recommendation is not valid.

Reviewer 23485

Comment: None.

PI Response:

None.

Reviewer 23427

Comment: Although it was stated at the review that sites could be found that would be unlikely to impact sacred sites, this is insufficient. Each site should be investigated for this possibility. Even then it will be difficult to convince the tribes.

PI Response:

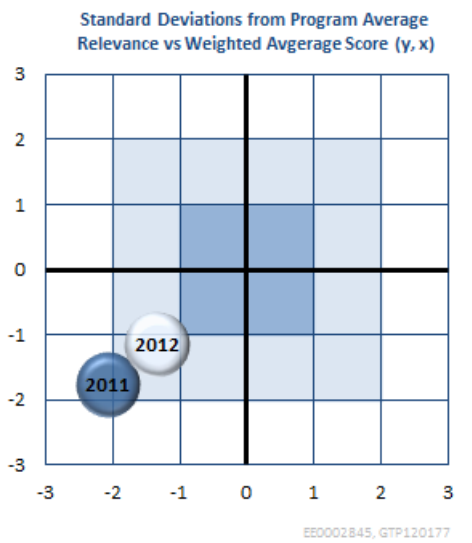
Although the reviewer may not understand the importance of sacred site, we must respect the wishes of the Tribe and will not conduct characterization activities on or near sacred sites.

Reviewer 23627

Comment: The project should add the results of resistivity measurements to the 3-D modeling, if the resistivity data are of good enough quality. Otherwise magnetotelluric (MT) data should be collected.

PI Response:

MT has been collected but was funded using non-DOE sources. These data will be integrated into the reservoir model to identify high and low permeability zones.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002845
Project: Alum Innovative Exploration Project
Principal Investigator: Miller, Clay
Organization: Ram Power Corp.
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23537

Score: 2.0

Comment: The objective of determining the best combination of a multi-faceted “resource characterization” has great value in the world of exploration. At some point, it was probably agreed that Z-tipper Electromagnetic (ZTEM) surveys may add value to the geophysics portfolio. It is uncertain if/when coiled tube drilling was ever imagined to be worth pursuing. And certainly the confirmation of a 400 MW resource is always welcome. Rather than relying on a GeothermEx report discussing the "capacity" of this potential resource, flowing well data would be a much better attribute to bring to a peer review.

PI Response:

Reviewer 23485

Score: 2.0

Comment: This project has two objectives that are relevant to the Geothermal Technologies Office's goals. The first objective is to evaluate and demonstrate two innovative exploration methods, a passive aerial electromagnetic (EM) method (ZTEM) and coiled-tube drilling. The electrical method is an inexpensive alternative to ground-based conductivity measurements that could be useful for studying many geothermal targets in the upper two kilometers, and the coiled tubing drilling could reduce drilling costs in some circumstances. Although it is not stated in the presentation, the application of a complete suite of exploration tools at this site will also provide a case study of use to other exploration projects. The second is to confirm a resource capable of producing 30 to 80 MW.

The project is on-going, and has not yet had an impact on the Geothermal Technologies Office's goals.

PI Response:

Reviewer 23427

Score: 2.0

Comment: The objectives of the project support the Geothermal Technologies Office's hydrothermal goals. It is fair to say that the project has demonstrated some advancement in addressing knowledge gaps and barriers; but impact is below what could be expected, primarily because of management changes.

Original end date was 8/30/2011!. A no-cost to extension request is underway and a new schedule has been developed.

PI Response:

Reviewer 23627

Score: 3.0

Comment: The project's intention is to define the best combination of exploration methods for validation of a resource and have that ultimately lead to power production at the site.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23537

Score: 3.0

Comment: With some exceptions (previously mentioned) the combination and integration of the tools discussed in this presentation are a solid approach if another tool, geologic/structural mapping, were integrated in to this program.

PI Response:

Reviewer 23485

Score: 2.0

Comment: The general approach taken by this project towards characterizing the geothermal prospect is reasonable. They have employed a range of number of complementary methods, and organized their targets in a logical way. Unfortunately, the quality of this scientific work cannot be assessed based on the presentation, as the personnel on the project have changed and the interpretation and application of some previous work has been interrupted.

PI Response:

Reviewer 23427

Score: 3.0

Comment: This project includes tasks to validate a variety of innovative exploration and drilling technologies which aim to accurately characterize the geothermal site and thereby reduce project risk. Phase 1 exploration tasks consist of two parts: (1) surface and near surface investigations and (2) subsurface geophysical surveys and modeling. Phase II will consist of siting and drilling at least one production well. Phase 3 will consist of extended flow tests to confirm the geothermal resource. This will be followed by an overall assessment of the productivity of the Alum geothermal area. Finally, an evaluation of the relative contribution of each exploration technique in reducing risk during the early stages of the geothermal project will be done and a final report will be written for delivery to the Geothermal Technologies Office.

Project will validate two new exploration methods: Z Axis Tipper Electromagnetic System (ZTEM) for application to geothermal and a coiled tube slimhole drill rig. ZTEM is a passive airborne electromagnetic system, which uses the natural time varying changes in the earth's magnetic field to detect conductors, map geology and explore for large poorly conductive features such as regional faults and porphyry copper deposits. Although this project says ZTEM has not been previously used in geothermal, ZTEM has been successfully used for commercial mining and geothermal applications since at least 2007.

PI Response:

Reviewer 23627

Score: 3.5

Comment: The scientific and technical parts of the project, as well as the tasks to be performed, look to be clearly defined.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23537

Score: 1.0

Comment: This project, in its current make-up, is clearly dead. The principal company no longer can accomplish any of the work it agreed to perform. Ram Power is now a holding company and has no staff capable of following through on these tasks. They didn't even show up at the Peer Review.

PI Response:

Reviewer 23485

Score: 2.0

Comment: This project gathered a lot of data in its early stages, but has stopped progressing. Regarding the objective of testing methods, they have learned about the logistics of these methods. They learned that the coiled tubing drilling did not work in the geology at this site, and have flown the Z Axis Tipper Electromagnetic system (ZTEM) and received a 3-D interpretation. It is not clear how they will determine the value of the ZTEM data, but the broad range of other datasets and the planned drilling will provide information for this evaluation.

How much progress has been made integrating these data into a model that can guide drilling? Because the project personnel changed before this work was completed, it is not clear how much progress has been made.

PI Response:

Reviewer 23427

Score: 2.0

Comment: The assignment of a 'Fair' score is based upon the delays created by the change in management which has adversely impacted this project. Further, lithologic and structural conditions in Alum proved to be an insurmountable challenge for coiled tube drilling.
However, it is stated that significant accomplishments have occurred in exploration surveys, analysis/modeling, and drilling.

PI Response:

Reviewer 23627

Score: 2.0

Comment: The project has suffered from considerable delays. The explanation given is the take-over of Ram Power and their recent problems with construction of a power plant in Nicaragua. This explanation is hardly acceptable. Lot of progress has been made at this point; however, and it is necessary to complete the project.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23537

Score: 1.0

Comment: While some good work was performed in the past, it is impossible to get around the fact that the remaining work cannot be completed unless it is handed off to someone else.

PI Response:

Reviewer 23485

Score: 1.0

Comment: This project is in trouble because the ownership of the company has changed and they have been unable to commit people to this project because of other constraints. Corporate knowledge has apparently been lost, requiring the data integration process to have to start again. The project certainly needs a no-cost extension, and it is not clear that the company intends to go forward with it even if that is granted. Fortunately, they have asked the presenter to prepare a report summarizing what is known and what the status is. That report will be a good basis for deciding where to go from here.

PI Response:

Reviewer 23427

Score: 2.0

Comment: The major issue is the Ram Power Corp. acquisition of Sierra Geothermal, Inc. and the impact on the project. I did not get a clear picture from the pre-review material that there is a strong corporate commitment to this project. At the review, the presenter made the case that Ram Power is committed. Other than this issue, management seemed to have been appropriate for this project; although it is not clear that this was true for coiled tube drilling.

PI Response:

Reviewer 23627

Score: 2.0

Comment: The obvious lack of good project management is causing the delays.

PI Response:

STRENGTHS

Reviewer 23537

Comment: Greg Nash and University of Utah offer solid skills. Per the Peer Review Q&A, Greg is no longer with Ram Power (although he would like to be funded to follow through).

PI Response:

Reviewer 23485

Comment: This is an interesting target with a broad set of geological and geophysical data, and it is an environment where faults may be expected to provide favorable permeability. Because it is in the same setting as the project at Pearl Hot Springs, both projects could benefit from coordinating their work.

PI Response:

Reviewer 23427

Comment: A re-evaluation of historical and new data has shown that there is an excellent chance of a commercial geothermal resource being located but not necessarily at Alum Mine.

PI Response:

Reviewer 23627

Comment: The project is targets the testing of innovative methods for exploration and drilling. Furthermore, a goal is to confirm a geothermal reservoir for production of electricity.

PI Response:

WEAKNESSES

Reviewer 23537

Comment: The industry partner, Ram Power, effectively no longer exists and is therefore not capable of completing this work.

PI Response:

Reviewer 23485

Comment: This project suffers from loss of key personnel and knowledge. For example, they tested the Heli-Coil drilling, and decided it did not work. A useful report for the Geothermal Technologies Office would include information about exactly what happened, and suggestions about what environments it might or might not work in. The presenter suggested that no one knows the details of what happened well enough to write that report. Perhaps he will find out that concern is not true.

PI Response:

Reviewer 23427

Comment: The major issue is whether the acquisition by Ram Power, Corp has put completion of this project in doubt.

Further, lithologic and structural conditions at Alum proved to be an insurmountable challenge for coiled tube drilling which was one of the factors which was used to justify the project. Also, it was stated that Z Axis Tipper Electromagnetic system (ZTEM) was useful but not necessary for this project. Alternatives may be cheaper and more available. Thus, both 'innovative' features have been disposed of. The Geothermal Technologies Office may want to clarify what remaining funds will be used for.

PI Response:

Reviewer 23627

Comment: Probably the lack of support from the industrial partner.

PI Response:

IMPROVEMENTS

Reviewer 23537

Comment: One of two recommendations should be considered. Either (1) this project should be shelved with all data dutifully provided to the national database or whoever for retrieval and follow through at some later date or (2) the money should be blended with another nearby project, Pearl Hot Spring. Danni Stockli and company (minus Ram Power) plus Greg Nash and University of Utah would then be charged (if they chose to accept the challenge) with modifying and blending the two projects into one. The detachment fault setting of both and the structural underpinnings of the potential geothermal resource in this part of the Basin and Range is a story worth understanding and disseminating. But allowing another penny of this money to go to Ram Power for any reason is wasteful.

PI Response:

Reviewer 23485

Comment: If this project is to be continued, it needs to be jump started. Getting the presenter actively involved and writing a status report is a good start, but the project does not have adequate personnel at this time. This project could benefit a lot from collaboration with the Pearl Hot Springs project, which has a large number of participants who are actively studying a nearby field in the same geological setting.

Make certain that the evaluations of the two innovative methods provide information that is useful for applications in other environments.

PI Response:

Reviewer 23427

Comment: It appears that all the factors which led to approval of this project are still in play. The issue of a no-cost extension and Ram Power's commitment should be resolved quickly.

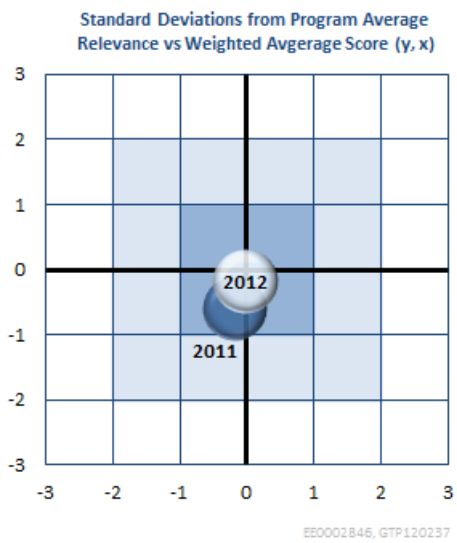
PI Response:

Reviewer 23627

Comment: The innovative aspect of the drilling with a coil tube has failed. It is very important to report this results within the final report and analyze why the coil tubing did not fit to geothermal drilling.

Similarly, it is necessary to show in detail the advantages and drawbacks of the innovative exploration methods which were tested and report which of them can or can't be recommended and why.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002846
Project: Validation of Innovative Exploration Techniques at Pilgrim Hot Springs, Alaska
Principal Investigator: Holdmann, Gwen
Organization: University of Alaska Fairbanks
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23404

Score: 2.0

Comment: If this work is successful it will have an impact in a rural area of Alaska. This will potentially have, if successful, an impact on this rural community. It is unclear that this work will have significant impact on US geothermal as a whole. It does not appear that the technologies evaluated provide any new or special insights into geothermal evaluations here or elsewhere. The technologies that will be relied on are somewhat standard. This is unfortunate given the project's remote location. It would have been useful if some of the methods attempted in this project would have been more definitive regarding aspects of the resource. There is nothing innovative about the work presented in this project.

PI Response:

In this project we used a combination of standard/traditional ground-based measurement approaches as well as remote sensing for data acquisition for geothermal resource assessment. The aspect that we proposed as innovative and worked on most intensively was the use of airborne Forward Looking Infrared Radiometer (FLIR) images for mapping geothermally anomalous features and characterizing the geothermal resource by providing a first-order quantitative estimation of the geothermal flux in Mega Watts (which is a valuable indicator of the production potential of the geothermal resource) for the system we are exploring.

Though FLIR and FLIR type sensors have been used in the past for geothermal studies, their use has been limited to mapping surface hot-spots or at best to make surface temperature maps. Geothermal literature lacks documentation on using such detail surface temperature data and deriving meaningful quantitative estimates on themal flux which would give an early indication to decsion makers on whether or not the site in question has the potential to serve as a viable resource for development.

In this study we adapted surface energy balance equations used in some volcanological studies (to study lava flows and crater lakes) for the purpose of estimating thermal flux of geothermal waters. Details of the algorithm used for this quantitative analysis are presented in Appendix 1 (Haselwimmer and Prakash, 2011), and are the subject of a peer reviewed publication currently in submission. It is important to note that the technique for thermal flux estimation that we have exemplified at the Pilgrim Hot Springs in Alaska will work well for both low temperature and high temperature geothermal resources as it is based on temperature difference between goethermal features and the ambient background, and on the concept of surface energy balance. Therefore, it will be possible to use this technique widely for first order resource estimation.

We would also like to point out that early results of the FLIR data analysis over the Pilgrim Hot Springs were presented at the 2011 Geothermal Technologies Office Peer Review meeting and were very positively reviewed by all three reviewers

(Reviewer numbers 60, 40, and 12) who found it to be a "nice use of modern thermal imagery technology", "coud provide nice way to map geothermal", and "relevant" respectively.

Reviewer 23427

Score: 3.0

Comment: The purpose of this project is to test an innovative geothermal exploration technique that, if proven, would reduce the cost of preliminary geothermal exploration for low and moderate temperature geothermal resources. However, the innovative technique mentioned, forward looking infrared radiometry (FLIR), was found to not be useful in this project.
This project relates to the Geothermal Technologies Office goal of developing low and moderate temperature resources, and reducing the cost of geothermal exploration.
Project end date is 6/30/2013.

PI Response:

We defer from the reviewers conclusion that 'FLIR was found to be not useful in this project'. It is true that the FLIR in itself did not help to pin point the upflow zone, but that was never the expectation. The FLIR was found to be valuable as a tool for mapping the limits of the shallow hot water aquifer as evidenced by higher surface temperatures and snow-free areas in the Spring time images in an otherwise frozen landscape. FLIR also helped in accurately estimating thermal heat flux of the geothermal system, raising our confidence to move forward with further prospecting.

Reviewer 23627

Score: 3.5

Comment: This project is an important part of developing suitable methods for geothermal conditions in Alaska and other arctic areas.

PI Response:

Thank you.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23404

Score: 2.0

Comment: Given the remote location of the site/study area, the researchers have tried to utilize remote sensing methods to better understand the geothermal resource. This attempt has value because in such an area if remote sensing methods were to "work" that would help for future evaluations. It appears that the approach was sound; however only limited success was met. It was stated that ground truth was really only attained through direct measurements of drilling holes and modeling the thermal profile. It is unclear which of the remote methods would be recommended for further use.

PI Response:

It is important to clarify here that for future evaluations especially in remote areas, the remote sensing will play an important (and cost saving) role in finding potential geothermal sources and narrowing down areas for ground validation. This is a huge benefit especially in remote areas, in spotting blind geothermal resources, and in investigating areas that have previously not been well explored. At the Pilgrim Host Springs, remote senisng analysis, especially the use of FLIR, helped to delineate vegetation and snow melt anomalies that helped to define the limit of shallow hot water aquifer. It also helped for heat flux estimate indicating that the resource had greater potential than initially estimated in the 1980s based on ground-based surveys alone.

It is true that further decisions on defining the exact drilling site was guided heavily by by ground-based temperature measurements and modeling thermal profiles.

Reviewer 23427

Score: 3.0

Comment: The challenge addressed by the project is the high cost of exploration for moderate temperature geothermal resources such as commonly found in interior Alaska.

The first Phase of this assessment included the use of a combination of innovative geophysical remote sensing techniques (including forward looking infrared radiometry, or FLIR) intended to map the spatial extent and total heat flow to the surface and make a preliminary estimation of the developable extent of the reservoir, coupled with more traditional ground-based exploration techniques to pinpoint the location of the upflow zone, map the spatial extent and total heat flow to the surface, and estimate the temperature and depth of the reservoir. The second Phase of this project will involve drilling and testing a series of holes of varying depth as well as accessing existing wells that were part of a late 1970s and early 1980s resource evaluation effort to confirm the results from Phase I. The third Phase will involve developing a more complete understanding of the reservoir through flow tests and water sampling of the holes, and development of a numerical reservoir model.

PI Response:

We would like to add that this technique can also be applied to resources located in difficult to access areas beyond Alaska.

Reviewer 23627

Score: 4.0

Comment: This projects seems to be of high scientific and technical quality. It is addressing methods that might be applied in the difficult conditions in Alaska. It has replication potential for other similar geographical conditions.

PI Response:

Thank you.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23404

Score: 2.0

Comment: The technical accomplishments for this project are on track to meet the project objectives. This project has some stumbling blocks related to access due to adverse weather conditions.

PI Response:

While we have had some logistical challenges, they were not entirely unexpected. As the reviewer state, we have been able to remain on track in terms of budget and timeline despite these challenges, which can in part be attributed to the strong partnership we have developed with local entities and the USGS in executed the program.

Reviewer 23427

Score: 3.0

Comment: Two airborne thermal infrared (forward looking infrared radiometry or FLIR) surveys over Pilgrim Hot Springs were conducted. Field surveys have also been conducted to support airborne data acquisitions and validate airborne observations. The research team believed they had identified a much larger area of interest influenced by the geothermal system than previously detected and concluded that the resource appears to extend away from the immediate hot springs in a northeast trending direction. Upon re-evaluation, they decided this was not the case.

It is stated that the project is on track and preliminary results are encouraging. For the 2012 field season – magnetotelluric (MT) survey planned for April 2012; drill two 2500' temperature gradient holes to confirm conceptual model in 2012; and refine the conceptual model.

PI Response:

The reviewer may have misunderstood some of the comments made during the oral presentation. We did identify a secondary area of interest to the northeast that was VERIFIED upon further evaluation and ground truthing. However this secondary area, while exhibiting thermal anomalies that can almost certainly be attributed to weak geothermal activity, was not ulitmately selected as a drilling target. Our current model for the system is suggestive of thermal fluids originating near the area of the known thermal springs, rather than fluid transport for significant distance sub-surface from a source located to the northeast. The anomaly to the northeast is therefore not considered the primary target for our resource confirmation drilling.

Reviewer 23627

Score: 4.0

Comment: The accomplishments, results and progress are as expected from the project plan.

PI Response:

We agree.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23404

Score: 3.0

Comment: It appears that the researcher has done a good job of organizing and coordinating both technical and financial support from other agencies to continue to move this work toward its end. Their ability to connect with the USGS and utilize their technical knowledge and resources is commendable. This is exemplified by their ability to obtain state funds to leverage Geothermal Technologies Office support. Also, they co-opted with a few Native American groups in their effort. Projects that are engaged in efforts to support the Native Americans are worthy of commendation.

PI Response:

Thank you. We have worked hard to build strong partnerships to support the program, and believe this will increase the chances of the site being developed should our exploration phase prove encouraging.

Reviewer 23427

Score: 2.0

Comment: The greatest challenge has been operating in the arctic, and particularly the long distance from infrastructure (Nome, with a population of 2500 residents is 50 miles by road) and the short field season. They also encountered significant spring flooding due to beaver dams blocking drainages that limited access to the site in 2010 well into July. They approached this issue by conducting more field work during the fall and late spring where snow machine access to the site is possible.
They have concluded that helicopter support will not be needed to complete the project. I wonder if more analysis in the beginning would have shown that drilling in the NE area was not justified or/and the risks were just too high.

PI Response:

No response entered.

Reviewer 23627

Score: 4.0

Comment: The project management seems to be professional.

PI Response:

Thank you.

STRENGTHS

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Two of the slides presented during the peer review covered Project Management and Coordination.They covered the budget and timeline, management activities, and variences. We are not clear on why the reviewer comments that we did not provide information for this criterion.

Reviewer 23427

Comment: The team has been resourceful in addressing field issues as they arise. Also, there appears to be a good resource which can address local needs.

PI Response:

Thank you.

Reviewer 23627

Comment: This seems to be a well-organized and professionally performed project giving professional results from the exploration methods. The results are valuable for selecting methods that are most suitable elsewhere at similar geological and environmental settings.

PI Response:

Thank you.

WEAKNESSES

Reviewer 23404

Comment: Given the technologies presented and evaluated by the researcher, they were unable to come to a decision or statement regarding which of the applied technologies means something new or different to the Geothermal Technologies Office. These projects are about moving geothermal forward. The researcher indicated that drilling holes coupled with a thermal model would provide an assessment. This means that all of the ancillary work done did not contribute significantly to the effort, this is not a fault of the researcher, and it is OK, but it should be so stated by the researcher.

PI Response:

We would like to re-iterate that assessing the potential location of the upflow zone and targeting the location of drill hole was guided heavily by ground-based temperature measurements and modeling of sub-surface temperature profiles. However, the preliminary work was very useful in providing the first order estimates of the resource potential of the geothermal system, which was an important indicator of whether the geothermal system has enough heat resource to be a viable target for further exploration or exploitation (see PI reponse to relevance section for more details).

Reviewer 23427

Comment: The major weakness appears to be underestimating the degree of difficulty in field operations and perhaps not allowing sufficiently for contingencies for expected difficulties.

PI Response:

While we did mention some of the logistical challenges associated with this site during the oral presentation, we do not believe these were underestimated. We were familiar with the site in advance of submmitting the proposal, and have been able to keep the project on schedule and within the approved budget.

Reviewer 23627

Comment: No obvious weaknesses are apparent.

PI Response:

Thank you.

IMPROVEMENTS

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Given the current status of the project, there is probably not time for significant improvments or course adjustments at this time.

Reviewer 23427

Comment: At this point in the project, I have no suggestions for improvement. Perhaps there could be a section added to all projects on 'lessons learned'?

PI Response:

A lessons learned section will certainly be included in our final report.

Reviewer 23627

Comment: This project should consider using Transient Electro Magnetic (TEM) soundings, either instead of the magentotelluric (MT) or as a supplementary method to be able to correct for static shift in the MT measurements. The TEM soundings can be expected to have higher resolution in the uppermost 1 km than MT.

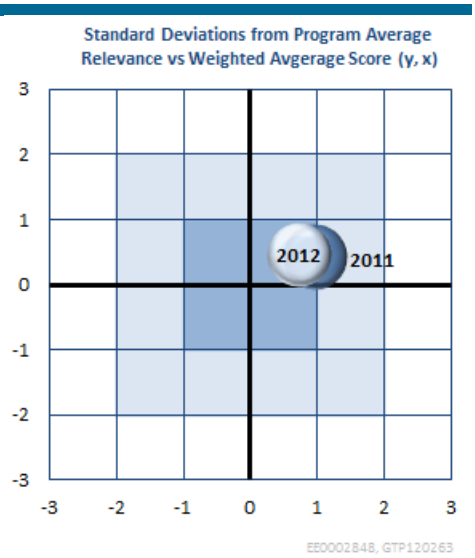
PI Response:

Response provided by Bill Cummings:

TEM is commonly used to mitigate MT static distortion caused by variations in surface resistivity and topography at scales comparable to the 100 m MT measurement dipoles. However, TEM is also commonly problematic in geothermal settings (Cumming and Mackie, 2010). Therefore, it is no longer provided by contractors as a default companion survey for geothermal MT surveys, especially for small surveys or for surveys where a 3D inversion of the MT will be conducted (usually without the TEM included). At Pilgrim Hot Springs, the Fugro Resolve airborne EM survey indicated that, within the main target area, the resistivity is relatively uniform. Moreover, topography is almost flat. Therefore, although the TEM was omitted mainly to fit the MT project within the budget, this is a reasonable risk to take at a prospect like Pilgrim Hot Springs.

Another concern is that 3D distortion will be caused by the small lateral dimensions of the surface conductor associated with the springs embedded within high resistivity permeafrost. It is expected that the detailed and widespread but shallow Resolve survey results can be used to constrain the shallow part of the 3D inversion of the MT.

Cumming, W., and Mackie, R., 2010, Resistivity imaging of geothermal resources using 1D, 2D and 3D MT inversion and TDEM static shift correction illustrated by a Glass Mountain case history. Proceedings World Geothermal Congress, Bali 2010.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002848
Project: The Snake River Geothermal Drilling Project - Innovative Approaches to Geothermal Exploration
Principal Investigator: Shervais, John
Organization: Utah State University
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23537

Score: 3.0

Comment: The objectives of this work are (understand the distribution of heat flow in the Snake River, document the previously unrecognized thermal anomalies using drilling and wire line coring technology and apply seismic, magnetic, and geothermal prospecting surveys to discovering these blind geothermal anomalies) is relevant and appropriate.

PI Response:

Reviewer 23485

Score: 3.0

Comment: This project can impact the Geothermal Technologies Office's objectives by 1) improving the understanding of a large area with geothermal potential; 2) identifying specific blind geothermal sites that might be exploited; and 3) documenting performance of geophysical methods looking for blind systems in this region. Part of this impact has been realized, as they have characterized large parts of the Snake River Plain, and identified a 160C system at Mountain House.

PI Response:

Reviewer 23427

Score: 4.0

Comment: The project goal is to document innovative new ways of finding blind or previously unrecognized geothermal resources in a region with documented heat flow amongst the highest in the continental United States. Southern Idaho is a region of vast untapped potential in a setting that is not currently being investigated by industry. The project has made notable progress in support of the Geothermal Technologies Office goals.

The project end date is June 30 2012.

PI Response:

Reviewer 23627

Score: 4.0

Comment: See comments on strengths and weaknesses.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23537

Score: 2.0

Comment: From the presented material, it was very difficult to tell how this team incorporated “new ways of finding blind or previously unrecognized geothermal resources (in this region).” Drilling targets were selected on the basis of previous worker’s research. This effectively made this program a drilling program.

PI Response:

Reviewer 23485

Score: 3.0

Comment: This project has assembled a team of capable researchers and is applying a range of geological and geophysical methods to the Snake River Plain. They have identified three characteristic areas and have drilled all three, and are in the process of including what they learned from the drilling into their conceptual models. Despite the project name, the methods used are not innovative. However, the study is comprehensive and is leading to new understanding of this area.

PI Response:

Reviewer 23427

Score: 4.0

Comment: The project uses a combination of slimhole wireline coring, wire line geophysical studies of the completed drill holes, and surface geophysical surveys. The slimhole coring uses a large mining industry truck-mounted drill which allows hitting target depths at significantly lower cost than with traditional oil field drill rigs, and also provides near continuous core to document lithologies, alteration assemblages, and fracture distribution. Wireline diamond drilling also allows drilling under lost circulation conditions.

PI Response:

Reviewer 23627

Score: 3.5

Comment: See comments on strengths and weaknesses.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23537

Score: 3.0

Comment: At least one of the three main holes has one encouraging zone with reasonable temperatures. Whether this constitutes a resource useful to anyone remains to be seen.

PI Response:

Reviewer 23485

Score: 4.0

Comment: This project has reached most of its goals. They have identified characteristic targets, located and drilled them, and found one that is quite hot and potentially exploitable. The knowledge they are developing certainly will reduce the exploration drilling risk for the Snake River Plain, and may encourage development that might not otherwise occur. If they carefully document how geophysical methods performed and why, this will be a very valuable project.

PI Response:

Reviewer 23427

Score: 4.0

Comment: A Phase 1 report was completed that compiled existing geologic mapping, field data, well logs, geothermal gradient measurements, groundwater temperature maps, and geophysical data, along with new maps of structural

lineaments. This report evaluated each drill site in terms of its geothermal potential and linked each site to a specific setting and mode of geothermal evaluation.
Completed three drill holes and conducted Vertical Seismic Profiles, gravity and magnetic field surveys and surface seismic surveys.

'Project Hotspot' has shown that slimhole diamond wireline coring is an effective exploration tool in complex volcanic environments where lost circulation is endemic.

The project has documented an aquifer of extraordinary thickness (project statement) in the central Snake River and documented a new 160ºC (320ºF) thermal resource at Mountain Home AFB with artesian flow to surface.

PI Response:

Reviewer 23627

Score: 4.0

Comment: See comments on strengths and weaknesses.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23537

Score: 3.0

Comment: Drilling is difficult and this project ran into a few obstacles (always) associated with a deep drilling program. They seemed to overcome these, however.

PI Response:

Reviewer 23485

Score: 3.0

Comment: The management team has accomplished a lot and stayed on schedule, despite the issues that always occur in field demos.

PI Response:

Reviewer 23427

Score: 3.0

Comment: The project has maintained schedule and achieved its goals amidst drilling difficulties.
Challenges included drilling ahead under lost circulation conditions, hole stability in interstratified volcanics and sediments, unstable sediment interbeds (clays, sands), and time needed to over-bore hole to set casing. Unstable sediments at one site caused failure of the hole and loss of trapped drill rods, necessitating a new hole offset from the first in order to complete the drilling program. Lost circulation materials (LCM) used as needed but mostly drill with lost circulation/no mud returns.
At Mountain Home AFB, collapse of the initial drill hole required abandonment of that hole and the drilling of a new hole offset from the first. Set casing to greater depth in the initial hole, and used rotary drilling through sediments to speed progress.

Future directions will focus on completing core analysis and integrating all of the geologic and geophysical data into a coherent paradigm for greenfield exploration of blind geothermal systems.

PI Response:

Reviewer 23627

Score: 4.0

Comment: This project seems to be very well managed.

PI Response:

STRENGTHS

Reviewer 23537

Comment: The team was able to drill three decent holes.

PI Response:

Reviewer 23485

Comment: The project's strengths are discussed in other sections of the review.

PI Response:

Reviewer 23427

Comment: The project has maintained schedule and achieved its goals amidst drilling difficulties.

Project management has been flexible and adjusted well to field challenges.

The focus on completing core analysis and integrating all of the geologic and geophysical data into a coherent paradigm for greenfield exploration of blind geothermal systems is a strength.

PI Response:

Reviewer 23627

Comment: This is an excellent project. The objectives are very clear; the management structure is solid; there is a strong scientific team with international participation. The methods applied are up-to date and very professional. The progress and results are as expected.

PI Response:

WEAKNESSES

Reviewer 23537
Comment: This project was a drilling project that was billed as something more. There is really nothing "new" about drilling into an area where previous workers think/suspect there might be a resource. To date, a resource has not been identified.

PI Response:

Reviewer 23485

Comment: The seismic data does not appear to show much.

PI Response:

Reviewer 23427

Comment: Any specific project weaknesses were not evident from the material provided.

PI Response:

Reviewer 23627

Comment: The project is not addressing resistivity measurements which are usually one of the most diagnostic methods in geothermal exploration

PI Response:

IMPROVEMENTS

Reviewer 23537

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23485

Comment: The most important thing to be done is to communicate to others how the various approaches worked, so that they may benefit from the reduced drilling risks this project could produce.

PI Response:

Reviewer 23427

Comment: Is it possible to make estimate of the MWe potential of the Snake River area?

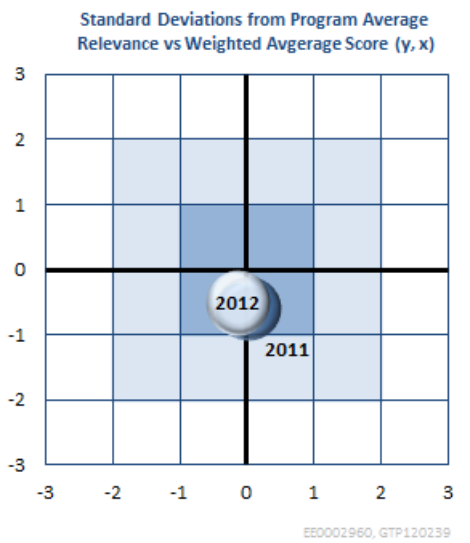
It is interesting to me that over almost a 40 year period (my involvement in geothermal) that the tools have gotten better, but the basic approach is still the same. Eventually you have to drill wells. In about 1976, Scott Keys of the USGS demonstrated a low temperature acoustic televiewer to us in Washington DC!

PI Response:

Reviewer 23627

Comment: The project should consider including the results of resistivity surveys.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002960
Project: Detachment Faulting and Geothermal Resources - An Innovative Integrated Geological and Geophysical Investigation in Fish Lake Valley, Nevada
Principal Investigator: Stockli, Daniel
Organization: University of Kansas
Panel: Exploration Validation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23401

Score: 3.0

Comment: This project has high potential which is reduced by management problems.

PI Response:

Reviewer 23404

Score: 2.0

Comment: The work presented represents a careful combination of seismic, thermochronometry, and shallow thermal gradient work. In addition, this university lead effort has managed to successfully engage students for educational purposes. The methods being evaluated are generally "low" in cost and it is fortunate that the methods applied show some continuity and correlatable results. There is nothing innovative about any of the methods utilized in this project.

PI Response:

Reviewer 23537

Score: 3.0

Comment: This project’s objectives substantially advance the Geothermal Technologies Office’s program mission and goals. As detailed mapping forms the basis for understanding how and where geothermal systems exist in the Basin and Range, this work establishes this foundation.

PI Response:

Reviewer 23485

Score: 3.0

Comment: The objective of this project is to perform a comprehensive integration of structural and thermal information to understand the spatial and temporal evolution of structure and temperature surrounding the Pearl Hot Spring geothermal play. This project can impact the Geothermal Technologies Office's objectives in two ways. First, it might lead to a geothermal development at this site, and second, the methods used here may be used at other similar locations to reduce risk. Of course, the impact will not be realized until the project is finished.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23401

Score: 4.0

Comment: The much-needed field validation is eagerly anticipated.

PI Response:

Reviewer 23404

Score: 3.0

Comment: The combination of methods applied in this project appeared to complement each other. Each of the methods is relatively simple and straightforward and this is a plus. (It is likely that the simple methods facilitated student participation.) The combination of methods has allowed for a geologic model to be developed that the researcher is able to corroborate. The seismic method was considered successful because of the inferred velocity contrast along the fault surface, and from that the conclusion that there exists fluid migration along the fault surface.

PI Response:

Reviewer 23537

Score: 4.0

Comment: The PI and his (remaining) team established a very technically sound and rational approach to understanding how and where geothermal systems occur in the Basin and Range. There is no substitute for mapping and understanding the structural setting first before endeavoring to spend large dollar amounts on any other aspects of an exploration

program. The integration of this fundamental work with geophysics, geochronology and thermochronology to date has been rigorous and appropriate.

PI Response:

Reviewer 23485

Score: 4.0

Comment: The scientific approach is very good. The technical approach is to do a detailed and comprehensive analysis of the structural information in the area, and incorporate this into a realistic geological/structural model that can be used to guide the interpretation of thermal data and to provide hypotheses to be tested with confirmation drilling. The approach is to use every type of information that is available to identify fracture systems that might be favorably oriented to the stress field and therefore permeable. The innovative work using thermochonography could have provided additional constraints, but turned out not to be useful because the mineralogy was not appropriate. The rationale for a drill site, intersecting the flow conduits that are slightly removed from the highest surface temperature gradient, seems to be good.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23401

Score: 2.0

Comment: Unfortunate university problems are holding up this project.

PI Response:

Reviewer 23404

Score: 2.0

Comment: The technical progress has been hampered, to an extent, due to funding limitations created by personnel movement. This is unfortunate and is somewhat detrimental to the success of the project. Nonetheless, the project has moved forward. Although it is unclear if the project has moved significantly past Phase I in its efforts.

PI Response:

Reviewer 23537

Score: 4.0

Comment: To date this work has blended structural and geological mapping and analysis, geophysics, geochronology and (the innovative) thermochronologic analyses into a 3-D model that drives ongoing exploration. This is a well-designed, cost-effective (to date) and sound approach toward achieving overall objectives.

PI Response:

Reviewer 23485

Score: 3.0

Comment: A lot of geophysical and geological data has been reviewed, collected and analyze, and a model has been developed to make a decision about a site to drill, and is leading this project towards its goal. A lot will be learned if the hole is drilled, and the broader benefits will be realized results of the hypothesis test are analyzed and published even if the geothermal well is not viable.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23401

Score: 2.0

Comment: Please see previous remarks.

PI Response:

Reviewer 23404

Score: 2.0

Comment: It appears that this work is is well organized and directed, but the hold pattern that it has been thrown into is unfortunate. This has delayed progress and perhaps reflects on the attention that should have been paid to management and coordination.

PI Response:

Reviewer 23537

Score: 3.0

Comment: Despite the fact that an initial principal in this work (Ram Power) no longer effectively exists and that the PI on this work transferred to another university and was left to complete work with no budget (not his fault but not Geothermal Technologies Office's fault either), he was able to accomplish work toward the overall projects and productively manage his time and (dwindling) resources to achieve tangible project outcomes. This shows tremendous initiative and skillful oversight.

PI Response:

Reviewer 23485

Score: 2.0

Comment: This project is being driven by an enthusiastic and effective PI who has a strong technical plan, and who continues to make progress despite delays due to changes in his University and changes in the industrial partner. One cannot tell from the material presented how much of the money has been spent or committed, or whether additional money will be released to allow the project to proceed to completion.

PI Response:

STRENGTHS

Reviewer 23401

Comment: Please see other remarks.

PI Response:

Reviewer 23404

Comment: There is a solid combination of well accepted methods applied to the development of the geologic model. It appears that credibility of the thermochronometric method in this location has been developed.

PI Response:

Reviewer 23537

Comment: The (effectively remaining) team, the approach and the value-added of applying this work in this portion of the Basin and Range..

PI Response:

Reviewer 23485

Comment: Strong geological model based on a lot of understanding of structure, stress, etc. broad range of information incorporated into a physically realistic 3-D model. Final site chosen based on a conceptual model of the flow field. PI is committed and energetic.

PI Response:

WEAKNESSES

Reviewer 23401

Comment: Please see other remarks.

PI Response:

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23537

Comment: Ram Power's role. Ram did not intentionally decide to implode but this fact should be acknowledged by the Geothermal Technologies Office and remaining funds should be apportioned to University of Texas to manage.

PI Response:

Reviewer 23485

Comment: Funding uncertainties must be really frustrating! Material could explain the technical status more succinctly.

PI Response:

IMPROVEMENTS

Reviewer 23401

Comment: Please see other remarks.

PI Response:

Reviewer 23404

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23537

Comment: Timing. Hopefully the University of Texas and University of Kansas will resolve their money issues and allow for Danni Stockli and his team access to funds so that they can reasonably pursue the remaining tasks with available funding.

PI Response:

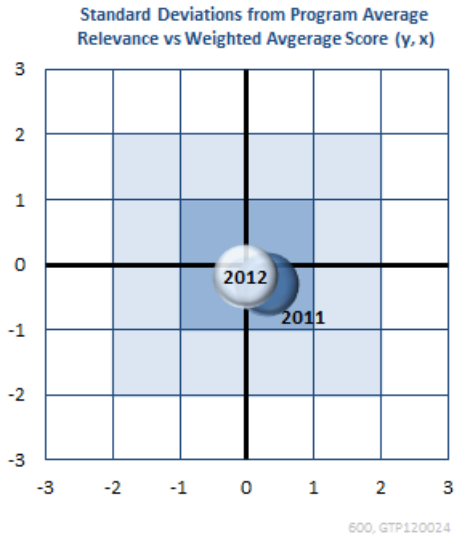
Reviewer 23485

Comment: Broader benefit to community will only occur if value of geophysics and other measurements are explicitly discussed in reports. The conclusions about high velocity (mineralized) and low velocity (permeable) faults will only be believed by others if they are carefully documented.

PI Response:

HIGH TEMPERATURE TOOLS, DRILLING SYSTEMS, AND ZONAL ISOLATION

Review: 2012 Geothermal Technologies Office Peer Review
ID: 600
Project: Geopolymer Sealing Materials
Principal Investigator: Sugama, Toshi
Organization: Brookhaven National Laboratory
Panel: High Temp Tools, Drilling Systems, Zonal Isolation



RELEVANCE/IMPACT OF RESEARCH

Reviewer 23433

Score: 3.0

Comment: This project aims to develop a cement product that can be used for the temporary sealing of cavities and fractures in a geothermal well. These would otherwise lead to problems during the drilling phase of the operation. Typical problems of lost circulation may require additional isolation liners, issues of dealing with lost circulation and often constraints on drilling activities resulting from limitations to the density of drilling mud that may be used. The cement must, however be capable of degradation at high temperature so that in the production phase of the well, the cement may be cleared and circulation (i.e. production of geothermal fluids) may be established. Being able to seal the borehole on a temporary basis is clearly of great importance, and equally, it is important to be able to reopen all possible flow paths into the well when it is desired to put the well into production. The idea of using a cement based on blast furnace slag (which is a cheap and environmentally attractive material) together with selected additional components to allow initial setting and future degradation of the cement is an excellent idea. The relatively low cost of the proposed cement(s) should allow for reduction in the cost of geothermal wells, particularly when it is estimated that it will be possible either or both to reduce the number of casing strings that must be run or to save time by not having to deal with problems of lost circulation. The investigators have proposed, and are well established in pursuing this objective, and have made useful progress so far.

PI Response:

I agree.

Reviewer 23412

Score: 3.0

Comment: This product would abate the damages caused by loss of circulation during drilling. The expansion during the curing process could also aid in reduction of skin effect on the natural fractures.

PI Response:

I agree.

Reviewer 23471

Score: 4.0

Comment: This project has very high applicability to the problem of zonal isolation in geothermal systems by developing chemical diverters to plug fractures that have been opened during EGS shear stimulations so that treatment fluids can target different depth intervals of an open hole. These chemical diverter systems have the advantage that they can be used in open-hole intervals of a well, thereby gaining access to a greater proportion of the natural fracture population than would be the case for traditional cement-and-perforate operations. The diverter agents being developed here are derived from industrial by products (blast furnace slag and Class C and F fly ashes, with appropriate catalyzing agents and other additives), and are designed to function as temporary fracture sealing agents that self-degrade in the presence of water. These agents would also have some utility in controlling lost circulation zones during drilling, although given their temporary nature their utility for this purpose would be limited to potentially productive portions of a geothermal reservoir, which are not well-suited to traditional (cement-based) sealing agents.

PI Response:

I agree.

Reviewer 23509

Score: 2.0

Comment: The PI poorly defined "success" in terms of the stated goal of achieving self-degradation in the sealing material. As best as this reviewer can tell from the presentation and project summary material (the Geothermal Resources Council (GRC) Transaction paper is not available for download on the GRC website), self-degradation was related to a qualitative visual observation of cracks induced in specimens after testing. No testing or analysis was presented that would indicate feasibility of physically removing the "degraded" cement sealer from fractures after emplacement. Indeed, tests conducted at higher pressure suggest less "degradation" based on the same qualitative visual evidence for fracturing. The PI also did not explain how the decomposition of the relatively small amount of CMC in the cement would enable removal of the majority of the insoluble and reactive cement components left behind. High pressure water injection would simply push these materials into the fracture and eventually permanently plug the formation.

PI Response:

The reviewer's concerns about the feasibility of physcically removing the degraded sealer and the low content CMC-containing sealer from fractures will be resolved from the results of our ongoing study using 6-in.-long API slot testing apparatus.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23433

Score: 3.0

Comment: The scientific and technical approach is sound and well thought out. Starting from cheap and readily-available raw materials (blast furnace slag and fly ashes) is an excellent idea. The experimental approach is straightforward, and is complemented by the use of sophisticated analytical techniques so that the investigators are able to determine the

processes of setting and subsequent degradation of the trial cements. In particular, the investigators have evaluated the influence of carboxy methyl cellulose on the setting and degradation of the cement, and the effects of making small additions of magnesium oxide. This latter material is effective in causing a slight expansion of the cement as it sets, thereby reducing the tendency to cracking and increasing the strength. The investigators have also taken pains to investigate the effects of high pressure (to 1000 psi) on the setting and degradation processes. This is important to do in view of the projected use of the cements in deep geothermal wells. Finally, the work has reached a point where the results can be transferred to a commercial operator (Halliburton) for their evaluation.

PI Response:

I agree.

Reviewer 23412

Score: 3.0

Comment: Technical approach is adequate.

PI Response:

Thank you.

Reviewer 23471

Score: 4.0

Comment: This project is scientifically strong and employs a broad suite of laboratory testing (under various pressure/temperature conditions) and analytical techniques (FT-IR, XRD, SEM) to characterize the reactions involved and optimize them for use under realistic geothermal conditions. I was impressed by the attention paid to the thermodynamics/kinetics of the reactions involved and the role of various additives (sodium silicate, MgO) both in promoting the self-degradation processes of the sealants and in rendering greater volumetric expansion upon setting to improve fracture-plugging performance. On a scientific basis, this was one of the strongest projects that I reviewed. However, since all the lab testing appears to have been performed on solid plug samples, I would also have liked to see flow-through experiments carried out on artificial fractures in EGS reservoir rocks (e.g., granites) to study sealant distribution within fractures and the temporal evolution of fracture permeability during sealant placement and subsequent degradation.

PI Response:

Using API slot testing apparatus, our ongoing work is foucused on evaluating the ability of temporary sealers to plug the 6-in.-long slots of different width spacing as well as to degrade in slots. This result will respond to all the reviewer’s comments.

Reviewer 23509

Score: 2.0

Comment: The technical approach on this project appeared to be flawed at the outset as no quantitative target metrics were presented to assess progress towards a self-degrading seal material. Many such metrics were possible including gas

or water permeability, bulk modulus, density, pore size distribution, and many others. The PI also did not explain the rationale for focusing on CMC or list other systems that were considered (if any) during the course of the project.

PI Response:

In response to reviewer's comments, we plan to determine water permiability and porosity of sealers. Unfortunately, I didn't explain in the preliminary work why CMC was selected. In our preliminary work, we evaluated several different celluloses as self-degradation promoters. As a result, CMC was selected based upon its ability to promote self-degradation and to retard setting of sealer at elevated temperatures.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23433

Score: 3.5

Comment: The project has made very good progress so far. Two formulations of cement have been developed having both the properties of sufficient initial strength and also an ability to be degraded and removed when required. The cements are based on blast-furnace slag, which is cheap and readily available, as well as apparently has no environmental disadvantages. The setting and degradation processes have been investigated by a range of experimental techniques, including scanning electron microscopy (plus energy-dispersive X-ray analysis), differential scanning calorimetry, thermogravimetric analysis and Fourier transform infrared spectroscopy. These techniques have led to the elucidation of the mechanisms involved in the setting and subsequent degradation of the cements, and in particular the contributions of carboxy methyl cellulose and magnesium oxide.

Progress has been sufficiently good that the cement formulations have been handed to a commercial company (Halliburton) for further evaluation.

PI Response:

Thank you.

Reviewer 23412

Score: 3.0

Comment: This product, if commercialized, will help mitigate the damages of loss circulation during drilling especially when drilling with gelled drilling fluids. I also thought the expansion during the curing process could increase natural fracture width.

PI Response:

I agree.

Reviewer 23471

Score: 4.0

Comment: This project has been highly productive in meeting its goals following closely on its intended “Tasks and Schedule” plan, and has completed the essential laboratory testing/characterization of various sealing materials and published a series of reports on the results of that testing. The two most effective formulations have now been transferred to their collaborators at Halliburton for independent evaluation and developing of field-deployable formulations and emplacement techniques. I was also pleased to see that Halliburton would be looking at the effect of high effective confining pressures (confining pressure – pore pressure) on CO2-release-driven fracturing that is needed for self-degradation to progress effectively; this is the one technical concern I have about this project when sealants are allowed to swell within the confines of initially permeable natural fractures under high effective normal stresses.

PI Response:

The reviewer's concern about self-degradation performance of expandable sealer under high effective pressures will be resolved from the results of our ongoing experimetnal work on evaluating the sealer's plugging and self-degradation performance in API lost circulation slot testing under appropriate pressure.

Reviewer 23509

Score: 1.0

Comment: Tangible output from this $872 K project is very low. No peer-reviewed papers in a quality scientific journal have been issued. Only two presentations appear to have been given and the GRC paper is not available on the GRC website. The number of cement formulations tested is very modest and as discussed previously, the lack of detailed characterization of "self-degradation" leaves open whether the core project goal was actually accomplished.

PI Response:

If reviewer provides us with more specific information on what kind of characterization must be known for defining self-degradation , I would like to try to obtain such information. Nevertheless, the outcome from our ongoing work on API slot testing should respond to some of the reviewer's concerns. We would be pleased to send copies of the GRC papers.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23433

Score: 3.5

Comment: The project management appears systematic and effective. There is a good balance between the experimental and analytic work, and a good appreciation of the importance of achieving a commercially valuable result. The work appears to be on track, and a favorable sign is that the selected cement compositions have been passed to Halliburton for evaluation.

PI Response:

Thanks.

Reviewer 23412

Score: 3.0

Comment: I liked the collaboration with industry especially Haliburton and others. The first deployment of the product would probably be by the service company as a pumping service, but it would also be unique if the product could be marketed as a product to be available for drilling rig personnel to mix on the rig.

PI Response:

I will reach out to the drill rig industry regarding the maketings of this technology. Thanks.

Reviewer 23471

Score: 3.0

Comment: This project utilizes a very effective multi-level collaboration between the Brookhaven National Lab team at the basic science level (with input from Dow Chemical Corp.) and Halliburton Energy Services at the applied/field level. The project has now been handed off to Halliburton for field readiness testing and formulation, which is the logical next step. Although listed among the collaborators and briefly mentioned in the presentation, it was not clear what the actual roles of Alta Rock and Sandia were in this project, and greater specificity on this issue – in particular regarding design and implementation of field prototype trials in fracture-dominated high-temperature wells -- would have been helpful.

PI Response:

Based upon many years of field experience, Alta Rock and SNL played an essential role in advising and suggesting to us the technical and economical feasibility of this new sealer in field prototype trials.

Reviewer 23509

Score: 2.0

Comment: PI has done a good job in engaging Halliburton and spending is on track. However, the lack of clear technical goals and limited tangible output from this project are the PM's responsibility to recognize and correct. With the project nearing completion, it is too late for course corrections.

PI Response:

Again, our ongoing experimental work is being focused on in-house scale-up demonstration using API slot testing apparatus. The outcome from this demonstration would provide clear technical goals and tangible output.

STRENGTHS

Reviewer 23433

Comment: The project addresses a known and specific requirement of the industry, namely the development of a solution to dealing with the common problem of lost circulation when drilling a geothermal well while at the same time allowing the subsequent opening of these flow paths when the well is put on production. Current solutions, for example, the placing of additional casing strings that must subsequently be removed or perforated are expensive and possibly unnecessary. The solution proposed, to place plugs made from a cement that can subsequently be degraded and flushed out of the well, is a very worthwhile approach. Further, the cements proposed are made from cheap and readily available materials. The investigators have adopted a combined experimental and analytical approach that has enabled them to

elucidate the mechanisms involved in the setting and degradation processes. A final strength is that the results obtained so far have enabled trial cement formulations to be passed to a commercial service company for evaluation.

PI Response:

I agree.

Reviewer 23412

Comment: The strengths of the project are the previous comments.

PI Response:

No comment.

Reviewer 23471

Comment: This is a scientifically strong and productive project showing significant promise for the development of temporary sealing agents for zonal isolation in EGS systems. Particularly notable were the attention paid to effects of specialized additives in promoting the self-degradation process and promoting optimal swelling/sealing properties in the presence of water at realistic in situ temperatures and pressures.

PI Response:

Thanks.

Reviewer 23509

Comment: Project attempted a clever idea to do the opposite of what most cement chemists strive to achieve in terms of cement durability. Use of cements would also speed industry adoption due to extensive experience with cements in well construction.

PI Response:

I agree.

WEAKNESSES

Reviewer 2343:

Comment: The reviewer has a definite concern relating to the degradation of the cements. Photos of degraded cement presented by the investigator appeared to show test samples that were cracked into a number of pieces, but it was not clear how strong the cracked pieces might be. If the degradation is limited to forming cracks in an otherwise solid material, the reviewer believes that such pieces would not be easily removed from, for example, narrow fractures around a borehole. If on the other hand, the cement breaks down into a fine or even powdery material there would be less of a problem. The investigator should carry out tests aimed at seeing how easily degraded cement may be flushed out of narrow cracks (with or without rough walls).

No mention was made in the investigators' summary of the possible adverse environmental impact of using the new cements. The reviewer notes that some sodium hydroxide is liberated during the cement degradation process which is probably of not much concern, but it is possible that undesirable species may leach out of the blast furnace slag or fly ash at some time. A few comments concerning these issues would be of interest. The reviewer does, however, note the claimed beneficial environmental effects of using the new cements stated on page one. The reduction in carbon dioxide emissions resulting from the non-use of regular Ordinary Portland Cement.

PI Response:

Current ongoing work was designed to respond to these questions; namely, API slot testing would provide us information on the magnitude of plugging and disintegration of sealers in slots with various different width spacing and pressures. If the ideal feature of a disintegrated sealer is a small particle, we plan to incorporate fine sand into sealers. In additon, we will conduct chemical analysis to identify any undesirable chemicals leached out from slag and fly ash to ensure that the used industrial by-products would be environmentally non-regulated materials.

Reviewer 23412

Comment: As with all collaboration and laboratory projects getting a product to commercialization is difficult. Intellectual property and the "not invented here" can be cumbersome.

PI Response:

This issue will be referred to BNL Technology Transfer Office.

Reviewer 23471

Comment: No major weaknesses noted.

PI Response:

Thanks.

Reviewer 23509

Comment: Key weakness on this project was lack of quantitative metrics and plan to test against those metrics for self-degradation. Also lacking was a plan to evaluate feasibility of removing "degraded" sealer from fractures. Hence, it is virtually impossible to assess whether the original project goals were met. The modest number of materials prepared, limited characterization, few publications and presentations suggests less than effective use of project funding.

PI Response:

Yes.

IMPROVEMENTS

Reviewer 2343;

Comment: The reviewer would welcome an analysis of the potential problems and solutions concerning environmental issues involved in the eventual use of the new cements.
An operational issue that might be worth examining is what happens to the degraded cement as it is flushed out of the borehole when or before the well is put into production. Does the cement degrade into small particles that are easily handled by the cuttings removal equipment or could it happen that large masses of cement might be released into the borehole, thereby jamming the drill stem? Further, does the degradation happen slowly over a long time, so that pieces of cement are still being released for some time after the well has been put into production?

PI Response:

As described previously, we will survey the enviromental issue of this new cement. The morphological feature of degraded cement and its flow or removal characters will be investigated under API slot testing.

Reviewer 23412

Comment: The project is nearing completion and it would be difficult to recommend any improvements.

PI Response:

Thanks.

Reviewer 23471

Comment: This technology has now been transferred to Halliburton for field formulation and implementation design. An essential next step will be testing and validation of these sealing agents under real-world conditions in fracture-dominated geothermal test wells.

PI Response:

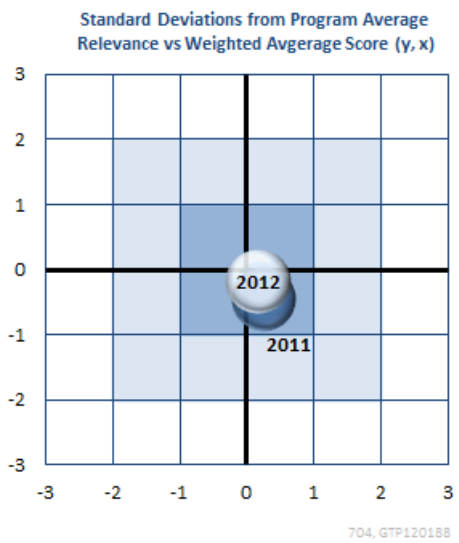
I agree.

Reviewer 23509

Comment: With the project at likely over 85% spent at this time, it is too late for major course corrections. The PI should attempt to quantify the self-degradation properties he is claiming as much as possible with the remaining funds and hopefully get at least one peer reviewed journal paper out before the project closes.

PI Response:

In an attempt to quatify the self-degradation properties, the in-house scale-up API slot test is currently being undertaken. This test result will provide some answers to the reviewer's comments. I will try to prepare a peer reviewed journal article.



Review: 2012 Geothermal Technologies Office Peer Review
ID: 704
Project: Technology Development and Field Trials of EGS Drilling Systems
Principal Investigator: Raymond, David
Organization: Sandia National Laboratories
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23433

Score: 3.5

Comment: A perennial problem in the development of new technologies lies in bridging the gap between early demonstration and widespread adoption. The problem is particularly acute in industries where high levels of investment per project are required, since the consequences of failure are more costly and more visible. Further, if the project carries significant safety or environmental risks, the consequences of failure are even more important. The geothermal industry scores very highly in all the above categories, so it is not surprising that it is reluctant to experiment with new technologies, particularly at large scale. It is the object of the present project to bridge this gap, by assisting and, in effect, subsidizing, a user of the new technology to demonstrate that the technology is, in fact, more efficient than current practice. This is thus a very useful, even required, activity in the present economic and cultural environment.

PI Response:

PI concurs that with the lack of geothermal wells being drilled it is imperative to demonstrate these new technologies to invigorate economic growth within the geothermal industry.

Reviewer 23412

Score: 3.0

Comment: The impact of this research is basically a field trial of PDC bits that the vendor selected to drill granitic rock. The impact is the increased penetration and the bit life is better.

PI Response:

The impact of this research is pathways to reduced geothermal well construction costs to spawn increased geothermal development. Increased penetration rates and improved bit life are means to realizing this.

Reviewer 23480

Score: 2.0

Comment: The project's objective is to come up with technology solutions to drilling problems. This is a very ambitious undertaking since drilling problems cover a wide gamut of hardware, process, and material issues. However, the project seems to focus solely on PDC bit development, with some reference to percussive drilling. Even if successful, percussive drilling may not have lasting impact on geothermal drilling unless the technology can be proven cost effective. Wisely,

the percussive drilling portion of the project has been tabled. Though the project is ostensibly directed toward EGS drilling systems, there is no discussion of unique requirements of EGS drilling systems, such as highly deviated wells, and how the project will address them. ROP is not the sole measure of drilling cost/effectiveness, and the PI should demonstrate the impact in a quantitative sense. Just what are the cost factors affecting EGS drilling, and how do they vary from hydrothermal drilling? If PDC bits can function effectively in hard rock geothermal environments, there will be a positive impact on geothermal drilling. Over the years, efforts to improve the functionality of PDC bits for this purpose have been unsuccessful.

PI Response:

PI concurs that prior efforts to demonstrate the benefit of PDC bits in geothermal have been unsuccessful but this demonstration has proven that efforts to improve the functionality of PDC bits over the years have been successful otherwise this demonstration would have failed as well. The PDC bits used in this demonstration drilled hundreds of feet of granitic rock that just a decade ago was inconceivable. The abrasion resistance of PDC cutters has made this bit technology economically viable for geothermal drilling. Further, additional cutting structure features have been introduced (e.g., depth control components) that allow advanced drag bits to survive the rigors of hard rock drilling. The actual field drilling performance data presented on this project invalidates the negative comments presented by this reviewer. While not presented in the peer review presentation materials, the economic benefit of these performance improvements have since been addressed providing additional defense to the technology and the exceptional performance that has been demonstrated.

Percussive drilling in oil and gas/mining applications is likewise mature. Field trials of percussive hammers in geothermal will likewise establish the suitability of this technology.

Reviewer 23519

Score: 3.0

Comment: The geothermal industry drills only a few wells among several drilling companies. Obviously, the oil industry and the mining industry drill 1000 times more wells than the geothermal industry. The primary objective of this project is to develop and demonstrate EGS drilling solutions based on ‘mature and proven’ rock penetration systems.

As such, working with the Navy GPO on a drilling project in hard rock using oil industry PDC bits has shown (in this case) that PDC bits can achieve a higher ROP than standard roller cone bits. Working with the Navy provides freedom in publishing which is highly valued. However, a policy to identify potential technologies should look for any opportunity even in drilling and stimulation projects conducted by the oil industry. Here the actual well data may not be released but results on improved drilling could be reported as seen by Sandia researchers.

Efforts to demonstrate a pneumatic down hole hammer was tabled in the drilling opportunity with the Navy.
No other, technologies from the oil industry or mining industry are being considered at this time.

As fracturing natural gas wells is at an all-time high for natural gas wells, well stimulation methods for gas may offer significant improvements to the future of geothermal EGS.

Also, the term ‘mature and proven’ implies relativity low cost. Some evaluation of technologies being considered for examination under this project should consider, the cost-benefit for future EGS drilling.

PI Response:

PI concurs that a broad view of improved technologies would be of interest yet this project was proposed to focus on improved rock reduction technologies with PDC bits and pneumatic hammers being the primary technology focus areas. The cost-benefit analyses of these technologies are presently underway.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23433

Score: 3.5

Comment: From the purely scientific point of view, it is to be regretted that the program being carried out is consciously avoiding the trial or use of advanced new technology. The stated object of the project is, however, to convince potential drillers of geothermal wells that the risks in using some ready but not yet widely used "mature" technologies are minimal and that good results are almost guaranteed. For this reason it is understandable that the investigators have taken a conservative approach to the selection of the technology that will be used. The main thrusts of the project are to demonstrate that the use of PDC drag bits is economic in geothermal wells, and that down-the-hole hammers are an effective means for driving the drill bit. In summary, the objectives are: 1) to achieve risk reduction by carefully applying known technologies; 2) To show that laboratory results can indeed be duplicated in the field; 3) To engage Service Companies to provide equipment and services to the Geothermal Industry; and 4) to gain acceptance of the new techniques by the Drilling Industry.

PI Response:

It is generally agreed that the project approach taken is conservative in that technology chosen for demonstration is judiciously selected, yet the first objective, as stated in review materials, is to reduce the risk of the technology application by bearing that risk within the project framework as industry will not bear that risk themselves. The difference is that technology demonstrated within this project is not immune to failure as its first use in the geothermal industry is potentially within this project. The second stated objective is not to show that laboratory results can be duplicated in the field but rather that field testing is necessary to address the inclusion of phenomena that may not exist in laboratory testing.

Reviewer 23412

Score: 4.0

Comment: Field experiments are difficult to coordinate. Comparing bit A and bit B will not be apples and apples but the experiment tried and obtained very good results.

PI Response:

The project was not executed as a field experiment but rather as introduction of a PDC bit in a production drilling environment. The performance obtained via this technical approach is evidence of the maturity of this technology.

Reviewer 23480

Score: 2.0

Comment: The approach uses field testing with stakeholders, an important factor for industry acceptance. Direct involvement of drillers and service companies is essential for success, and the PI's efforts are notable here. The overall, 3-phase approach is logical and straightforward. A representative field test site is important. However, the PI does not present evidence that the wells in the Chocolate Mts are representative of geothermal conditions likely to be encountered elsewhere. An explanation for the abrupt shift from generic technology development and testing to PDC bits is not given. Are PDC bits likely to provide the greatest cost savings of available technology options? This point needs clarification. How does the project build upon the history of disappointing performance of PDC bits in geothermal wells? Presumably, new bit designs by service companies will lead to better ROP/lifetime, but those designs are predicated on expected performance in hydrocarbon wells. Perhaps the application of "fit-for-purpose" approach will lead to PDC bits developed expressly for geothermal wells. The apparent commitment of suppliers/manufacturers is encouraging. EGS drilling systems will likely have to make highly deviated, even horizontal, wells with precisely steered, multiple legs and unconventional completions. These characteristics of EGS wells are not addressed by the project, which seems more concerned with ROP rather than overall cost performance.

PI Response:

While the well constructed in the Chocolate Mountains may not be representative of geothermal conditions elsewhere it itself was constructed for geothermal exploration and accordingly serves as a representative example of conditions that may be encountered. The project builds upon the performance of bit testing in new wells by employing the latest thermo-stable cutter technology available to the industry. It is true that these designs are predicated on hydrocarbon wells; but these designs provide a baseline for improvements that can be developed specific to geothermal well construction requirements. PI acknowledges that advanced performance will be needed to construct the complex well geometries demanded by EGS conditions yet basic rock reduction capabilities must first be demonstrated in conventional geothermal completions used today. Once proven in this configuration, this technology can potentially be adapted to the more stringent requirements of EGS drilling conditions. This has proven to be the case with multi-lateral completions using Rotary Steerable Subs in the hydrocarbon drilling industry; geothermal well construction may follow a similar evolution with the introduction of the appropriate baseline technology to the industry.

Reviewer 23519

Score: 2.0

Comment: The scientific approach is weak because the goals are so open ended. This project is evaluating mature and proven rock penetration systems of which a large number of technologies from differing BHA configurations - bit types - hammer drilling and other technologies occupy this space.

To improve the level of scientific approach, I suggest, creating an industry steering group to perform prescreening of potential hard rock drilling technologies. This would aid in the justification of suggested phase II work and help in identifying new testing opportunities within a community of EGS researchers.

PI Response:

The reviewer suggests an interesting approach with an industry steering group. However, this was essentially realized in the overall project plan as deployed. This steering group consisted of Sandia, the developer (USN GPO), drilling contractor (Barbour Well), and service company (NOV Downhole). While it would be interesting to evaluate different technologies in controlled drilling field trials, the objective on this project was to partner with production drilling opportunities to demonstrate mature technologies that are ready for near-term commercialization. Since the partners have a vested-financial interest in the well construction, the overall approach used works well with this paradigm. To use an

independent steering group as proposed would require a test budget to support the field drilling research and not reliance upon industry for this component of the project.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23433

Score: 3.5

Comment: The project is built around the drilling of an exploration well in the Chocolate Mountains. Although the original intention had been to demonstrate the use of both PDC bits and down-hole hammers, only the former was done (because of caution expressed by the drilling contractor.) Two PDC bits were run. Both gave good results, and, equally importantly, clear indications as to how further improvements can be made. In terms of actual results, the bits achieved a 2.5 times improvement in rate of penetration. Since these results were achieved in a real well, they may be considered very convincing and an excellent outcome.

PI Response:

The PI concurs that project results are convincing and an excellent outcome. Because the geothermal drilling industry is risk-adverse, industry has not realized the benefit of advanced technology. The project outcome has demonstrated that alternative technologies can be used to improve geothermal drilling.

Reviewer 23412

Score: 3.0

Comment: The project has results and accomplishments and should be considered complete or almost complete. Further progress should be the dissemination of results.

PI Response:

PI concurs that results and accomplishments standalone and complete. Dissemination of results is occurring through submission of results to conferences.

Reviewer 23480

Score: 3.0

Comment: The field test plan was well formulated and executed. Data from actual drilling experience at a site in the Chocolate Mts using two different PDC bit designs are presented. These are notable, and one bit performed well as measured by ROP. As commented on elsewhere, improved ROP may not be the most desirable objective for geothermal drilling. Some analyses point to improved/fewer materials, reduced footprint, efficient practices as having greater impact on cost. Where is cost breakdown pie chart? Has that changed over time? The geophysical test well used for the PDC bit test may not be indicative of future EGS drilling; temperature at depth was low.

PI Response:

PI acknowledges that the temperature at depth was low but it was expected to be higher motivating the US Navy to consider this site within the Chocolate Mountains. PI concurs that ROP is not the most desirable objective yet improved ROP is one potential pathway to reduced drilling costs given the current poor ROP/life performance of baseline technology used for geothermal well construction.

Reviewer 23519

Score: 3.0

Comment: The drilling of the Navy well as a means to gain insight on new technology is highly valued by this reviewer. The documentation of bit performance (ROP – Torque) is helpful in identifying the potential use of PDCs in hard rock geothermal drilling. A more detailed report is expected from Sandia on this work. I suggest that the report also cover the granite in more detail as to quartz size to go with the bit post-mortem documentation. My understanding is that, PDC cutters can break when hitting large quartz in the granite.

It is unfortunate that only oil industry PDC bits were tested. PDC bits have been around for over 25 years. Not much is unknown about them.

PI Response:

Additional project documentation from the field testing is forthcoming.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23433

Score: 3.5

Comment: The management approach, to engage a number of stakeholders with different interests, is demanding but has been carried out well. It is also efficient to the extent that the investigators have been able to make use of activities (e.g. the drilling of the trial well in the Chocolate Mountains) that would have been done in any case. The reviewer considers that the investigators have done an excellent job in view of the difficulties inherent in organizing the several different parties involved.

PI Response:

Significant project resources have been expended to integrate the multi-organizational team to achieve project success. The praise of the reviewer in achieving this is gratefully acknowledged.

Reviewer 23412

Score: 4.0

Comment: Coordination of the field trial with drilling contractor, bit vendor and the data collection was an effort that was very well executed.

PI Response:

Close coordination of the field trial with various participants was necessary to ensure success and highlights diligence necessary to introduce advanced technology to the drilling industry.

Reviewer 23480

Score: 3.0

Comment: The project's collaborative activities have brought together an exceptional array of industry stakeholders: developer; service companies; drilling company. Field tests were well planned and executed, and data collected from those tests will be properly processed and stored. Design improvements to bits are planned, based on results of field tests, but the future testing, modification, and commercialization of those designs is not obvious. Future emphasis placed on percussive drilling may detract from the project's objectives vis a vis PDC bits.

PI Response:

Future testing and commercialization of improved bit technologies for geothermal drilling will occur beyond the original scope of this two year ARRA-funded project with on-going field collaborations with industry in year three with direct sponsorship from the DOE GTO. The commercialization of this technology will occur seamlessly as the PDC bit service company is directly involved in development of new product line that can be offered to the geothermal drilling industry. While percussive drilling may be addressed on this project as well, the primary emphasis on PDC bits to date will be carried to completion within the context of this project's objectives.

Reviewer 23519

Score: 2.0

Comment: Sandia's work is managed by the Geothermal Technologies Office so this section should be directed to technical management of the project.

There needs to be greater input from industry to better identify potential technologies and as to which technologies should be evaluated. I'm concerned, this program could become a PDC bit development program.

PI Response:

The Peer Review process used by the DOE Geothermal Technologies Office exists for the purpose suggested by the reviewer - to provide verification and potential of the technologies being pursued by the geothermal program.

STRENGTHS

Reviewer 23433

Comment: The major strength of this project is that it is executing a realistic program for the drilling of a geothermal well using proven but still advanced technologies. It has so far succeeded in its main objective of convincing field operators and service companies that the new technology (namely the uses of PDC bits to drill in the hard formations characteristic of geothermal reservoirs) is in fact viable and that real cost savings are possible.

PI Response:

The PI concurs that the project has succeeded in this regard. Notably the drilling contractor has expressed interest in continued use of this technology on future drilling projects.

Reviewer 23412

Comment: Collaboration with bit vendors with proprietary designs and demonstrating the bits ability to penetrate hard abrasive rock are the strengths of this project.

PI Response:

PI concurs - close coordination with the bit service company is vital to introduce advanced technology to this industry.

Reviewer 23480

Comment: The project team, consisting of stakeholders from industry, notably a developer, drilling company, and several service companies, is a positive indicator for a successful project. The project includes tests under actual drilling conditions in the field as opposed to laboratory-based tests.

PI Response:

The importance of field trials in proving-out drilling technologies is vital; laboratory testing is important for technology development under controlled conditions but field testing is the final proving ground.

Reviewer 23519

Comment: Working with the Navy GPO on a real geothermal drilling project. Instrumenting the drilling rig to better evaluate new drilling technology.

PI Response:

PI concurs - the strength of this project is use of in situ drilling conditions for technology verification.

WEAKNESSES

Reviewer 23433

Comment: It is unfortunate that the investigators were not able to convince the drilling contractor to try out a downhole hammer, as this would have added a second positive demonstration of a new technology. However, this is not the fault of the investigators, unless it be suggested that they be sent to charm school to become more convincing proponents of the new technology. Difficulties in running the selected drill bits (because of inadequate torque capability on the drilling rig) is not considered a significant problem but indicates that in future work, care must be taken to assemble a stable of equipment that will be adequate for the job in hand.

PI Response:

The drilling project that is the focus of this work was undertaken without specific knowledge of the rock formations to be encountered since the area had never been previously drilled to this depth. Accordingly, it was not possible to know what

all the requirements were in advance. Nevertheless, the problem with inadequate rig torque is representative of problems that may be encountered during introduction of new technology in that the infrastructure can be inadequate to support deployment of the advanced technology. This is not necessarily a weakness of project execution but rather a by-product of progress.

Reviewer 23412

Comment: The project has a simple conclusion with a demonstration that could appear to be a weakness. It was a success so the project has no weaknesses.

PI Response:

The demonstration achieved in this project is not a weakness. Prior attempts to introduce PDC bits to production drilling of geothermal wells have been failures. The technology has matured to viability and this project has clearly demonstrated that.

Reviewer 23480

Comment: Evidence that improved PDC bit designs are key to future EGS drilling is lacking.

PI Response:

The advent of rotary steerable subs over the last decade has resulted in increased use of PDC bits worldwide resulting in them now drilling 2/3 of all footage. Development of robust PDC bit designs for geothermal could have a similar impact on EGS drilling. As stated, these improved designs must first be demonstrated in true vertical conditions to establish their viability for continued use.

Reviewer 23519

Comment: Narrow focus on PDC bits may lead to missing other technologies for drilling in hard rock formations. No effort to look at other topics as hydrofracturing natural gas wells.

PI Response:

As stated earlier, this project was originally proposed to address specific rock reduction technologies.

IMPROVEMENTS

Reviewer 23433

Comment: It might be worthwhile looking for a site for a follow-on demonstration that involves the deepening or sidetracking of an existing well. Drilling would likely be occurring under deep and hot conditions, providing a good test environment for the new technology. However, the consequences of failure to perform might not be so damaging, since the total distance to be drilled would be less, with corresponding reduction in project cost "at risk". Losing or having an uneconomic outcome in the sidetrack or for drilling the extra depth would not be as expensive as the extra cost of drilling an entire well under uneconomic conditions. Drilling at greater depths might also entail using a bit of smaller diameter, again with less initial cost. These factors might tip the balance in convincing an operator to go ahead.

PI Response:

The original project intent was to demonstrate project improvements in an offset well; however, this is not an option as the US Navy will not be developing a secondary well in the Chocolate Mountains. Nevertheless, plans are underway in subsequent phases of the project to conduct follow-on testing with bits, with improved features, at other field sites. Although a direct side-by-side comparison will not be available, this subsequent field testing will likewise improve migration of advanced technology into the geothermal industry.

Reviewer 23412

Comment: I cannot recommend any improvements.

PI Response:

No comment.

Reviewer 23480

Comment: Do not move on to study of percussive systems until improvements in PDC bit designs have been documented and commercialized by a bit manufacturer.

PI Response:

Commitment of project resources is presently in agreement with this recommendation.

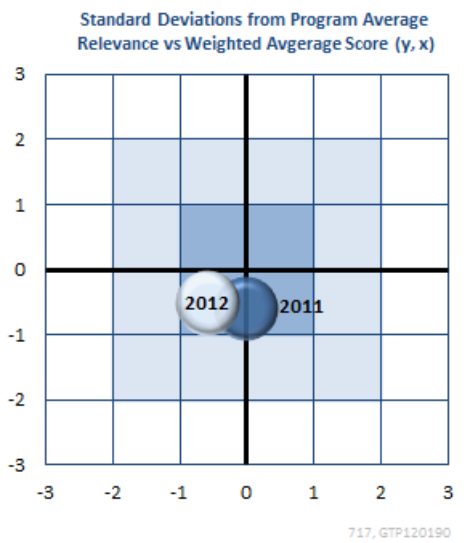
Reviewer 23519

Comment: To improve the level of scientific approach, I suggest, creating an industry steering group to perform prescreening of potential hard rock drilling technologies. This would aid in the justification of suggested phase II work and help in identifying new testing opportunities within a community of EGS/hydrothermal researchers.

It might be interesting to have Sandia and its instrumentation trailer show up to test a roller cone bit just like the PDC bits tested in under this program. Under the watchful eye, would the drilling crew improve ROP? I would NOT expect the increase reported by Sandia but I would expect an increase of 25 to 35%.

PI Response:

PI concurs that the creation of an industry steering group to identify technology development requirements would be of great benefit to the geothermal industry. As noted, to use an independent steering group as proposed would require a test budget to support the field drilling research or a consortium of operators/drillers willing to bear the cost of demonstrating these technologies on actual drilling projects. This project was structured to identify the wells of opportunity as part of the project work flow. The approach suggested could potentially work if the industry partners are onboard at the beginning of the project.



Review: 2012 Geothermal Technologies Office Peer Review
ID: 717
Project: Base Technologies and Tools for Supercritical Reservoirs
Principal Investigator: Lindblom, Scott
Organization: Sandia National Laboratories
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23521

Score: 3.0

Comment: The idea of building MultiChip Modules (MCM) with specific functionality that can withstand adverse conditions of pressure and temperature characteristic to EGS is excellent and the geothermal community can greatly benefit from electronics like these. Additionally, the team is investigating test tools for pressure, temperature collar locator based on MCM. However, because no data/results are presented, it is difficult to make an educated estimation of the impact of research.

PI Response:

The MCM technology is widely known. We are collaborating with Auburn University on a MCM reliability study to identify materials and bonding techniques that will potentially raise the operating temperature of these devices. At the time of the review, Auburn was executing a test matrix with the most viable combinations of materials being tested. It is too early in the testing to report results of this testing. We did not have our MCM so we could not test and provide data/results. We could have presented results of the PTC sensing based on board level design, but this is also well know and would have provided little value to the reviewers.

Reviewer 23401

Score: 3.0

Comment: see other remarks

PI Response:

N/A

Reviewer 23568

Score: 3.0

Comment: The general issue of material survivability at high temperature is important.

PI Response:

Agreed.

Reviewer 23548

Score: 2.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23521

Score: 2.0

Comment: The team seems to be on top of things, with several efforts performed in parallel. Not too much information related to the scientific/technical approach was provided in the presented slides. More can be learned from the Summary, which has more information, especially identifying the major limitations of current high temperature devices. Not many details are presented in terms of how the work will be performed, but the team is investigating a large number of components used in the geothermal industry for sensing, e.g. seals, advanced materials shielding, cooling, wireline cables, cableheads, high temperature batteries, etc.
They focus more on 'what' will be done, not 'how'.

PI Response:

With so many pieces being developed in parallel it was difficult to go into detail, the 'how' in the time allotted. Perhaps I could have conveyed this better. At a high level, several of the components are being performed by external collaborators (wireline cables, HT batteries, MCM reliability, etc.). We are performing dewar testing, MCM design, and system integration. The details of each test would take more time.

Reviewer 23401

Score: 3.0

Comment: see other remarks

PI Response:

N/A

Reviewer 23568

Score: 2.0

Comment: The project was unfocused. It seems to be a mish mash without comparing technologies in concrete ways to achieve the same goal. For example, what is more important -- Dewar reliability or high temperature (HT) cable or

rechargeable batteries? There is a lack of synergy in the project. This is reflected in the statement from either the summary or presentation: "The technical approach is comprised of several tasks working in parallel to one another."

PI Response:

The goal of developing a tool for a supercritical well demanded that each piece of the system be tested and evaluated. The system as a whole must be evaluated, if any of the pieces fail the whole system will fail. Prioritizing one component's importance over another could create an inherent weakness in the overall system where the less important components become the failure point. In order to perform evaluations of all of these components, it was necessary for the testing to be done in parallel due to the time each component takes to test. The testing was compressed further as the project was scaled back from a 3 year project to a 2 year project due to funding. For example, when considering how to power this tool it was initially unclear whether HT cable or rechargeable batteries would be more suitable. This coupled with the long lead times of a HT cable drove the decision at the beginning of this project to consider both options and downselect the best option in order to acquire the cable (which ultimately was selected) within the project's timeline.

Reviewer 23548

Score: 3.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23521

Score: 3.0

Comment: This section is just an iteration of what was accomplished, without any results to support what was presented. Even if most of the devices developed are IP protected, some results can be shown, without jeopardizing the intellectual property.

PI Response:

This is a difficult area for us to approach. We erred on the side of caution as several of the manufacturers were very restrictive in what we could reveal from testing.

Reviewer 23401

Score: 3.0

Comment: Seems slow progress, but relative to the funds expended a good deal was accomplished.

PI Response:

Some of the test sequences did take longer than expected due to unanticipated delays. Parts availability and test equipment repairs (for dewar testing at 450C) were the biggest delay items.

Reviewer 23568

Score: 3.0

Comment: It is hard to evaluate the significance of the accomplishments but it seems as if a wide range of testing was done.

PI Response:

Agreed. We ran into the difficulty of presenting several of the accomplishments due to the 3rd party IP issues.

Reviewer 23548

Score: 2.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

PROJECT MANAGEMENT/COORDINATION

Reviewer 23521

Score: 3.0

Comment: Project management and coordination seems to be on track, and involves several external collaborations.

PI Response:

Agreed.

Reviewer 23401

Score: 2.0

Comment: This project seems unlikely to meet spend and technical targets in remaining time.

PI Response:

This project will be tight but should be able to meet it's targets. It has been difficult to scale back the effort due to the reduction of funding from 3 years to 2 years. Many of the activities needed to be condensed and this has proven to be a challenge.

Reviewer 23568

Score: 2.0

Comment: There were many unlinked partnerships. The scattered nature of the project meant that there was no overview of the project. Risk is inherent in research, but this was a development project that could have used a chessboard strategy, not just moving pawns forward one square at a time.

PI Response:

This project does have several operations running simultaneously. There perhaps could be improvements made in the future.

Reviewer 23548

Score: 2.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

STRENGTHS

Reviewer 23521

Comment: Ambitious project. Looks like they did not left anything out of their investigation, from electronics to seals, cables, dewars and high temperature (HT) batteries.

PI Response:

The scope of this project is very wide and attempts to ensure the survivability of each component was reviewed.

Reviewer 23401

Comment: Potentially very useful project, even at sub-critical temperatures, if costs can be brought down.

PI Response:

For a production tool price would need to be considered. If this proof of concept tool succeeds, reducing cost would be a logical next step.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

WEAKNESSES

Reviewer 23521

Comment: Presenting some data to support the progress is always a good idea.

PI Response:

We were very conservative in displaying data due to restrictions from manufacturers.

Reviewer 23401

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

IMPROVEMENTS

Reviewer 23521

Comment: Including a picture/graph/data to support the work performed adds a lot of value to a report.

PI Response:

Fair point. I will try to incorporate something in further work.

Reviewer 23401

Comment: Anything that gets tools out in the field for real-world problems to be observed will improve the project.

PI Response:

Agreed.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

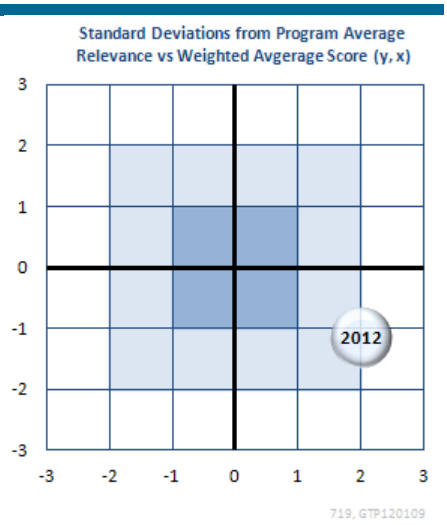
N/A

Reviewer 23548

Comment: With respect to the dewared tools it may be advisable to test the current state of affairs in the market (e.g. Calidus Engineering).

PI Response:

Noted. The original intent of this project (as a 3 year project) was to produce a 450C fluid sampler but was scaled back to a PTC tool when funding was restricted to 2 years. To date, we have not seen a fluid sampler capable of operation at this temperature.



Review: 2012 Geothermal Technologies Office Peer Review
ID: 719
Project: Multipurpose Acoustic Sensor for Downhole Fluid Monitoring
Principal Investigator: Pantea, Cristian
Organization: Los Alamos National Laboratory
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23527

Score: 1.0

Comment: It is not clear how this project will produce either technology or meaningful understanding that will advance geothermal programmatic goals. A cursory web search shows that the basic technique and component technologies associated with this class of sensor system have been investigated for at least ten years in other fluid transport applications yet the current work does little to demonstrate feasibility in the complex fluid environment of geothermal applications. The focus on the development of high temperature components appears to be putting the cart before the horse in that the basic ability of this type of sensor to perform meaningful characterization of fluid properties and measurements in field-like applications is highly questionable. In other words, why bother producing high-temperature components when it has yet to be demonstrated that this technology will produce valid measurements in representative environments with widely disparate fluid states that may include multiphase flow, diverse fluid compositions and relatively high particulate compositions? Proof of principle tests using water are largely meaningless. Principle challenges typically associated with acoustic measurement techniques are not adequately addressed.

PI Response:

The 'Relevance/Impact of Research' for this project was clearly stated on slide 5 of the presentation. Additionally, slide 15 shows a comparison of our technology with some important aspects of EGS reservoir characterization. It can be clearly seen that in terms of high temperature Well Logging Tools we are way ahead of the proposed milestones.
We clearly mentioned this before: we neither re-invented the wheel, nor we ever claimed we did. We are using existent acoustic technologies, packaged in a sensor suite that can perform measurements of different parameters at high temperatures in a very corrosive media (as the ones found in EGS systems).
Regarding 'putting the cart before the horse' remark: we performed several measurements in highly attenuating fluids, including heavy oil-based muds used in drilling by the oil industry. Additionally, we perform routine tests in the field (California and New Mexico) on systems that consists of multiphase liquids, gas and particulate matter using the acoustic based system. Based on our experience, the 'complex fluid environment of geothermal applications' is not a show-stopper, as we worked on similar systems. The main problem is related to the combination of high temperature and the very corrosive medium characteristic to EGS systems.

Reviewer 23474

Score: 3.0

Comment: The sensor package being developed by Los Alamos National Laboratory (LANL) addresses a need for advanced well characterization methods. The approach uses a single acoustic sensor to measure well parameters such as

temperature, pressure, fluid flow, and fluid properties. This information is needed to characterize potential geothermal resources and could be used throughout the life of the well to monitor the conditions there.

The project does not have any collaborators or sub-awards, so the team should consider mechanisms for commercializing the technology. Similar applications exist in the oil and gas industry, so there may be opportunities to apply this technology shortly after the technology is developed. A proactive approach to commercialization is encouraged.

PI Response:

The project is focused in developing a sensor suite for different properties determination in EGS systems. We are currently exploring commercialization with one major oil producer although this was beyond the scope of the project.

Reviewer 23548

Score: 3.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23639

Score: 2.0

Comment: This research is looking at a different approach in making fluid measurements the the downhole environment. It is early in the sensor phase development and the work is looking at a novel method, Swept Frequency Acoustic Interferometry (SFAI) to make the measurements as opposed to the typical Doppler method to characterize fluid flow along with temperature and pressure. There will be additional work required to package this sensor for downhole use, in its current configuration it is hard to understand how this would be packaged in a downhole tool. The use of a 5 MHz transducer could be problematic with fluid attenuation. There also the use of a very small sensor to characterize the entire fluid flow across the full cross section of the borehole will be problematic in areas of turbulence requiring an array of sensors to do it properly.

One of the stated objectives is the use of one sensor to make a multitude of measurements:(temperature, pressure, fluid flow and fluid properties). In trying to do this from one sensor certain properties will dominate the sensor response leading to an underdetermined solution which is why the logging industry typically uses multiple different sensors to solve for all the unknowns.

PI Response:

We agree that there is additional work needed to package the sensor for downhole use. However, this was not part of the scope of the proposed project. Because of the complexity of the sensor and the harsh working conditions, we focused only on the development of the sensor. This was clearly explained in the proposal and the presentation.
A 5 MHz transducer can be problematic. However, we are using a broad-band transducer, that has very good response to frequencies ranging from approximately 100 kHz to 10 MHz. Where attenuation is a problem, the lower frequency range can be used successfully. We do have a lot of experience with acoustic measuremetns in very attenuative liquids and do know exactly how to solve these minor issues.

As mentioned during the presentation, there are several active parts in the sensor developed by us, each of them focused on the measurement of certain parameter of interest.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23527

Score: 1.0

Comment: The critical challenges associated with this technology were not addressed in the technical approach. The idealized conditions investigated in the experimental portion of the project do not address any key barriers associated with evaluating the viability of this type of acoustic sensor and do little to advance the state of the art for this technology. A more valuable approach would seek to characterize measurement capabilities of the technology in field-like fluid conditions. If the technology cannot provide reliable measurement of multiphase flows and characteristic geothermal fluid compositions what is the point of developing high temperature components?

PI Response:

As mentioned above, the critical challenges are related to high temperature in very corrosive media and these were addressed from the beginning of the project. Field-like fluid were investigated successfully by us in the past and these were straight-forward measurements. See above for more details on multi-phase flow, highly attenuating liquids, gas and particulates.

Reviewer 23474

Score: 3.0

Comment: The general approach to the work appears to be logical, and the facilities available to support the work appear to be sufficient. The measurements are based on Swept Frequency Acoustic Interferometry and resonance tracking, and these are generally considered to be reliable methods for downhole sensing. The work to date has already met many of the Geothermal Technologies Progam's goals for high temperature operation. To date the team has validated performance up to 290C, whereas DOE's goal is to reach 300C by 2020. In addition, temperature measurements have been shown to exhibit no hysteresis. Verifying that the technology will work at higher pressures would be valuable information to have.

Future work will evaluate fluid properties and flow regimes. Part of this work should also address the ability to assess geothermal fluid homogeniety (such as particulate matter) to ensure the measurement tool can resolve differences that may occur.

PI Response:

No response entered.

Reviewer 23548

Score: 3.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23639

Score: 3.0

Comment: The technical approach has been reasonable evaluating the various aspects of the transducer response at temperature and pressure. The lab work appears to be thorough with measurements made over the range scoped in the proposal. The reduction of funding did result in the reduction of the scope of work.

The documentation does discuss the use of a single senor package but does not suggest or detail what the total sensor package would be. One sensor is sensitive to temperature but not pressure and another (hollow spheres) that are sensitive pressure. Using a single sensor to make all the various measurements will be difficult as certain environmental conditions will tend to dominate certain configurations. There is a discussion of the interrelated corrections that are needed to make all the various measurements is discussed so understanding the potential uncertainty of each measurement needs to be understood as that will impact the other measurements.

PI Response:

As discussed above, the sensor consists of several active parts, each of them targeting a specific parameter. Slide 7 provides info related to the interelated corrections needed to be made.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23527

Score: 2.0

Comment: Planned objectives appear to have been for the most part accomplished but the value of these accomplishments is considered to be trivial in light of the issues mentioned in other evaluation sections.

PI Response:

See responses above.

Reviewer 23474

Score: 4.0

Comment: The project appears to be progressing according to schedule. It is currently about 90% complete and will conclude at the end of FY12. It should be noted that the work was funded at a lower amount than was originally proposed, so the project was de-scoped to account for the budget shortfall.

As previously noted, the team has shown good progress toward demonstrating an acoustic sensor that can monitor various aspects of a geothermal reservoir. These accomplishments directly relate to the Geothermal Technologies Office's goals for geothermal energy development, and when fully verified will provide a tool for characterizing downhole conditions.

They have also addressed issues related to materials selection (e.g., high-temperature adhesives) that may also benefit the community.

Several aspects of this work have been described in scientific papers. To date, six papers are either under review or being prepared.

PI Response:

No response entered.

Reviewer 23548

Score: 3.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23639

Score: 2.0

Comment: Lab measurements have been made testing basic concepts over a range of conditions. While there has been accomplishments made demonstrating the basic concept it is hard to visualize how the current sensor geometry will work in a downhole tool. More understanding of the overall sensor configuration for the downhole environment needs to be done.

PI Response:

We agree that 'more understanding of the overall configuration for the downhole environment needs to be done', but this is outside of the scope of this project. This is clearly defined in both the proposal and the presentation.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23527

Score: 1.0

Comment: This project appears to have been planned with little regard to issues of importance that would have been immediately flagged by individuals familiar with the technical concerns typically associated with the development of acoustic measurement technologies for subsurface fluid production applications. Relevant activities should have been defined in consultation with individuals more familiar with the development and application of fieldable devices of this type.

PI Response:

We interacted quite a bit with 'individuals' familiar with measurement technologies for subsurface fluid production applications. Some of these were involved in the 'Fenton Hill' geothermal project more than 20 years ago, while others are from the oil industry side.
As mentioned several times already, this project had nothing to do with 'the development and application of FIELDABLE devices' at this stage. While we are definetely interested in commercializing the technology, the time-frame and funding of this project did not allow us to pursue this path in the past.

Reviewer 23474

Score: 2.5

Comment: The project only includes researchers at Los Alamos National Laboratory (LANL). While the technical work has progressed well, it would be nice to see more interactions and involvement with potential users of the technology. Since the Geothermal Technologies Office has invested in the development of the sensor tool, the next step would be the transition of the technology to field use. Some coordination with external entities (either another government lab or a commercial organization) would be good to ensure the products of the work are advanced when the period of performance expires.

PI Response:

We do plan to do this in the future.

Reviewer 23548

Score: 3.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23639

Score: 3.0

Comment: The project management and coordination have been reasonable and has adapted the scope and tasks for the reduction of available funding.

PI Response:

No response entered.

STRENGTHS

Reviewer 23527

Comment: Nothing to add to this section.

PI Response:

No response entered.

Reviewer 23474

Comment: The sensor technology under development by LANL combines multiple sensing capabilities (temperature, pressure, fluid composition, etc.) in a single measurement tool. This approach allow for a more compact sensor package while also offering good sensitivity for the user. The project team is aware of the challenges of working in the downhole environment and has addressed several issues related to high-temperature performance. They have also demonstrated the ability to operate at pressures to 22 MPa, and the potential for higher pressure operation was discussed at the Peer Review.

In addition to the technical work, they have also made an effort to publish the results in scientific journals.

PI Response:

No response entered.

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23639

Comment: The strengths of the project have shown the ability to use an acoustic module in a new Swept Frequency Acoustic Interferometry (SFAI) mode. It has shown that different acoustic transducers can respond to various downhole environmental conditions. Work has also been done on the various electrical connections (cable and connector) along with the theoretical modeling.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23527

Comment: I have nothing to add to the comments made in the preceding evaluation sections.

PI Response:

No response entered.

Reviewer 23474

Comment: More interactions with the user community would be nice to see. At present the work is done entirely at Los Alamos National Laboratory (LANL) and no outside collaborators are providing inputs that could shape and direct the work. Those inputs are often quite helpful in making sure that the research is considering the needs of the industry. In this case, both geothermal and oil and gas applications could be used to define product requirements.

PI Response:

No response entered.

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23639

Comment: The weakness in the approach is the understanding of how the exact downhole sensor geometry would be configured and the type and configuration of the various transducers needed to make the measurements (e.g. two for fluid flow and another one for pressure). The current discussion of a single transducer to obtain all the various parameters of temperature, pressure, fluid flow, fluid properties (density, viscosity, fluid composition) seems problematic. By using one sensor there are only so many responses that can be measured and certain environmental parameters will dominate creating an under determined condition or through the use of multiple corrections leading to large uncertainties.

Fluid flow can only be accomplished with two phase flow.

PI Response:

We did not propose or claim that the measurements will be performed with a single transducer. We are developing a sensor that has several active parts, each of them focused on a different parameter to be measured.

IMPROVEMENTS

Reviewer 23527

Comment: I have nothing to add to the comments made in the preceding sections.

PI Response:

No response entered.

Reviewer 23474

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

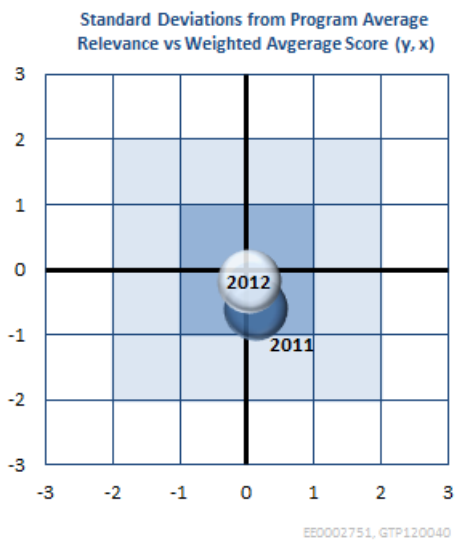
No response entered.

Reviewer 23639

Comment: Instead of trying to address all the temperature and pressure conditions there should be some focus of the required downhole sensor geometric configuration for a typical geothermal borehole. Also suggest to work with additional fluids especially some representative sample fluids from actual geothermal wells.

PI Response:

The geometric configuration was outside of the scope of this project.
As mentioned in the presentation, we planned from the beginning to perform measurements on additional fluids characteristic to EGS systems.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002751
Project: High-Temperature Circuit Boards for use in Geothermal Well Monitoring Applications
Principal Investigator: Hooker, Matthew
Organization: Composite Technology Development, Inc.
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23568

Score: 3.0

Comment: It was not initially clear why polymer circuit boards were an advantage, but discussion brought out that high-temperature polymer circuit boards could be made in a large form factor not achievable with other materials.

PI Response:

Reviewer 23548

Score: 3.0

Comment: The development of high-temperature circuit boards is a crucial step to enable further geothermal tool development.

PI Response:

Reviewer 23412

Score: 3.0

Comment: Higher temperature application electronics are becoming higher in demand.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23568

Score: 3.0

Comment: A systematic plan is in place with relevant short beam and tension testing for adhesion and mechanical strength. Supporting finite-element modeling of the composite was also reasonable. However, it seems prudent to keep second and third choices of qualified polymer on the back burner in addition to the first choice 1280.

PI Response:

Reviewer 23548

Score: 3.0

Comment: A thorough, systematic approach to obtaining optimal and cost-efficient materials.

PI Response:

Reviewer 23412

Score: 3.0

Comment: The need for higher downhole temperature electronics and other applications is always increasing. I liked the bench testing of the different products and testing of mechanical properties. Not to be subjective but it was beneficial to have seen the Honeywell presentation and their solution of ceramic circuit boards. This technology could help Honeywell reduce the cost of their circuit board measurements.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23568

Score: 3.0

Comment: The team has produced a clear, downselect winning material – CTD-1280. What only remains is for Sandia to fabricate the circuit boards.

PI Response:

Reviewer 23548

Score: 3.0

Comment: Results are on track.

PI Response:

Reviewer 23412

Score: 3.0

Comment: Progress to date is a prototype that was available for review.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23568

Score: 4.0

Comment: Management has done an excellent job interfacing with Calumet and Sandia.

PI Response:

Reviewer 23548

Score: 3.0

Comment: Project partners appear to be integrated and coordinated.

PI Response:

Reviewer 23412

Score: 3.0

Comment: Management and coordination was adequate.

PI Response:

STRENGTHS

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23548

Comment: A cost effective way to manufacture high-temperature circuit boards. This will remove one of the obstacles for geothermal/high-temperature tool development.

PI Response:

Reviewer 23412

Comment: Good approach to material selection and mechical property testing.

PI Response:

WEAKNESSES

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23548

Comment: No clear indication of the required specifications for deployment in tools.

PI Response:

Reviewer 23412

Comment: No weaknesses are apparent. The project is performing as proposed.

PI Response:

IMPROVEMENTS

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23548

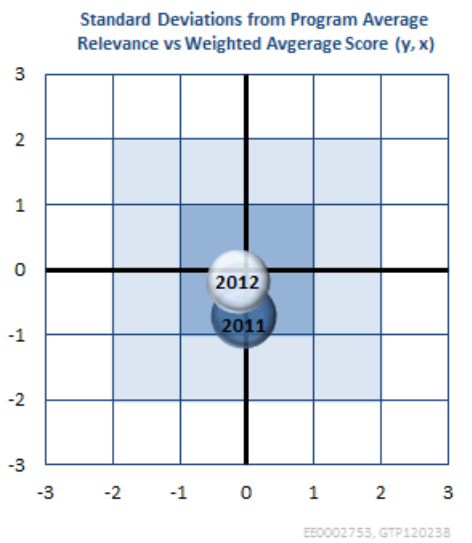
Comment: None.

PI Response:

Reviewer 23412

Comment: The project is near completion and it would be difficult to suggest improvements.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002753
Project: Harsh Environment Silicon Carbide Sensor Technology
Principal Investigator: Pisano, Albert
Organization: University of California, Berkeley
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23521

Score: 3.0

Comment: Due to the harsh conditions of pressure, temperature and corrosiveness present in typical Enhanced Geothermal Systems (EGS), the development of instrumentation that can work in such adverse conditions can have a positive impact in several areas related to sensors and well monitoring.
Long-term chemically inert and thermally stable sensors are a 'must' in typical EGS
SiC seems to be the material of choice for several projects related to high-temperature instrumentation.

PI Response:

No response entered.

Reviewer 23519

Score: 3.0

Comment: In general, all high-temperature, >300C, work in SiC offers significant impact to the geothermal industry--if there is direct commercialization of the technology or there are students with the technical skills to create SiC solutions for the geothermal industry. Commercialization can in the form of manufacturing and selling the SiC electronic devices directly to the user or in the form of new logging or drilling tools used by the geothermal industry.

I don't see any of this work resulting in a new sensor for commercial use by the geothermal industry as a component or as a logging tool. I do see this work being useful in training students in high-temperature SiC for future use by the geothermal industry. This work can benefit geothermal well monitoring, deep natural gas exploration, aircraft control systems and other industrial applications of high-temperature SiC electronics and sensors.

The part of the project focusing on a pressure sensor is the most interesting and perhaps the most needed by the industry. At this time, there isn't any pressure sensor with low enough drift for use in monitoring a geothermal reservoir at temperatures above 250 C. Also, at this time, there isn't a pressure sensor capable of supercritical well logs above 350 C. Unfortunately, work presented in this review is limited to the SiC pressure sensor element which will require significant additional development in order to make a complete sensor transducer for application inside a well tool.
I don't see the development of a SiC temperature sensor as having any commercial value because there are a number of low cost temperature sensor solutions already on the market. This part of the project only offers teaching experience to SiC students.

I suggest, to achieve the most impact from this work, there needs to be a commercial partner for taking the SiC pressure sensing element to the next stage of development for use in geothermal reservoir monitoring. Otherwise, the real value and impact of this work is the development of students working with SiC as a sensing element to temperatures above 300 C. In working with such high temperatures, the students are looking beyond SiC as a material but also at die and wire attach.

PI Response:

No response entered.

Reviewer 23567

Score: 4.0

Comment: Temperature-stable pressure-sensor capable of continuous operation at supercritical temperatures is currently not being offered commercially. The development of such sensor system would provide geothermal industry a solution to address the need.

PI Response:

No response entered.

Reviewer 23548

Score: 2.0

Comment: While highly useful for the development of sensors for well characterized (testing & laboratory) environments, it may be still a bit early for field applications.

PI Response:

The Principal Investigator is disappointed in this particular ranking and review comment, since part of the testing and laboratory environment includes use of geothermal brine at high temperature and pressure. This will result in a very realistic test of the sensors, albeit not in the field.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23521

Score: 3.0

Comment: The scientific/technical approach is definitely interesting, and apparently the team performed quite a bit of related work in the past. However, it is not clear to me what is the effect of pressure on the temperature sensor, and that of temperature on the pressure sensor.
The approach on bonding technology is sound, and I'm very curious what the results of harsh environment exposure of bond will look like, as pretty much everything exposed directly to water at temperature close to the critical point results in bond degradation.

PI Response:

No response entered.

Reviewer 23519

Score: 4.0

Comment: The scientific approach to the development of SiC sensors at Berkeley is sound. Their development of sensing elements using SiC and semiconductor manufacturing technology is highly valued by this reviewer. The validation of bonding technology for temperature >300 C is valued and a significant contribution to the scientific approach of this work.

Vibration and long-term temperature testing was not part of the existing project and was not outlined as part of future research. Some consideration was given to the future interface of the pressure and temperature sensors to amplifiers as will be required in a complete system solution. Unfortunately, there are limitations on existing commercially available electronics for interfacing capacitive sensors at temperatures above 200 C. If this project moves forward, I would suggest work on second generation pressure sensor in conjunction with on-sensor (very near sensor) SiC electronics to allow for a simple user interface at geothermal temperatures.

PI Response:

No response entered.

Reviewer 23567

Score: 2.0

Comment: Several aspects have to be included in the approach to ensure that the technology feasibility could be proven to the extent that a practical outcome is possible. Those may include evaluation of interconnects and interconnect insulation suitable for sensor signal readout, stability of sensor top surface elements when exposed to geothermal brine, preliminary studies of reliability and stability of the sensor.

PI Response:

The Principal Investigator is disapointed in this ranking, since the testing of interconnects is included in the testing and laboratory environments to which the sensors will be exposed. Also, the interconnects will all be on the REVERSE side of the SiC chips, and in the field, interconnects will not be exposed to the brine. Perhaps the reviewer misunderstood the stated testing protocol?

Reviewer 23548

Score: 3.0

Comment: Very thorough approach with a clear vision in mind.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23521

Score: 3.0

Comment: The work seems to progress according to plan. As mentioned before, the effect of pressure on temperature determination and the effect of temperature on pressure determination should be addressed early in the project. If this has major implications, new approaches should be investigated earlier, rather than later.
Task 3, Bonding Technology, seems to proceed along the right track, and tests in environments specific to EGS are planned for the future.
Exposure testing was performed on individual materials to be used in sensor fabrication. AlN is excluded as a candidate in the proposed sensors due to failure at conditions close to the critical point of water.

PI Response:

No response entered.

Reviewer 23519

Score: 3.0

Comment: The results for the pressure sensor are very interesting. The linear range is impressive. The likelihood of long term stability is reasonable. There is a need to add additional SiC analog circuit to allow for interfacing to other tool electronics.

Testing at 600 C is valued and provides student with challenging projects which could benefit the future geothermal industry.

PI Response:

No response entered.

Reviewer 23567

Score: 2.0

Comment: The project is behind the original project plan. Some delays were encountered and sensors fabrication and testing milestones remain to be achieved.

PI Response:

The Principal Investigator is disappointed in this ranking, since all delays were communicated to DoE immediately, and DoE acceptance of the delays acquired. Further, a delay due to a fire in the fabrication lab can hardly be considered to be the fault of the Principal Investigator. The fire was caused by another group using the fabrication laboratory and completely burned out an entire fabrication bay.

Reviewer 23548

Score: 3.0

Comment: Considering the fundamental nature of this research, it is remarkable how far the group has progressed. They seem to deliver on the stretch targets they have set for themselves.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23521

Score: 4.0

Comment: Coordination/project management seems to be under control.

PI Response:

No response entered.

Reviewer 23519

Score: 4.0

Comment: Of my many years working with university research projects, this might be one of the better managed projects given the loss of their facility. The PI has done a great job.

PI Response:

No response entered.

Reviewer 23567

Score: 2.0

Comment: Consulting with the geothermal industry experts and refining sensors target characteristics and packaging approach will address technology readiness for use as part of the sensor system at a later stage.

PI Response:

The Principal Investigator is disapointed in the ranking given by the reviewer. The Principal Investigator has consulted with personnel at CalPine Geothermal Power Plant, Matsukawa Geothermal Power Plant, and engineers at Fuji Electric, the company with the largest market share of installed geothermal power plants in the world. The designs and research approach were fully described to these three groups and affirmation received. Is there some other group that the reviewer would like the Principal Investigator to consult?

Reviewer 23548

Score: 3.0

Comment: Fit for purpose and capable to overcome obstacles -the burnt down lab.

PI Response:

No response entered.

STRENGTHS

Reviewer 23521

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23519

Comment: Managing the project with loss of facility and a large number of grad students.The work on the pressure transducer shows some promise.

PI Response:

No response entered.

Reviewer 23567

Comment: There is definitely a need for such sensor technology and benefits are obvious for geothermal exploration.

PI Response:

No response entered.

Reviewer 23548

Comment: Many opportunities for deployment can be considered.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23521

Comment: Temperature effect on pressure determination and vice-versa was not taken into account. This can have a major impact on the final design of the sensor and should be addressed.

PI Response:

The Principal Investigator explained that the folded diaphragm design of the pressure sensor effectively decouples the pressure sensor from temperature effects. Principal Investigator does concede that no pressure effects on temperature measurement were considered. But since the temperature sensor is inside the sensor system (and therefore not subjected to pressure) the Principal Investigator didn't feel this explanation was necessary. In future reviews these topics will be clearly explained.

Reviewer 23519

Comment: Work on the temperature project is nice but lacks any real commercial value.

PI Response:

Principal Investigator offers that the temperature sensor and pressure sensor exist on the same chip, making their measurements only 1 mm apart, and so this provides the first-ever co-located temperature and pressure measurement system available. If reviewer is unimpressed with this achievement, then Principal Investigator concedes the point.

Reviewer 23567

Comment: The scope of the project may be not broad enough to produce meaningful results.

PI Response:

The Principal Investigator does not understand this comment, since two geothermal power plants and one geothermal plant manufacturer have affirmed that the scope of the project should indeed produce meaningful results.

Reviewer 23548

Comment: The reviewer fully appreciates the wide spectrum of issues related to sensor development. But there is a perception that little thought is put into the practical deployment of the sensor.

PI Response:

Principal Investigator concedes that no information was given concerning the practical deployment of the sensor, and that all attention has been given to development of prototypes.

IMPROVEMENTS

Reviewer 23521

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23519

Comment: Drop the temperature sensor. Increase testing on the pressure sensor and consider concepts for future analog SiC circuit interface to HT SOI electronics.

PI Response:

Principal Investigator will increase testing of the pressure sensor and will consider concepts for SiC interface circuits.

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

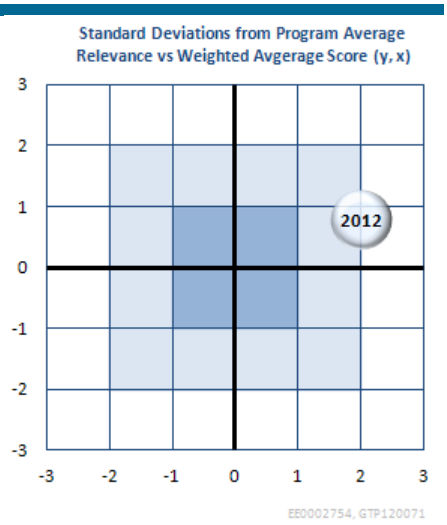
No response entered.

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002754
Project: OM-300 - MWD Geothermal Navigation Instrument
Principal Investigator: Ohme, Bruce
Organization: Honeywell International, Inc.
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23527

Score: 4.0

Comment: This project appears to be furthering the development of needed high temperature electronic components and sensor technologies that may be employed in geothermal applications. It addresses current market technology deficiencies and is on the path towards commercial relevance. The development of high temperature navigational technology will further future geothermal directional drilling capabilities and will be critical to the eventual demonstration of EGS.

The development and integration of chip and board level fabrication and assembly practices for these temperatures is especially relevant as they form the backbone of general high temperature tool development. I am not sure how much of a role SOI technology will play in future applications but it is probably best to have multiple candidate material technologies at this stage of high temperature electronics R&D.

PI Response:

It is our opionion that SOI (Silicon-on-Insulator) is necessary for silicon-based integrated circuits to operate at these temperatures. Silicon IC's are generally much more advanced (in terms of number of components and functions that can be integrated) than non-Silicon options (such as Silicon-Carbide) and will be for some time. Therefore SOI is the most logical and practical choice for applications temperatures in the range of 300C.

Reviewer 23519

Score: 4.0

Comment: To support the long-term goals moving EGS from an idea to a realized cost effect form of energy, directional drilling at geothermal temperatures is required. Although, the directional steering technology developed within this project will have some value to conventional hydrothermal geothermal, EGS will be dependent on the development of measurement while drilling (MWD) for mining heat from layers of horizontal rock formations which can support EGS reservoirs.

This project is also supporting the continued development of HT SOI (Silicon-On-Insulator) electronics, electronic assembly practices for 300 C and MEMS sensor development for geothermal temperatures. All of these issues will benefit the whole geothermal industry not just future EGS.

Existing MWD systems are temperature/performance limited by the directional sensing elements needed for bit inclination and bit azimuth. The means by which MWD tools work is through ‘dead reckoning’, where bit inclination and azimuth readings are taken every time the drilling stops. These readings create a known directional vector. As the

drilling advances the drilling bit, these vectors and changes in depth are used to determine bit location. As advancing the bit 1000s of feet in depth means small errors in the directional vector calculation will accumulate providing the driller bit location errors of 100s of feet which could take the drilling outside of the desired formation.

This work is advancing azimuth by using HT SOI inside a conventional flux-gate magnetometer circuit. To measure inclination, a new MEMS sensor based on parallel beam is under development. Honeywell is implementing additional HT SOI electronics to create a complete sensor package as is consistent with MWD tools used in the oil industry.

PI Response:

I'm not sure I understand the reviewer's comments in the first paragraph that imply this work will only apply to hydrothermal technoligies. The reviewer comments do not explicitly state this, but I get the impression that the extension of the flux-gate capability to this temperature range was not fully conveyed. This work includes use of new materials to extend the flux-gate technology (which is used in oil industry MWD tools) to temperatures needed to support EGS. As such, this work is not really employing a "conventional flux-gate magnetometer"

I appreciate the reviewers comments on the challenges and requirements for dead reckoning navigation using MWD tools.

Reviewer 23568

Score: 4.0

Comment: Measurement while drilling (MWD) to EGS temperatures of 300 C is highly relevant to the Geothermal Technologies Office as control of directional drilling is necessary as part of drilling technology improvement to achieve efficient resource exploitation.

PI Response:

No response entered.

Reviewer 23548

Score: 3.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23527

Score: 4.0

Comment: The approach appears to be well planned and systematic. It covers critical elements of both the development of component technologies and their integration. The state of the art for SOI technology has been logically and efficiently

expanded and should further the improvement towards commercial availability. Associated sensor development appears to be pursued with reasonable risk management levels that should result in the production of useful sensor technologies.

PI Response:

No response entered.

Reviewer 23519

Score: 3.0

Comment: The overall program approach is very good with a focus on sensor development and the use of HT SOI and state of the art non-magnetic high-temperature packaging.

Missing are the system target requirements. What are the required system measurement accuracies expected for future EGS? It is unfair to simply assume oil-gas MWD standards. Oil-gas directional sensors have over 20 years of development and operate at temperatures below 180 C. Also, the EGS target formation will be larger than most oil or gas baring formations as EGS requires much larger rock exposure for harvesting heat.
Some effort in identifying requirements should be undertaken by the IP by talking with other EGS researchers as AltaRock and Geodynamics.

There is little discussion in the review on progress of the flux-gate magnetometer work undertake by Applied Physics Systems. This leads me to believe this work maybe failing to reach the target temperature of 300 C.

The scientific approach to this project could be improved by looking at past work done at Sandia Labs on the actual downhole temperatures seen while drilling. In short, the proposed MWD steering package must be survivable to temperatures of 300 C but have reasonable measurement accuracies at temperatures between 250 and 275 C as measurements are normally taken just after drilling (and its mud circulation) have stopped providing a short period of time at temperature below the formation temperature.

PI Response:

The goal specification are the higher accuracy requirements of oil and gas. If the specification are reached, lower accuracy requirements for geothermal drilling will have also been achieved.

The suggestion for requirements review with AltaRock and Geodynamics is appreciated.

Due to the limitations of 20 minute presentations, there are limited opportunities to cover every aspect of our technical approach and progress. We apparently failed to convey progress on flux-gate extension to 300C and associated circuit demonstration. We have identified materials for flux-gate construction to meet 300C goals that will be applied in this work. We have also demonstrated ciruits at 300C for flux-gate sensing (although not yet in the form that they will be incorporated in our demonstration units).

Reviewer 23568

Score: 2.0

Comment: The objective is to be met by improving on acceleration and magnetic field sensors and electronics to EGS conditions. These two sensors are the key variables as the former measures dip angle and the latter measures azimuth. The critical path for success requires extending Silicon-on-Insulator electronics to 300°C. In a perfect world, this would have been proven first before conducting all the other component tests.

PI Response:

In the previous peer review (2011) I believe there was more information on the extension of SOI electronics to 300C. Due to the limitations of 20 minute presentations, it is difficult to cover all of the aspects of our progress. We apparently failed to convey the fact that we developed an SOI electronics infrastructure (wafer process, electrical rules, simualtion models, etc) and demonstrated it at 300C. Furthermore, all of the necessary component development using the SOI electronics has been completed and the components required have been manufactured. We tried to convey this in the back-up slides, but apparently this reviewer either missed it or still has reservations about it.

Reviewer 23548

Score: 3.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23527

Score: 4.0

Comment: Milestones were well thought out and results appear to be on track and of value.

PI Response:

No response entered.

Reviewer 23519

Score: 3.0

Comment: This project has developed several new HT SOI devices which have use in a large number of other geothermal projects as the dual comparator and the quad line driver.

The development of an MEMS inclination sensor appears to this reviewer as a positive direction. I have reservations over the 300 C flux-gate magnetometer.

The lack of a complete packaged drilling assembly is unfortunate however completing the sensors will allow for others to follow this work forward.

PI Response:

The comment in the second paragraph echoes earlier comments from this reviewer regarding a perceived lack of progress in extending flux-gate technology to 300C. It is difficult to convey all aspects of our approach and progress within the limits of the peer review. We have done work to develop to support the extension of flux-gates to 300C and expect it will be functional. We will see how it turns out.

Reviewer 23568

Score: 2.0

Comment: The timeline shows that the schedule for 300 C testing is being met. Evidently there are a few prototypes ready for testing but custom high-temeprature dies are still in fabrication. Overall, the jury is still out. This was a high-priced Geothermal Technologies Office investment.

PI Response:

Again, I would have thought the back-up slides (which were not presented) would have conveyed the fact that all of the customer high-temperature dies have been fabricated and verified (includinge testing at 300C) as fit for use in the demonstration.

Reviewer 23548

Score: 3.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23527

Score: 4.0

Comment: Management of resources and technical tasks has been competent. Budgeting has been reasonably planned and realized, albeit accompanied with the types of delays and overruns conventionally associated with electronics fabrication efforts.

PI Response:

No response entered.

Reviewer 23519

Score: 4.0

Comment: If there is one thing Honeywell does well (perhaps to a point of over doing it) is project management for government-funded projects. In fact, Honeywell lacks a means to manage projects which require flexibility when commercial realities are subject to changes.

So, while managing the project well under the Geothermal Technologies Office contract, commercialization of the final product may find significant obstacles. My suggested improvements are provided to help overcome this weakness.

PI Response:

We appreciate the reviewers comments (such as earlier tips on the application and sources of information).

Reviewer 23568

Score: 2.0

Comment: Most management is in house and described using buzz words about process. Nothing was said of substance of how the moving parts meshed. I was left with the impression that there was not much interaction among the pieces and that overall the cost of the project was higher than if it had been efficiently managed.

PI Response:

It is not clear how this misconception was formed. Admittedly, the presentation focusses more on technical approach and progress than on the project management process. There has been regular interaction among team members including weekly calls and periodic face-to-face meetiongs. For sure, it is challenging to develop in parallel all of the pieces incorporated in this project (IC's, sensors, assembly materials, housing, etc). Timely, efficient, and flexible project management are key to getting the most out of the combinded efforts.

Reviewer 23548

Score: 3.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

STRENGTHS

Reviewer 23527

Comment: This project evolves existing technologies and techniques with an acceptable risk level that is likely to produce a useful commercial product. A complete system package will be delivered that has near term field relevance.

PI Response:

No response entered.

Reviewer 23519

Comment: The development of other HT SOI devices which will find applications in other EGS projects is a significant strength. The development of sensors for 300 C operation, even if those sensors don't meet the requirements for an MWD tool drilling in EGS wells they may find other EGS applications.

PI Response:

No response entered.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23527

Comment: Nothing major. The focus of the project is on the integration of the sensors and associated signal processing components. There will ultimately have to be a focus on the precision and utility of the tool but that should be a focus of future efforts once the basic system package is proven.

PI Response:

No response entered.

Reviewer 23519

Comment: Commercialization of a final product is not truly addressed. There is a real potential that the sensors will not met the real world requirements of MWD tools drilling tight EGS formations.

PI Response:

Commercialization is our objective. It is clear to us that further work will be required beyond what is completed in this project. Hopefully we will have addressed risks sufficiently to establish technical feasibility. This is a pre-requisite for continuing down the commercialization path.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23527

Comment: No significant suggestions to offer. The details of the lessons learned associated with the system fabrication and assembly should be made available to further industry practice in this area.

PI Response:

No response entered.

Reviewer 23519

Comment: To protect the impact of this work, I suggest the following priority in decision making as the project comes to an end.

Highest priority is item 1 and so on.

1. Inclination sensor. This sensor provides the change in depth as drilling progresses. Error in this measurement is most likely to cause drilling to run outside of the desired formation.

2. Azimuth sensor. There is ongoing work on solid-state magnetic sensors in HT SOI which could provide an alternative to the magnetometer work in this project.

3. Complete packaging with interface circuits. Here, even if this project fails to make a complete MWD sensor package available to the drilling industry, the MWD tool designers will consider working directly with the sensors in items 1 & 2.

Finally, there is a need for secondary future design elements for backing up the MWD tool directional sensors. For example, pressure sensors inside the MWD tool can be used to monitor changes in depth during horizontal drilling. LWD sensors as measuring the natural background gamma from the desired formation can aid in assuring the drilling has not exceeded beyond formation boundaries.

The scientific approach to this project could be improved by looking at past work done at Sandia Labs on the actual downhole temperatures seen while drilling. In short, the proposed MWD steering package must be survivable to temperatures of 300 C but have reasonable measurement accuracies at temperatures between 250 and 275 C as measurements are normally taken just after drilling (and its mud circulation) have stopped providing a short period of time at temperature below the formation temperature.

PI Response:

Since the design goal is 300 C, it is too early for a 275 C retreat.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

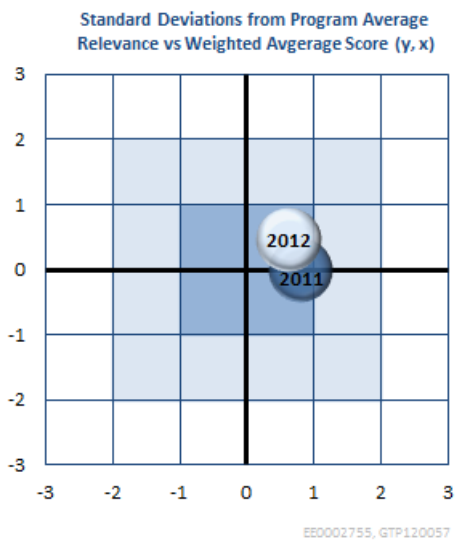
No response entered.

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002755
Project: Pressure Sensor and Telemetry Methods for Measurement While Drilling in Geothermal Wells
Principal Investigator: Vert, Alexey
Organization: GE Global Research
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23527

Score: 4.0

Comment: The development of the SiC chips, ICs and associated fabrication and assembly practices will significantly further much needed high temperature tool development efforts. I am less enthusiastic about the telemetry aspects of the project as mud pulse telemetry has limited application in geothermal drilling applications that sometimes utilize air or aerated fluids to minimize formation damage effects. The core processing technology of the project is nonetheless relevant and holds great promise. The superior theoretical performance potential of SiC should be evolved to commercial relevance and this project serves this purpose.

PI Response:

Reviewer 23521

Score: 3.0

Comment: Based on the importance of achieving the project's objectives relative to the broader geothermal program's mission and goals, the development of silicon carbide based digital and analog integrated circuits plays an important role in the direction of manufacturing electronics for downhole instrumentation. The EGS systems are well-known for their extremely harsh conditions, having a negative impact on existing commercial electronics. Many other projects can benefit from high-temperature electronics mounted in the borehole. E.g. signal amplifiers can benefit pretty much all projects related to sensing.
However, the title of the project is "Pressure sensor and Telemetry methods for measurements while drilling in geothermal wells", but the PI focuses almost exclusively on electronics development.

PI Response:

Reviewer 23519

Score: 3.0

Comment: In general, all high-temperature, =>300 C, work in SiC offers significant impact to the geothermal industry--if there is commercialization of the technology. Here commercialization can in the form of selling the SiC electronic devices directly to any user or in the form of new logging or drilling tools used by the geothermal industry. GE did not directly state a commercialization process.

The goals of this project are highly valued for their application and technology development. However, the stated goal of only 400 hours is too short for most applications. This is true because tool builders will require the well owner to buy a logging/drilling tool electronics once most of the 400 hours has been expended. For example, a reservoir recovery test can take 4 to 10 days. At 10 days, 240 hours has been expended and it now becomes difficult for the service provider to use that tool again on a second project. If the expected operating life was 1000 hours or 2000 hours, the tool builder or service provider would have many applications of which to recover the cost of the tool.

SiC as a technology has every benefit over silicon except cost. Cost is a major factor as indicated above. Not just the cost for the device but for all of the components needed to operate any set of electronics at temperatures above 250 C. In short, all high-temperature applications also require high-reliability. Because of the cost issue, there may not be support for SiC electronic devices as an electronic device until the aerospace industry has a complete inventory of electronic devices needed to build engine control systems.

PI Response:

Reviewer 23525

Score: 4.0

Comment: This project pursues an extremely relevant research track: that of developing the electronics to survive 300 C environments so that data may be telemetered out during drilling. The investigator is taking a very innovative approach to SiC electronics as well as to high-temperature dielectrics so that a high temperature electrical telemetry system may be fabricated and tested. This system shows all the necessary components, from analog op-amps (to interface to the sensors) all the way to digitization and transmission of the data. As one would expect from early stage SiC NMOS electronics, the investigator is using a 4-bit digital stream (lower resolution and lower bit rate) but is showing that operation at 300 C will be feasible. This system is sure to have high impact in the industry, since drilling costs are sure to be reduced when such data is available during drilling. Although field tests are not specifically part of this contract, the investigator is aware of the need to test in environments similar to that which will be experienced downwell. Testing to date seems to be limited to temperature testing in dry air. But this is appropriate for an electronics module that will, presumably, work in a hermetically-sealed package. The investigator is aware of the packaging challenge, and has made a little progress with that, but in an appropriate way, the investigator is concentrating mostly on the development of the electronics.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23527

Score: 4.0

Comment: The fabrication, assembly and testing approaches of the project were well thought out. The team assembled to perform the work was highly qualified and likely a significant contributor to the successes achieved to date. The functional and reliability testing performed to date were well planned and relevant.

PI Response:

Reviewer 23521

Score: 3.0

Comment: The scientific/technical approach is based on electronics development using SiC MOSFETs. SiC seems to be the material of choice for the high-temperature electronics community, and it is used by several groups around the world. The team is developing both analog and digital SiC integrated circuits in parallel. Testing of failure modes and yield analysis are performed on the developed ICs.
The PI is making use of a commercial pressure transducer .

PI Response:

Reviewer 23519

Score: 4.0

Comment: The scientific approach to the development of SiC integrated circuits by GE researchers is sound. Vibration and long-term temperature testing is highly valued. The parallel development of ceramic based packaging was required and critical to future success in geothermal applications.

The reported testing of resistors and capacitors along with the SiC devices is highly regarded by this reviewer and represents a complete solution outside of building a logging tool.

The only comment I offer towards improving the scientific approach is for continued testing to validate or correct for long-term measurement drift. Proving very low measurement drift is essential for success in geothermal well monitoring.

PI Response:

Reviewer 23525

Score: 4.0

Comment: The investigator is taking a deliberate, comprehensive approach to the development of the electronics. First, the investigator is obtaining components from the commercial sector whenever possible, and qualifying those components for operation at 300 C himself, making sure to select the best components for moving forward. Second, the investigator is developing unique, innovative solutions to the high-temperature electronics when there is none available commercially. In particular, the investigator is to be commended for taking the approach of a thin-film metallization and interconnect on an aluminum nitride coated substrate. Although more difficult to do in the beginning, this method allows for more reliable interconnect as well as lower parasitic losses (unwanted resistances and capacitances) in the circuit. Although the eutectic bonding approach makes it very difficult (or impossible) to do re-work of the circuit board, the approach does make for strong, reliable junctions in the interconnect. The project seems adequately staffed, and is moving forward on time and on budget.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23527

Score: 4.0

Comment: Fabrication and testing appear to have produced a useful tool platform for this stage of development of the technology. Critical technical barriers and issues have been identified and reasonably addressed. Performance characteristics of the transistor and circuit technologies appear to have been reasonably demonstrated. There was not much detail provided on the "downstream" telemetry components so no comments can be provided for aspect of the tool. It would be nice to have been given a little more detail on what is planned for this part of the system.

PI Response:

Reviewer 23521

Score: 2.0

Comment: Progress seems to be according to plan. Tests in wet-medium (water or brine) should be performed for the components exposed to the downhole fluid.

PI Response:

Reviewer 23519

Score: 3.0

Comment: This project has generated a simple SiC chip set for making two analog measurements and enabling those measurements to be access via a cable to the surface. This is a significant accomplishment.

The project title describes use of the SiC devices for pressure and temperature measurements while drilling. However, such an application would require the development of 300 C mud pulse communication and the development of additional logic drive circuits. The lack of a measurement while drilling (MWD) tool capability does limit the score.

Given the value of MWD technology within the drilling industry, it is possible that secondary private industry development will continue this project to MWD applications in geothermal.

PI Response:

Reviewer 23525

Score: 4.0

Comment: The investigator reports excellent progress, and indeed, there has been a great deal of progress since the last review (this reviewer performed a review last year of this project). This progress rate is very impressive, given the aggressive targets the investigator has set out for himself.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23527

Score: 3.0

Comment: No major issues here. The technical accomplishments and results attest to good overall management of the project.

PI Response:

Reviewer 23521

Score: 3.0

Comment: Project management and coordination is properly performed. Three jobs were created and the PI has quite a few external collaborations, which are important to a successful development of the project. Minor problems related to some delays in execution of some of the tasks, but good performance overall.

PI Response:

Reviewer 23519

Score: 3.0

Comment: This is a mature project. The project has had two PIs. Given the changes in PI, this project has continued to make progress. The only short coming are comments regarding the commercialization process of technology developed by GE.

PI Response:

Reviewer 23525

Score: 3.0

Comment: The investigator did not mention much about the project management portion of the project, and so, there is little to comment upon. However, the project seems well organized, is on time and on budget,

PI Response:

STRENGTHS

Reviewer 23527

Comment: A useful electronics platform for high temperature sensor signal and device control processing has been developed. The material technology holds great promise for elevated temperature operation and critical system fabrication and assembly practices have been developed.

PI Response:

Reviewer 23521

Comment: The high-temperature ICs developed in this project can have a great impact on several other geothermal projects, which can benefit directly from this work.

PI Response:

Reviewer 23519

Comment: In general, all high-temperature, =>300 C, work in SiC offers significant impact to the geothermal industry. The goals of this project are highly valued for their application and technology development for geothermal reservoir monitoring. This technology can open new applications for high temperature (HT) electronics within the geothermal industry and potential find applications within the aerospace industry.

PI Response:

Reviewer 23525

Comment: The primary strength of the project is that the investigator has assembled an effective, well-considered research plan for developing the 300 C electronics module, and is proceeding in a logical, coordinated way. The investigator has, or has access to, a very wide range of technological skills, and is directing those skills to the solution of the technical challenges. These skills include high-temperature testing, analog and digital electronics in the novel NMOS SiC, LTCC and Aluminum Nitride circuit boards, and gold metallization, along with eutectic bonding. This is a full-palette approach to research, and it is a very strong way to proceed.

PI Response:

WEAKNESSES

Reviewer 23527

Comment: No major weaknesses to mention. I have a little concern for the relevance of the mud pulse telemetry communication method for reasons previously stated but there should be a reasonable use for this technology in a large subset of drilling fluid environments.

PI Response:

Reviewer 23521

Comment: No tests in water/brine at high temperature were performed for components that will be directly exposed to the downhole fluid.

PI Response:

Reviewer 23519

Comment: The stated goal of only 400 hours is too short for most applications. This is true because tool builders will require the well owner to buy a logging/drilling tool electronics once most of the 400 hours has been expended.

PI Response:

Reviewer 23525

Comment: These weaknesses are minor weaknesses: The investigator does not seem to be prepared to test any of the modules in a high-temperature, wet, and high-pressure environment.

PI Response:

IMPROVEMENTS

Reviewer 23527

Comment: Nothing to add.

PI Response:

Reviewer 23521

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23519

Comment: I suggest, to achieve the most impact from this work, would be to create geothermal well logging and drilling tools using SiC for power devices and front end analog circuits while HT SOI (silicon-on-insulator) for digital circuits.

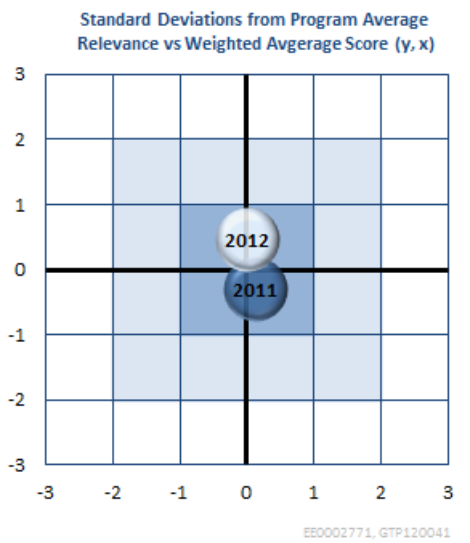
The only comment I offer towards improving the scientific approach is for continued testing to validate or correct for long-term measurement drift. Proving very low measurement drift is essential for success in geothermal well monitoring.

PI Response:

Reviewer 23525

Comment: This is an excellent project, but it was mentioned by other reviewers that the investigator may want to team with one or more of the other participants in the Geothermal Technologies Office in order to source micro-pressure sensors. This would allow a lower-noise pressure measurement to be made, since the micro-pressure sensor may be installed much closer to the circuits, minimizing noise due to wiring.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002771
Project: High Temperature, High Pressure Devices for Zonal Isolation in Geothermal Wells
Principal Investigator: Fabian, Paul
Organization: Composite Technology Development, Inc.
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23397

Score: 3.0

Comment: This project has the potential to have significant impact on the goals of the Geothermal Technologies Office; however, these impacts have not been realized to date in this project. As shown on Slide 5, the ability to isolate zones in a hot geothermal wellbore would be an enabling technology for EGS. Current packer technology will not work at the elevated temperatures found in a geothermal system and this project is designed to overcome the limitations of current packer technology through the use of porous packer material. Therefore, the relevance of this project is rated high. However, the impact of the work thus far is rated low as the accomplishments to date are few and do not demonstrate the ability of this technology to be successful in accomplishing the requirements shown in the top table on Slide 7.

PI Response:

Reviewer 23412

Score: 4.0

Comment: This research has a high relevance to help conformance issues with geothermal, oil and gas, EGS, EOR and waterflood. One of the most innovative research applications I have reviewed.

PI Response:

Reviewer 23471

Score: 4.0

Comment: This project offers a clever solution to the problem of zonal isolation in geothermal systems. Other systems for zonal isolation are also under development by other groups, including the use of chemical diverters to plug fractures that have been opened during EGS shear stimulations so that treatment fluids can target different depth intervals of an open hole. However, chemical diverters will not work for hydrofrac treatments, because the porous and incohesive nature of the diverters means that the plugged fractures will readily reopen once the fracture propagation pressure is reached. Thus, hard mechanical diverters (e.g., packer-type systems) of the type under development here is needed when multi-zonal

EGS treatments have to be accomplished through hydrofracing alone or through a frac-and-shear-stimulation (combined) approach.

PI Response:

Reviewer 23526

Score: 3.0

Comment: This is an interesting project, and can potentially have a significant impact given a number of technical challenges can be overcome. Removable, non-formation intruding plugs/diverters can be a very useful tool for developing geothermal reservoirs.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23397

Score: 2.0

Comment: The limited scientific detail provided to the reviewers may be a result of both the reluctance of the PIs to release data and the limited time given for the presentation; however, there were so few technical details provided it is extremely difficult to assess the scientific and technical approach. The material has only been tested to 88°C and with a differential pressure of 40 psi. The temperature that the system must be able to withstand is lowered in theory by the fact that the porous packing material will allow flow through the annulus, keeping the wellbore cool. However, no consideration was made to the increased amount of flow that the surface pumping equipment must be able to handle during stimulation operations. Additionally, no clear engineering assessments of the deployment and retrieval of the system downhole have been provided. This procedure is not trivial and should be addressed. Finally, the issue of the absolute pressure of the system needs to be addressed. The PI did not know at what maximum pressure that the material had been tested, but indicated that it really had only been tested at 40 psi differential pressure. The downhole system will be at considerably higher absolute pressures and this will surely have an effect on porous polymeric material. The PIs must test this material at elevated pressures in order to assess its viability.

PI Response:

Reviewer 23412

Score: 4.0

Comment: This project has adequate technical approach to determine how the product will behave and how it should be deployed.

PI Response:

Reviewer 23471

Score: 4.0

Comment: The approach being followed here is innovative, in that it would employ a porous compact of polymer particles that would be pumped in place against an upper (or lower) retaining basket, before a releasing agent allows the encapsulating jacket on these particles to expand, forming a permeable barrier. This barrier is being engineered in such a way that it would form a partial barrier to flow, allow creation of a high-pressure treatment zone below the seal, while still allowing enough fluid circulation through the seal to keep it cool and prevent premature failure. This offers a key advantage over traditional open-hole packer systems, which although they seal tightly will often fail as fluid circulation ceases and they heat up. I see this factor, plus the ability of the system being designed here to seal against a severely washed out or irregular borehole, as the key advantage of this system over a traditional (inflatable) open-hole packer system. (Incidentally, the problems associated with hydrofrac bypass and fracturing of the borehole wall by traditional inflatable packers were overstated by the presenter, since these packers are inflated to lower pressures than their differential pressure design limits, but dynamically respond to treatment pressure so that the internal packer pressure tracks the test interval pressure, thereby maintaining a good seal. Packer bypass can occur, but in a reasonably smooth hole the fluid losses around such a packer are usually relatively small.)

PI Response:

Reviewer 23526

Score: 2.0

Comment: While the approach is novel, the presenter may not have a full grasp of the intended application. Very important characteristics of the porous plugging material didn't seem to be well characterized, such as temperature and pressure dependence on porosity/permeability, required flow through rates for cooling the material at high reservoir temperatures, and the overall permeability of the plug itself (200 darcy). It is unclear to me that a fracking pump would be able to build necessary pressures if having to overcome rates on the order of bbls/minute.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23397

Score: 2.0

Comment: This project has completed over two years of work and only two graphs of data and results were shown. Again, the limited scientific detail provided to the reviewers may be a result of both the reluctance of the PIs to release data and

the limited time given for the presentation, but two years and $700,000 of work should warrant much more detail than what was presented. The review presentation indicates that Phase I and II are complete and they are ready to move to Phase III which is the capsule design and manufacture. As a reviewer, I am not satisfied by the technical progress shown in the review presentation and the summary material to agree that the project is ready to move to Phase III. Perhaps more results and data have been shared with the Geothermal Technologies Office (GTO) to warrant moving to Phase III. Flow testing at elevated pressures and temperatures demonstrating the viability of this material downhole as well as detailed engineering specification approved by a drilling and completion engineer are minimum steps that need to be taken before the GTO funds manufacturing efforts.

PI Response:

Reviewer 23412

Score: 4.0

Comment: Accomplishments and progress were very presented.

PI Response:

Reviewer 23471

Score: 2.0

Comment: Progress so far is reasonably good, but project is nearing completion (targeted end date January 2013) and they still have not finalized several key aspects of the design, which still appear to be in the lab testing phase. Also, the temperature limits exhibited by their current polymers (220-230 deg C) will be limiting in some geothermal wells, and higher temperature formulations will be required. Also, results from lab testing done by this group so far indicate relatively small pressure drops (only a few tens of psi) across their polymer compacts under high flow rates in the lab, and much greater pressure drops will be required in actual field practice when trying to reach shear or hydrofrac treatment pressures ranging from hundreds up to several thousand psi. Although longer seal lengths will help, attaining such high treatment pressures will require much tighter (lower porosity) compacts than appear to be in reach at present, pointing to the need for more careful consideration of particle shape and particle size distributions and/or a means for achieving tighter initial encapsulations.

PI Response:

Reviewer 23526

Score: 3.0

Comment: While I do have a few technical concerns which I mentioned in the other evaluation category, I feel that the project is generating good results and making good progress. The accomplishments to date are interesting, have a

isolation capability that is uses such low stresses on the walls can be important. The project will need to demonstrate the technology is an existing geothermal well, at reservoir pressures and temperatures, to prove the concept.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23397

Score: 2.0

Comment: The project management seems adequate for this project; however, more oversight of the relevance of the milestones needs to be taken. Additionally, it is not clear to this point how much input the "Project Collaborators" have had. Listed are Brontosaurus Technologies, AltaRock, and Geodynamics; however, no details of the nature of these collaborations were given. Nothing substantive about these collaborations was provided and thus from a project management standpoint this must contribute to a low rating. Finally, after two years of project time and limited technical results presented, one would look to the project management to keep the project on track.

PI Response:

Reviewer 23412

Score: 4.0

Comment: Project management and coordination with research collaborators and industry collaborators has taken place.

PI Response:

Reviewer 23471

Score: 3.0

Comment: Project management and coordination appears to be good, with a logical design, testing and development approach.

PI Response:

Reviewer 23526

Score: 3.5

Comment: The awardee's project management and coordination activities seem to be in line with program's expectations. I was happy to see that they have a geothermal well consultant on their team, and also that they are in discussions with EGS development sites and researchers.

PI Response:

STRENGTHS

Reviewer 23397

Comment: Current packer technology will not work at the elevated temperatures found in a geothermal system and this project is designed to overcome the limitations of current packer technology through the use of porous packer material. Therefore, the relevance of this project is rated high. The PIs have identified one of the most significant barriers to EGS technology and are attempting to address this barrier through innovative methods of zonal isolation. The idea of allowing fluid flow through the packer material to cool the material and to distribute the forces along a longer distance in the wellbore annulus is innovative and interesting.

PI Response:

Reviewer 23412

Comment: This project has leveraged other mineral recovery from geothermal fluids.

PI Response:

Reviewer 23471

Comment: This is a novel approach for achieving zonal isolation under flowing conditions, amenable to either shear or hydrofrac stimulations. The ability of this system to remain cool during a treatment and to seal against washed out or rough borehole walls is seen as a potential advantage over traditional inflatable, open-hole packer systems.

PI Response:

Reviewer 23526

Comment: The main strength of the concept is the lower borehole wall stresses needed to apply the seal, and also the delivery method to emplacing the capsules.

PI Response:

WEAKNESSES

Reviewer 23397

Comment: Progress on the project to date is limited and the scientific approach is not very comprehensive. The project PIs need to take a more active approach in using the listed collaborators to improve the project as well as identify potential areas of weakness in the approach. Some of the weaknesses listed in this review include the lack of experimental data, particularly at high pressures and temperatures and the lack of engineering assessment of the deployment and retrieval. Also, the PIs should perform a detailed stimulation design using their material to indicate the necessary increase in pumping power during stimulation due to flow through the porous packing material.

PI Response:

Reviewer 23412

Comment: No apparent weaknesses.

PI Response:

Reviewer 23471

Comment: Pressure drops currently being achieved under lab testing are still low relative to what will be required in the field. Thus, more development is needed to increase pressure drops along the seal length, either by adjusting the shape and size distribution of polymer particles or by tightening the encapsulation sheaths.

PI Response:

Reviewer 23526

Comment: Two main weaknesses as I see it. 1) The high permeability of the seal, which may not allow for adequate pressure buildup to allow for tensile or shear failure, during a fracking operation. Seal permeability of ~200 Darcy is greater than many production reservoirs. and 2) Temperature requirements of the seal--both for activation of the trigger and stability. What will happen if circulation is lost and the seal reaches reservoir temperature?

PI Response:

IMPROVEMENTS

Reviewer 23397

Comment: The project PIs need to take a more active approach in using the listed collaborators to improve the project as well as identify potential areas of weakness in the approach. Also, the PIs should perform a detailed stimulation design using their material to indicate the necessary increase in pumping power during stimulation due to flow through the porous packing material. Finally, the PIs must test this material at elevated pressures in order to assess its viability. This is perhaps the most important improvement recommended. If the material loses a significant amount of its hydraulic resistivity under elevated pressures, then this would be a show-stopper.

PI Response:

Reviewer 23412

Comment: No improvements are recommended.

PI Response:

Reviewer 23471

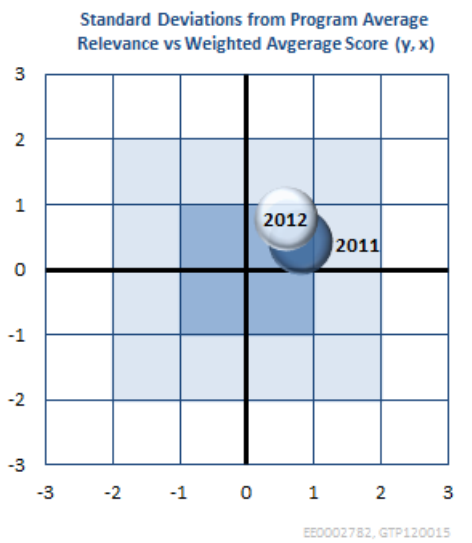
Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23526

Comment: I believe these are captured in my other comments.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002782
Project: High Temperature 300°C Directional Drilling System
Principal Investigator: Dick, Aaron
Organization: Baker Hughes Oilfield Operation, Inc.
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23527

Score: 3.0

Comment: This is a highly relevant project with great potential impact for geothermal applications. It will address many known barriers to the introduction of directional drilling hardware for high temperature applications. This being said, the limited release of technical details associated with the development effort due to proprietary retention of information by the awardee will limit advancement of the industry as a whole. A more collaborative mindset would be more beneficial to Geothermal Technologies Office objectives but this is at least a good step to at least providing enabling hardware to the geothermal industry.

PI Response:

Reviewer 23433

Score: 3.8

Comment: Directional drilling will be an important future component of geothermal drilling systems. It will become more important as knowledge of the reservoir and particularly the extent and orientation of fractures - natural and artificial - become known. The knowledge will be gained by the expected development of seismic and other techniques e.g. measurement while drilling (MWD). In this case, it will be advantageous to drill boreholes so as to intersect the maximum number of fractures, and/or to be able to drill sets of holes so as to be able to establish injection and extraction pairs of wells in a hot dry rock reservoir. In either case, it will be necessary to have a system capable of directional drilling. This project addresses this need in an efficient manner.

PI Response:

Reviewer 23478

Score: 3.5

Comment: This project is highly relevant to the Geothermal Technologies Office goals and objectives. If successful, it will contribute greatly to lowering costs of EGS drilling efforts. The bits, motors, and fluids may also be used in development of hydrothermal projects with similar positive effects on progress and costs. For the moment, the progress

can only be rated as Good Plus... not outstanding. At this time, there has been no real impact on the geothermal industry, but once it is completed, the invention of the metal to metal motor and the resolution of seal-related and coating-related challenges will open doors for deeper, hotter drilling suitable for EGS and deep hydrothermal projects.

PI Response:

Reviewer 23529

Score: 4.0

Comment: The objectives of this program are to develop a directional drilling system including drilling bits, positive displacement motor (steerable motor) and drilling fluid/equipment for 300°C environmental temperature and 10km depths. The development of the high temperature components will have considerable impact for EGS to drill hard and fractured formations.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23527

Score: 4.0

Comment: A comprehensive systems approach has been employed and relevant development areas have been addressed. The approach manages design, development and risk considerations in a balanced manner that will increase the likelihood of project success. Experimental components of the program are focused on the most likely apriori challenges and are being used to manage design decisions appropriately.

PI Response:

Reviewer 23433

Score: 3.8

Comment: The scientific / technical approach is very solid. The investigators have correctly identified the key problems in developing a high temperature drilling system, namely, bit design, motor design and drilling fluid specification. The project has been under way for some time, and significant progress has been made in all areas. The reviewer is particularly impressed with the systematic approach which has been adopted, where the different components of the program are being brought forward together. The project is being run within a company that has a first-class reputation in the design of drilling equipment of this type (bits and motors).

PI Response:

Reviewer 23478

Score: 3.0

Comment: In all ways, the project meets the standards for a "Good" rating. To achieve an "Outstanding" rating, the manufacturing stage should have begun. Still, the scientific and technical approaches appear to be quite sound. There has been very impressive progress made with regard to the machining of tight tolerance machining of the stator and rotors for the motor, the relacement of thermoelastic seals, the development of temperature - stable greases, coatings, and drilling fluids. When all this is proven in a high temperature well, the project will have become a real boon to both EGS and hydrothermal project development.

PI Response:

Reviewer 23529

Score: 3.0

Comment: The scientific/technical approach of developing the high-temperature components is clearly stated and well thought out. The project clearly understands the technical barriers, and has been having good focus such as eliminating rubber components in the positive displacement motor which are not suitable for extreme conditions and improving the seal, lubricant and bearing package for the drilling bits and optimizing drilling fluid solution. The technical path as well as the test plan is shown to be well organized.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23527

Score: 3.0

Comment: Progress has been per plan expectations, but delayed. Critical testing and prototype development is on track and should facilitate the accomplishment of ultimate objectives.

PI Response:

Reviewer 23433

Score: 3.5

Comment: Progress is judged to be very good overall, with significant achievements in the three component areas of the project (bit design, motor design and drilling fluid specification). The investigators have identified a number of potential problem areas (for example, in building a suitable 300 C test stand for testing the motor and the requirement to upgrade the drilling fluid testing equipment.) However, the activities proposed to address these issues are well defined, and it looks at present as if any problems will be overcome.

PI Response:

Reviewer 23478

Score: 2.8

Comment: Again, this would be a strong "Good" rating if the test stand, the bits, and the fluid studies were as far along as planned. The delays of up to nine months suggest that the whole project will not be finished on schedule. I do believe that this will also translate into cost over-runs eventually. Nevertheless, it appears likely that the technical objectives of the project will ultimately be met, if in "stages".

PI Response:

Reviewer 23529

Score: 3.0

Comment: The quality and productivity of the accomplishments/ has been good on overcoming the technical barriers and in relation to the resources. The metal-metal PDM has been designed and the key wear-resistant coatings have been tested. The drilling bits have been designed for the field trials. A drilling fluid that tested at 260°C has been leveraged and reformulated to 300°C. From my point of view, the preliminary design stage is appropriately completed. The final validation of the PDM and the drill bits as well as the system integration will be the key to the success.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23527

Score: 2.0

Comment: The delays are not unreasonable but are unfortunate. Technical delays are in general preferable to resource allocation based delays for a project of this type. This is particularly so because delays in project of this type are typically expected during more advanced stages of prototype and system testing. The manpower based delays to date will therefore more significantly compound future delays associated with hardware testing (which are less predictable).

PI Response:

Reviewer 23433

Score: 3.7

Comment: Management of the project is very good. The various components of the project are being brought along together, and all appear to be well in hand. Various possible snags have been identified and appropriate actions are being taken. Time will tell whether all aspects of the program come together in time for the field trials. As noted above, the project is being carried out in a company that has a long-standing excellent reputation in building equipment of this type, so it is not surprising that the project is coming along well.

PI Response:

Reviewer 23478

Score: 3.0

Comment: It appears as if the project management has been quite adequate, but not flawless. The latter is evidenced by the several delays anticipated. The schedule should have been more realistic to begin with and/or the management should have been more forceful in moving matters forward. From experience, I believe that further delays can be anticipated in the project's interfaces with Alta Rock and Geodynamics as field testing is implemented.

PI Response:

Reviewer 23529

Score: 3.0

Comment: The project did well on coordinating the right resources from multiple organizations and building partnerships. The tasks that were committed for motor and drill bits have three to nine months delay but future plan seems well structured.

PI Response:

STRENGTHS

Reviewer 23527

Comment: The awardee is well versed in the technology being developed and has an established track record of delivering solutions to the drilling community. They also appear to be engaged with with geothermal community (and immediate application uses) further increasing the probability that they will produce impactful work.

PI Response:

Reviewer 23433

Comment: This is a well thought-out project that addresses an important present requirement for the geothermal program, namely the need to drill directional wells. This present requirement will only become more important in the future, as can be understood from the increasing importance of directional drilling in the oil and gas industry. The investigators have chosen to work on a key aspect of the requirement for directional drilling, namely the development of a suitable (and mutually compatible) combination of drill bit, downhole motor and drilling fluid.

PI Response:

Reviewer 23478

Comment: The primary strength of this project is that it is being undertaken by a highly experienced, technically capable firm with many geothermal drilling hours logged over the years. They recognize the drilling needs for EGS progress and cost improvements and their efforts will keep these objectives in the forefront. The project has been broken down into logical phases with adequate Go/No-Go decision points, and steps are being taken to achieve the separate phase objectives in an orderly fashion.

If the timing of activities continues to be adequate or better, the products resulting from this work should be available to the geothermal community by 2014 or so.

PI Response:

Reviewer 23529

Comment: Expertise on drilling system design. Project is well managed and currently delivering to schedule. Budget allocated was sufficient at this point. Quality of deliverables has been good .

PI Response:

WEAKNESSES

Reviewer 23527

Comment: Dissemination of information to the R&D will be limited because of the proprietary claims of the awardee. This information, if available, would accelerate development in general across the industry.

PI Response:

Reviewer 23433

Comment: There is a potential problem in the completion of the 300 C drilling motor test stand as this has a particularly demanding specification.

There is also the potential for trouble in testing high-temperature drilling fluids, since, until the present, tests have been limited (by equipment availability) to 260 C. Both of these issues have been identified by the investigators, so the reviewer has no particular concerns at present.

A further issue involves the life expectancy of the motor in the presence of abrasive particles in the drilling fluid, which will be very likely when drilling hard, abrasive rocks. The investigators are evidently aware of the issue, but it is not clear whether it will become a dominating problem in the future.

The reviewer notes that the development of a complete capability to drill directional geothermal wells will depend on the development or availability of more equipment than is being worked on in this project. In particular, for drilling per se, it will be necessary to have a bent sub, stabilizers and/or other equipment to determine the direction of the hole, and it will be necessary to have surveying instruments capable of measuring the trajectory of the hole. The provision of bent subs should be straightforward, in any case if they are of the passive, non adjustable type. However, the development of surveying instrumentation is an entirely different issue. Surveying (determining direction and inclination of the hole) may be achieved by wireline methods or by measurement while drilling (MWD) equipment (more difficult) but in either case it must be capable of operation in hot, high pressure wells. This is not an area in which the investigators have any capability and so they are wise not to offer to work on any aspect of this issue. However, the managers of the Geothermal Technologies Office may wish to note that the best use of the high temperature bit, motor and mud combination will only be achieved if compatible surveying equipment with equivalent high temperature capability becomes available. Beyond the immediate issue of determining hole direction and inclination is, of course, the additional desired capability for geophysical logging. This will require development of additional high-temperature equipment.

PI Response:

Reviewer 23478

Comment: The only major project weakness appears to be the delays anticipated with regard to the test stand construction and the planned testing. Likewise, there may be further delays in the manufacturing and testing of the bits and bit components. The fluid creation and utilization may also need some adjustments, but these should be minor and not cause major problems. On the other hand, there will be a need for navigation tools to complement the new motors and bits and this tool is not yet available. The Geothermal Technologies Office funding of efforts to remedy this situation should be considered.

PI Response:

Reviewer 23529

Comment: Weaknesses are minor at this point.

PI Response:

IMPROVEMENTS

Reviewer 23527

Comment: No recommendations that were not already mentioned.

PI Response:

Reviewer 23433

Comment: As noted above , the project appears to be progressing nicely, so the reviewer has few suggestions for improvements. However, as noted above, enlargement of the gap between motor rotor and stator resulting from the abrasive action of rock particles in the drilling fluid may seriously shorten the life of the motor. While the investigators are evidently aware of the issue, it might be a good idea to expedite tests of suitable materials combinations to get a view of the scope of the problem at as early a time as possible.

Current motors are provided with a polymer seal between the stator and rotor of the mud motor. This is eliminated in the proposed design, while the machining tolerances have been tightened to reduce the (metal-to-metal) gap between stator and rotor in the new design. Nonetheless, the investigators believe that there may be a substantial loss of motor efficiency as a result of fluid leakage through the gap. This is also a problem in the building of air-free rotary screw air compressors, whose interior design is somewhat similar to that of the moineau mud motor. One solution adopted was to make the male rotor lobes with a small rib on their outer surfaces, whose radius is larger than that allowable for a free fit. When assembled, therefore, these ribs make positive contact with the recesses in the female rotor. During the first few rotations of the compressor, the ribs are therefore crushed until the clearance between ribs and the female rotor is zero. This ensures a completely tight fit. The investigators may wish to consider a variant of this idea in the design of their all-metal motor. The reviewer would be happy to discuss this issue further with the investigators.

PI Response:

Reviewer 23478

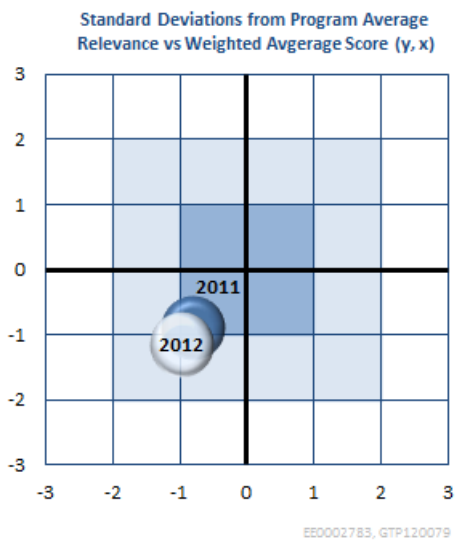
Comment: The only suggestion for project improvement at this stage is that the scheduling should have been more realistic. Beyond that suggestion, I would recommend that all efforts be made to optimally synchronize activities with Alta Rock and Geodynamics so as to minimize future project delays.

PI Response:

Reviewer 23529

Comment: As a general risk for the complicated high-temperature downhole systems, clearance control is always vital to the performance. Make sure the Thermal Expansion Coefficient (CTE) of each component has been considered and the clearances are good for the entire temperature range.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002783
Project: Microhole Arrays Drilled With Advanced Abrasive Slurry Jet Technology To Efficiently Exploit Enhanced Geothermal Systems
Principal Investigator: Oglesby, Kenneth
Organization: Impact Technologies, LLC
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23527

Score: 1.0

Comment: While the capability to economically drill multilateral wells to increase surface area exposure of fluids and volumetric access in EGS applications has great potential value, it is not clear how this project furthers the path to this capability. Fundamental technical feasibility issues associated with the proposed technology are not addressed in this project including the ability to drill in target environment conditions and deficiencies/limitations of surface pumping equipment to meet application needs. Jet and jet-assisted drilling techniques have been investigated since the 1950's and there have even been numerous projects within the last 20 years (many funded by DOE) that have delivered at least jet-assisted drilling systems using coiled tubing that have been tried in the field with modest success. Many of these issues, such as those associated with reliability of the pumping equipment with abrasive fluids are well documented. There are also many issues associated with the use of coiled tubing in the proposed manner, particularly at great depths and in deviated boreholes. None of these issues are addressed. How is this project even an advancement of the current state of the art?

PI Response:

Our current FLASH ASJ (supercritical abrasive) system is very different than the prior systems mentioned. The prior water jet system mentioned required 20+kpsi to cut even moderately soft rock and that was only for kerfing (narrow slots) and not, as we can do, drill a full bore. The old water jet methods also required very high pressures, not sutiable for coiled tubing, and even difficult with jointed connections and dirty enviroments- while we need only low 5000-8000 psi pressures. Other abrasive slurry system required air-abrasive mixture to be delivered downhole to a dual nozzle system- we mix at the surface and pump one abrasive liquid stream downhole that tne convertts to a gas in the downhole nozzle. Some high-rate (80-100 gpm) slurry system are in use today with the known erosion concerns- we use low rate (2 to 20 gpm) and low pressure with controllable erosion rates. We believe that we are targetting research on the key factors needed to advance this new technology. One component, coiled tubing has been very successfully used in Canada and Alaska for drilling laterals. We have much to research and test as we bench test, start drilling shallow and gradually go deeper and into hotter EGS formations. It will take time and money, but we will get there- a step at a time- and not a full jump.

Reviewer 23433

Score: 2.0

Comment: Accessing a large volume of rock from one main borehole is of great importance in geothermal reservoir heat extraction, particularly if the reservoir consists of hot dry rock with a small number of natural fractures. One way of

achieving this objective is to drill several smaller boreholes emanating from a larger initial bore. The smaller boreholes need not be of large diameter, and it may not be necessary (although it might be desirable) to be able to enter them. Drilling of such holes by means of a high pressure abrasive slurry jet may be one way of achieving this objective. An advantage of this technology is that the drilling device itself, namely a nozzle attached to the end of a coiled tubing drill pipe, is very simple, and contains no moving parts. It is thus much easier to make such a drilling device than the more usual system that involves rotating a conventional drill bit on the bottom of the hole. The jet drilling system, with no moving parts, is able to operate more easily than conventional equipment under the high temperature, high pressure conditions that are found in a geothermal well.

PI Response:

We agree that multipe bores or arrays has the potential to provide the necessary EGS performance improvement. The smaller the bore the better to overcome natural fracture paths. We do not need high pressure- cutting hard rocks with only 4000 psi across the nozzle. We agree with everything else said and thereby ask for a higher score for these very reasons given!

Reviewer 23478

Score: 1.5

Comment: The objectives of this project are quite relevant to the Geothermal Technologies Office goals and if successful, the concept could materially increase the efficiency of heat exchange in EGS projects thus lowering costs and increasing investor confidence. Note that I have said "IF" the project is successful. There could be partial successes or technical successes but economic failures.

With respect to impact, thus far there has been no material impact of the work done on this project to the needs and wishes of the geothermal industry. True impact will occur only after the field viability of this concept is proven in deep, hot EGS-type conditions. To date, there have been only lab tests. Not even quarry testing has been undertaken. It is imperative that the drilling technique be tested soon in hydrothermal conditions (i.e. sidetracks) if no EGS holes of opportunity exist. There will still be a long way to go towards this objective even after this project has been completed.

The low score is based on the total lack of impact, despite the lofty and admirable goals and objectives of the project. Patience and money will be required to get to the end of this exercise!

PI Response:

The reviewer is right- we need to get to field vertical and directional drilling in deeper and hotter environments. We also agree that it takes patience and money to make that happen. We have made good progress toward demonstrating the technology in the field. It will take more patience and money to get it into EGS applications, but we are working toward that goal.

Reviewer 23529

Score: 4.0

Comment: The project aims to develop a microhole arrays system in order to increase heat recovery and the efficiency of EGS. The potential benefits of the configuration in reservoir exploitation of the EGS have been evaluated. The FLASH ASJ drilling technology and the entire microholes completion method are innovative and consistent with EGS mission and

goals. If the program can successfully demonstrate the new drilling systems can drill 4-20 times faster than conventional rotary drilling, it will significantly reduce the cost of drilling EGS wells.

PI Response:

We agree.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23527

Score: 1.0

Comment: With the exception of the planned field testing, which may in a very limited capacity shed light on some of the system level issues with the proposed technology, it is not clear how most of the work performed to date facilitates even basic demonstration of feasibility of the proposed concept. The reservoir modeling tasks appear to be of little to no value (and are arguably intuitive) given the basic feasibility questions associated both with the rock reduction capabilities of this technology as well as the deployment of the surface equipment and conveyance method (coiled tubing). They dilute effort without addressing fundamental questions. A more logical staged approach would evaluate the potential of the proposed jet method to reduce rock in expected EGS borehole temperature, pressure and reservoir confining pressure conditions. (There was not much detail on the rock reduction method so it is not clear how the proposed process differs much from what has already been tried in the past. A description of the novelty of this work relative to prior work would have been of value.) The successful demonstration of the drilling technology could then have been followed by a serious conceptual description of the fluid/abrasive delivery system and directional capabilities of the conveyance system (coiled tubing). There have been numerous reliability issues reported with the high pressure pumping systems associated with abrasive drilling applications. Have any of these been considered or addressed in this work? This reviewer would also be interested in knowing the details of the coiled tubing studies performed by CTES. In addition to "pipe bending", numerous other issues associated with this application such as pumping friction losses through the interior of the tubing for the tubing lengths of interest, required flow rates and efficacy of hole cleaning, "lock-up" of the coiled tubing in deep, deviated borehole, etc need to be addressed.

PI Response:

The novelity of this work has been described in numerous documents for the project. Much of the technology is under patenting, thus great detail of each technology could not be addressed. Further it is important to walk before you run, and run before you fly. We are pursuing a systematic approach within each area of the technology development - drilling technology, feasibility issues and EGS potential benefits- but each area worked in parallel. I disagree with the value comment on reservoir modeling- the optimal configuration of the array, bore size, flow rate per bore and length of each bore of the microbore array is important for setting the drilling parameters. The modeling can help quantify the EGS benefits that can be derived from microhole arrays. Next, we do want to bench test at EGS conditions for the cutting action, but bench tests at those conditions is very costly and we quickly determined that hot 500F rock bench tests then field testing at ever deeper and hotter conditions were better demonstrations. We are fully aware of most all abrasive pumping technolgy as we just received our new patents on multiple methods of slurry pumping. We are early in this research and testing, so it will take time and money to make it happen at EGS cnditions, but we will get there.

Reviewer 23433

Score: 1.5

Comment: The heart of the drilling system is the jet nozzle through which a slurry of abrasive particles is directed at the rock face. Little detail is given as to how this actually functions, apart from the observation that the fluid carrying the abrasive particles is in a super-critical condition. Some work has been done to verify that supercritical fluid/abrasive slurries are capable of drilling hot rocks, but few details are given. There is an implicit assumption that the drilling device will work, allowing the investigators to concentrate on other aspects of the system. These other tasks include the identification of suitable tubing for the drill pipe, evaluating suitable carrier fluids and making hydraulic calculations concerning the fluid mechanics of fluid and abrasive particle movement to the drill nozzle (at depth) and evaluating the ability of the coiled tubing to sustain various bending loads while in hole. In addition, work has been done on the on-site generation of the carrying fluids, and studies have been made concerning the efficiency of heat extraction from various configurations of borehole in the reservoir. Work has also been done to identify means for directing the orientation and inclination of the jet-drilled holes as they leave the parent borehole, but this work appears to be theoretical at present. The investigators are carrying out all of these elements of the project simultaneously and apparently successfully, but no actual field tests have been carried out. It is thus premature to say whether the entire system will work or not. Previous work on a similar system using high pressure water without abrasives was not very successful.

PI Response:

Agree with all the earlier task descriptions. Field tests are required and we are working toward that direction as fast as possible. One correction- we are not utilizing high pressures- we only need 4000 psi across the nozzle to cut even Basalt- a vast improvement over prior high pressure water systems.

Reviewer 23478

Score: 2.5

Comment: This is a very complicated endeavor, and the principals have structured their approaches to evaluating the many components of the proposed system adequately. There are many technical challenges to meet and overcome, and the team appears to be systematically working in at least two parallel paths to address the theoretical and the practical parameters.

Thus far, almost all the work has been theoretical, with little practical application accomplished. With only 26% of the budget remaining, the most expensive field work lies ahead. My initial impression of the planned schedule for conduct of field studies of the drilling is that it is marginally realistic and very optimistic. As is well known, very few drilling-related time schedules are met and this project is so complex, that glitches are bound to occur.

One more thought, without the availability of navigation tools, it may be that the drilling of 40-80 microholes emanating from one bore will result in fluid short circuits, intersecting holes, and rapid depletion of the heat-in-place all to the detriment of the project.

PI Response:

We agree with the fair assessment of the project goals and the current budget limitations on getting into the field. Instead of a quarry test we will drill in our yard to avoid high mobilization costs. In the last paragraph, we disagree that hole would necessary intersect as they are spaced widely (vertical and horizontal). Even then the balancing nature of the microbores (if small enough) would still balance out the flows if intersections occur.

Reviewer 23529

Score: 3.0

Comment: The technical approach is clear and effective in terms of addressing knowledge gaps. The program evaluates and further develops the FLASH ASJ microhole drilling system in order to make it compatible with EGS specs, and designs arrays layout by using numerical evaluation to optimize the heat removal from the hard rocks. The program has good focus with identifying the heat exchange configurations, FLASH fluids, nozzle design and reservoir simulation, and has good collaborations with the right resources.

PI Response:

Thanks.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23527

Score: 2.0

Comment: Project objectives to date appear to have been met, however, for reasons mentioned in the Technical Approach section, it is not clear that any of the relevant technology and system feasibility issues have been addressed.

PI Response:

We have overcome significant pumping issues, nozzles issues and obtained meaningful bench test results, but no field tests yet- maybe this June. Of course we wanted to be further along than we are now, but it is research.

Reviewer 23433

Score: 2.5

Comment: As noted above, this is a complex project with a requirement to advance many aspects of the project simultaneously. Definite progress seems to have been made, but it is often difficult for the reviewer to determine how much has actually been achieved. For example, it is stated that that bench tests have demonstrated that "supercritical fluids with abrasives can efficiently cut rocks at 400 F fluid temperature with different configurations." However, no data are presented to show what rates of penetration were achieved, how much fluid and abrasive material was needed, and what sort of a borehole was produced. Meanwhile, work has gone on to model the heat flow to the borehole under various scenarios; to investigate possible limits imposed on the drill pipe; to investigate various means for steering the hole; techniques for generating the required fluids; and investigating safety issues. In most cases, although it is stated that the work has been begun, or possibly even been completed, it is difficult to evaluate how much progress has actually been made. Apparently no actual field tests have been carried out; such tests are bound to throw up unexpected problems, so until some real field work has been done, it is premature to say that the project is successful.

PI Response:

Agree that we have only performed bench tests and no field tests. In nozzle optimization bench tests slots are a better indicator of performance, which we have been doing on sandstones and granites. Also we just had the patent approved in the US and are working on patenting it in other countries- so we had to be somewhat reserved. We are not as far along as we had hoped, but we are working on performing field tests (500-1000 feet) in our yard area in June 2012.

Reviewer 23478

Score: 2.0

Comment: Thus far, all accomplishments have been in the realm of gathering the information required to determine what tools and materials will be needed to implement the proposed drilling techniques and to initiate simulations of the results of the microhole array use in an EGS environment. All is theoretical and only a few accomplishments have been "practical" i.e. related to the hardware needed to do the field work.

Progress is certainly being made in modeling, the identification of optimum gasses, and nozzle design, but the field work will be much more time-consuming than that allotted and it will be difficult to complete this project, with all objectives achieved, by mid 2013.

PI Response:

Agree to much of the comments. We have made good progress on "practical' equipment/tools and processes needed for the full system, but the system involves many different components and processes. We have solved many, many problems in using this new technology. We are pushing for a 'field' test in our Impact yard in June 2012 and what other field tests can be performed.

Reviewer 23529

Score: 3.0

Comment: The quality of the accomplishments and results has been good with respect to the resources expended. The simulation with Dual-K model for the microhole arrays demonstrates better heat transfer efficiency. Multiple nozzle configurations were studied and validated to be erosion resistant. Multiple FLASH fluids were evaluated for the extreme EGS conditions as well. More test data are expected in the next few months.

PI Response:

Agree with all comments made.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23527

Score: 2.0

Comment: For reasons mentioned previously, the planning of this project does not seem to have significantly furthered the goal of feasibility assessment of the technology. Some of these questions could have been at least conceptually covered using established approaches. For example, many of the questions associated with both pumping and deployment of the coiled tubing could have been explored via studies performed with standard CT simulation packages which are routinely used to plan CT pumping jobs. Some studies were apparently commissioned but it is not clear that the right questions were asked or considered from the system perspective. Only "pipe bending" studies are mentioned. Another point worth mentioning in this context relates to hole cleaning. The flow rates mentioned through the nozzle with respect to required gas production rates at the surface using a membrane or other generation system seem quite low for hole cleaning purposes. In essence you have two mutually competing objectives in this case, a potentially high flow rate required for

hole cleaning with a preferred low flow rate for rock reduction and gas production at the surface. These types of fundamental questions and concerns should have been more clearly defined as described in the work. If they were covered it was not obvious from the provided material.

PI Response:

CT pumping, system hydraulics and hole cleaning were studied and reported and the results delivered to the GDR. Standard CT programs will not simulate the phase dependent/ compositional system required, therefore we used the SPT Wellflow program that can more closely model such systems. Indeed there is a competition between cutting/drilling and hole cleaning and erosion. That was the reason for the hydraulic study, but not much slide space nor time was allowed in the presentation to go deeply into that aspect or findings. We are sorry that we did not make those findings clearer. We feel that much of those concerns have been answered for most of the operating range desired. Foams, also researched in this project, will be needed to obtain the full operating range desired.

Reviewer 23433

Score: 2.5

Comment: As noted above, this is a complex project with many components. The reviewer notes that progress is apparently being made in all aspects of the project, but it is not entirely clear how much has been achieved. It is understood that no actual field tests have been carried out, so that it is difficult to assess how well the different components of the project are being brought together. The work at Lawrence Berkeley National Laboratory (LBNL) is continuing more or less independently and apparently successfully. The reviewers only comment in this respect is that it might have been more prudent to establish that the drilling method actually works before engaging on complex modeling of heat flow in the reservoir.

PI Response:

The drilling was proven in bench tests earlier, thus the push for more optimization bench tests and modeling aspects. We wish that we had gotten into the field before the meeting, but that yard test should occur in June 2012.

Reviewer 23478

Score: 2.0

Comment: The listed number of team-management contacts (quarterly) seems far too few, even though the PI has said that there are additional calls and e-mails. The budget status is claimed to be "on target", however, the most expensive parts of the project are still to be accomplished in 2012 with only 24% of the funds left. The project has already experienced delays in connection with the bench tests and the CT pipe bending studies and I fear that more delays will occur during the bench and field testing operations (as such delays are almost routine in the drilling business).

I am not sure that this is an optimum management team for dealing with such a complex project. There are too many topics being studies all at once. This situation will only worsen during the field drilling and I am concerned that only a few of the team members have significant hands-on drilling experience.

PI Response:

Agree with this being a complex project with many components and all being worked simultaneously. The limited remaining budget is forcing the field tests to be performed in our yard. We do want more experienced drilling team members in the future, but with the industry so busy, few are available.

Reviewer 23529

Score: 3.0

Comment: Regarding the project management, every task that was committed looks to be on schedule, if not slightly delayed. The resources that were coordinated and the budget spent are both in good positions.

PI Response:

Thanks

STRENGTHS

Reviewer 23527

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23433

Comment: This is an ambitious project that is attempting to develop a complete drilling technology and simultaneously to demonstrate that the chosen technique, namely that of drilling multiple small diameter boreholes emanating from one central bore, is capable of extracting heat from a geothermal reservoir at lower overall cost than existing, more conventional techniques. If this can be achieved, it will represent a major advance in the technology of geothermal energy extraction. Even if it is not universally applicable, but can only be shown to be economic in a limited number of cases, this will be a worthwhile advance. It may also be that the entire system can not be shown to be economic, but even in that case there are a number of sufficiently interesting new techniques being investigated (for example in modeling the heat flow to the borehole from the reservoir) that will, in isolation, be worth having.

PI Response:

Thanks

Reviewer 23478

Comment: The only strength that I can see for this project is that its concept is "out of the box" and that is good, because it pushes the envelope and could some day result in new drilling techniques with, hopefully, dramatically higher ROPs, lower costs, and improved heat exchange all with regard to EGS development. Innovative thinking is good for the industry and the involvement of intelligent R&D specialists who are relatively new to geothermal is also welcome.

PI Response:

Thanks

Reviewer 23529

Comment: Collaboration with the right resources. Risks have been controlled and mitigated. Expertise on FLASH drilling system

PI Response:

Thanks

WEAKNESSES

Reviewer 23527

Comment: The tasks and accomplishments of this project do not address fundamental questions associated with the proposed drilling method and deployment of associated system hardware.

PI Response:

We did what was possible with the money and time available. We do want to do more.

Reviewer 23433

Comment: The investigators are aiming to develop an entirely new technology for extracting heat from a geothermal reservoir. To do this, it will be necessary to find solutions to a number of questions. First and foremost, it must be demonstrated that drilling with an abrasive slurry jet is feasible and economic. Issues here include being able to mix and convey the slurry from surface to the drill head. Can this be done over some thousands of feet without the slurry separating?

Can the slurry be passed throughout the jet nozzle without causing excessive wear? How effective is the drilling process when there is a substantial back-pressure outside the jet nozzle (i.e. when drilling at depth)? What shape of borehole is produced? Prior experiments with water jets have shown that very irregular shapes are often produced. How is the drill bit to be advanced into the hole? Experiments with water jet devices have shown that the drilling nozzle has to be fed into the hole in such a way that it makes a hole that is neither too large or too small - since the cutting process is "stand off" the bit cannot be allowed to contact the hole bottom. How will the cuttings and the spent slurry be recovered? Are they lost into surrounding fractures causing plugging? How is the borehole to be steered, and how will the operator know where the hole has gone if it is too narrow and/or irregular for it to be logged? If for some reason, the flow of abrasive-laden fluid has to stop while drilling is in progress, will the abrasive particles sediment to the bottom of, respectively, the drill pipe and the annulus? No description was provided of the device that will enable the jet drilled hole to kick off from the main borehole. Has this question been addressed? During the nineteen eighties, much work was done on a very similar jet drilling concept (except that water rather than an abrasive slurry was used for drilling.) This project had to grapple with many of the problems noted above, and was ultimately not adopted to any great degree.

In the case of the modeling of the heat flow from reservoir to borehole, how can one take account of a network of existing fractures (particularly if one cannot enter the jet-drilled holes to find if fractures have been intersected?) Prior experience

of trying to extract heat from systems with multiple injection and extraction paths has shown that it is easily possible to have short-circuiting in which the bulk of the fluids flow along only a few paths, thus decreasing the overall extraction of heat. All of the above comments lead the reviewer to believe that the project is very risky, since failure to come up to expectation in many of the areas designated will seriously reduce the value of the project.

PI Response:

Many very good questions. We are fully aware of the prior systems in that some of our patent inventors were instrumental in development some of that prior art. The prior waterjet art had problems with high pressures (joint issues and not compatible with Coiled Tubing)- which we only need moderate 5000-8000 psi pressures. Water jets require high flow rates and cut narrow slots in hard rocks and wash out soft rocks- we cut at low rates and low pressures and we cut full bores. Erosion is much less with our low rate system than prior high rate slurry systems.
Using the proposed well configuration (with multiple injection points and conventional production well), the risk of flow short-circuiting is reduced. The large total length of (uncased) microholes combined with self-regulation lead to substantially more flow paths compared to a conventional well configuration with a few feedzones intersected.

Reviewer 23478

Comment: The primary weaknesses in this project are its complexity , the inability to accurately steer the microholes, inconsistent feed rates and consequent frequent changes in hole diameter, and the need to identify all the tools and materials required for success. These weaknesses are so classified in light of the limited funds and time available to achieve stated objectives. If there were to be more money and more time allocated to the project, the weaknesses would be of minimal importance.

The PI and the team members are, no doubt, highly qualified in their respective fields, however, there is no statement given regarding their drilling and field experiences. Accordingly, an assumption is made that drilling and field work are not their strong suits. This will be a weakness unless other, experienced workers join the team for the field work.

Also, there is no deep drilling planned for this project, therefore all parameters have to be taken from data recorded in EGS fields such as that in Soultz, which parameters may or may not reflect conditions elsewhere.

Finally, there is the safety issue. Handling of super-critical materials is always dangerous and it might be more so in a field environment. The PI states that safety and environmental topics are being given much consideration, but the fact that this is necessary, constitutes a project weakness in my opinion.

PI Response:

The PI has considerable drilling experience in the oil and gas industry, having drilled offshore, onshore and at 22,000 feet in Louisianna. However, more experienced drilling team members would be welcomed. Energized abrasive systems for Impact will always be a safety concern and will always be held in great regard. DUe to budget limitations, no deep drilling was planned for during this project. We will some day…….

Reviewer 23529

Comment: Weaknesses are minor at this point.

PI Response:

Okay

IMPROVEMENTS

Reviewer 23527

Comment: Nothing to add to preceding statements.

PI Response:

Okay

Reviewer 23433

Comment: A major improvement to the project, that would inspire confidence that it will come to a successful conclusion, would be to address some of the questions sketched in the previous section. In particular, it is important to establish how effectively the jet-drilling system is able to make hole. If this cannot be done, then the entire project is called into question. Subjects for serious study include finding how fast the drill can advance in typical reservoir rocks, and whether this rate of penetration can be maintained in the presence of a back pressure typical of a geothermal well (some hundreds if not thousands of psi.) What is the observed rate of erosion of the nozzle? What will become of the spent abrasive, and can it be recirculated back to the top of the hole? What is the shape and size of the borehole? How is the bit to be fed into the hole in a controlled manner, with control from the surface many thousands of feet away? If the coiled tubing has to be bent in order for it to pass out of the main borehole, how will it be straightened again to allow it to drill forward in a straight line? All of these questions should be addressed as a matter of urgency.

Concerning the modeling of heat flow, some thought should be given to the likely practical system, with the possibility that the reservoir contains a number of distributed fractures that may completely dominate the flow situation.

PI Response:

All good questions, some of which have already been tested and documented. Agreed that a field test of vertical drilling would mean much to the development- and we want to do it as soon as possible. Other good questions must be answered later- probably not within this project. We will drill in an underbalanced condition and thus lower back pressures for more optimal drilling conditions for our FLASH ASJ sytem. Nature gives us the fracture system that we have and we must adapt to it. The use of a microhole array reduces the impact of hitting a single, dominating feature, which is indeed a main drawback of a conventional well configuration.

Reviewer 23478

Comment: It is too late to modify the project significantly, but in my opinion, strong emphasis should be put on completion of the bench tests as soon as possible, followed by whatever field tests can be accomplished at high temperatures and pressures. If these procedures are not implemented quickly, I fear that but time and money will run out without meaningful project results accruing.

PI Response:

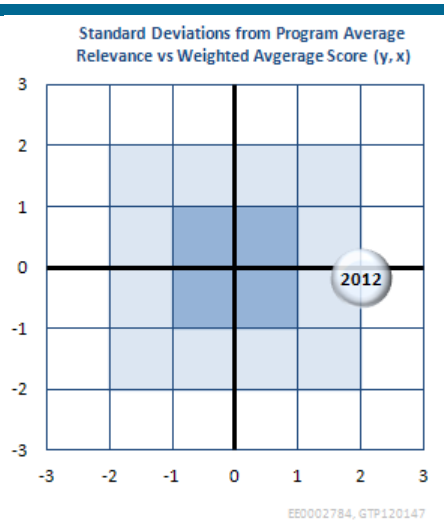
Agree fully and it a concern of the team.

Reviewer 23529

Comment: The project clearly states the strategies toward EGS direction. The overall assessment of this program has been good. It may just need to focus more on getting the firsthand experimental data.

PI Response:

We are focused now on minimal bench testing and getting to vertical coiled tubing drilling demonstrations as soon as possible.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002784
Project: Stinger enhanced bits for engineered geothermal systems (EGS)
Principal Investigator: Hall, David
Organization: Novatek, Inc.
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23527

Score: 2.0

Comment: The level of investment in this project seems relatively high considering that it is largely an adaptation of existing technologies and has the modest goal of increasing ROP 3-fold over conventional drilling systems. It does not appear at the moment that the technology holds particularly great promise for improving geothermal drilling economics. Many of the issues experienced in field trials to date resemble issues typically associated with the use of PDC bits in hard rock formations and one of the identified causes of bit failures (drilling parameters not suited to this particular type of bit) is also a well-known cause of failure for PDC bits. Thus little novel understanding seems to have resulted from this project. It is in many ways a reconfirmation that bits utilizing drag-based cutting mechanisms are susceptible to vibration induced damage. The use of the center indenter is novel but it is unclear if this feature actually improved performance in any meaningful way.

PI Response:

Reviewer 23433

Score: 3.5

Comment: This is a very important project. A major current limitation in the economics of geothermal well drilling is the low penetration rate and short life of drill bits. The issue becomes progressively more important as the well depth increases, since rock hardness increases and tripping times become longer. Roller cone bits have low rates of penetration in hard rocks while PDC bits are susceptible to high rates of wear, particularly under conditions of shock loading where tooth chipping or fracture become important. This problem is particularly acute in geothermal wells, that typically are intended to intersect volumes of fractured rock. Thus, any new development that promises either or both increased rate of penetration and increased bit life is extremely important.

PI Response:

Reviewer 23478

Score: 3.0

Comment: This project is relevant to the Geothermal Technologies Office objectives inasmuch as it is likely to make deep, hot drilling somewhat faster and cheaper assuming that the ROP and bit life objectives are met. The impact on the geothermal industry and on EGS development will not be earthshaking, but it will be contribute somewhat, since deep, hot wells are very expensive to drill. Also, the steer-ability of the bit suggests that it will have strong applications on all wells having multiple completions and/or kick offs.

PI Response:

Reviewer 23529

Score: 3.0

Comment: The program aims to develop a Stinger Enhanced Jack Bit that will increase the rate of penetration (ROP) by 3 times over conventional rotary drilling systems at depths to 10km and temperatures up to 300 C. The project aligns with the EGS goals of providing faster overall ROP and well construction and reducing the drilling cost.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23527

Score: 2.0

Comment: There was not much detail in provided material concerning the technical approach. It appears to have been largely an experimental effort with extensive testing of a variety of bit designs in laboratory and quarry-type conditions. Bit testing in the laboratory and the field are the ultimate proving grounds of the technology but it may have been beneficial to combine the testing effort with a complimentary analysis effort. If this was done it was not clearly stated. Many of the theoretical models used to describe self-induced vibration of PDC bits appear to be relevant for the stinger bit cutting mechanism as well. The development and use of these models may have been helpful to better understanding appropriate drilling parameters that mitigate vibration as well as optimizing bit designs to enable operation with a wider range of acceptable drilling parameters. While the development and testing approach used is ultimately required to prove the technology, hardware development and testing tends to be expensive and analytical efforts, particularly in the design and post-experiment evaluation stages, can help reduce associated hardware costs by improving understanding of the behaviors of the technology.
PI Response:

Reviewer 23433

Score: 3.6

Comment: Design styles of roller cone bits appear to have reached a point of very slow evolution; although there are steady improvements in materials, the basic design of roller cone bits - either milled tooth or carbide insert bits - is evolving very slowly. In particular, there appears relatively little prospect of increasing their rate of penetration. As regards PDC bits, again, the basic "wafer" design of the PDC cutters is also developing only slowly, and they remain at risk for damage by chipping under shock loading in hard rocks. The current approach, using a PDC cutter of novel conical design, is therefore seen as a very important new development. The design of the cutter is such that the conical point, by concentrating the load on a small area, is capable of high penetration in hard rocks, while the support provided by the widening area of the cone behind the cutting point provides help to resist chipping and fracture.

PI Response:

Reviewer 23478

Score: 4.0

Comment: The best thing about this project is that the PI's firm is just doing what it does best: it is designing, engineering, manufacturing and then testing (in house and in the field) multiple times until the end product is acceptable. This is not rocket science for Novatek. They are trying various designs, variously treated diamonds and various insert configurations. Then they give them out in the Oil Patch where they are tested and then rated for ROP and wear characteristics. Then the whole procedure is repeated until the objectives are achieved. This is the way R&D should be conducted!!

Despite what the presenter claimed, I can not believe that a single hydrothermal well would not be available in which to test these bits. It seems somewhat unproductive to be doing all the field testing in oil and/or gas wells having softer formations and offering little in the way of heat or pressure challenges.

PI Response:

Reviewer 23529

Score: 3.0

Comment: The scientific/technical approach of the project is straightforward. It focuses on the general engineering design iteration of a product, and testing and optimizing the corresponding hardware. The program has identified the technical challenges including improvement of the diamond's inherent brittle nature and thermal limitations, improvement of the wear and breakage at low WOB and high speed etc. in order to drill hard rock formation for EGS well conditions.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23527

Score: 2.0

Comment: It appears that much testing was done for this project with little in the way of encouraging results. This is the nature of R&D of course as sometimes conceptually promising technologies do not pan out. So, while significant effort was obviously put into this project and many results were obtained, they do not appear to have appreciably advanced the goal of developing a drilling technology with the potential to significantly improve the economics of geothermal drilling. The technical detail of the results was also relatively sparse in the provided material. It is assumed that more detailed description of the bit design characteristics, experimental drilling parameters and experimental results/data will be made available in the DOE Geothermal Data Repository. This data will be of value to the segment of the geothermal research community engaged in drilling research. Since the cutting mechanism of this bit type appears to be somewhere in between the shearing mechanism of a PDC bit type and the crushing mechanism of a roller cone it would be interesting to use test data to perhaps fine tune simulation tools used to describe cutting mechanics. Also, the use of the center indenter to stabilize the bit is an interesting concept but little description was given of the experimentally proven value of this feature. Were tests performed of the stinger bit with and without the center indenter? If not, such tests would seem to be appropriate for helping determine if there is value to bit feature.

PI Response:

Reviewer 23433

Score: 3.7

Comment: The results obtained so far are very encouraging. The project has already progressed to the point of running limited field tests (although not in a geothermal well.) These have shown that the new design of bit can out perform conventional diamond-enhanced roller cone and fixed-cutter (shear) bits. A very interesting observation is that whereas conical inserts operate better than hemispherically domed inserts in drag bits, they do not do so well when placed in conventional roller-cone bits. This is evidently due to the lower resistance of the conical design to sideways shock loading. It implies that the conical inserts will perform better and better as the indentation direction is closer and closer to the cone axial direction (see further comment below). It is also interesting to learn that substitution of thermally-stable (leached) diamond material in place of the conventional cobalt-containing composites appears to have relatively little effect in improving performance. This is interesting because it implies that there is relatively little sliding friction of the conical points against the rock, at least by comparison with drag type bits. This in turn suggests that the cutting process is very efficient.

PI Response:

Reviewer 23478

Score: 2.5

Comment: Novatek has been able to design, engineer, manufacture, and test a large number of bits to date, both in their on-site labs and in the field. The results vary considerably, but at least two of the Stinger bits ranked 3rd and 4th out of 17 trial bits with regard to efficiency in drilling hard quartzite. One bit drilled 2700 feet of moderately hard limestone without wearing out totally.

Photographic evidence was shown confirming the lab and field results are comparable, thus showing the validity of the PIs lab testing.

Novatek indicates that their Stinger bit is capable of steering the equivalent of 17 degrees per 100 feet. This is incredible. They also show, in photographs, that the Stinger bits are "challenged" by impacts when used in roller-cone bits and/or run with to light a WOB and at to high RPMs (both parameters that are preferred by drillers).

The accomplishments to date are good, but almost all of the money available has been spent. They claim to be 85% completed, but 98% of the money has been used. Can they do the remaining 15% with 2% of the funds? This situation requires that the score be downgraded from a 3 to a 2.5 in my opinion.

PI Response:

Reviewer 23529

Score: 3.0

Comment: The quality and productivity of the accomplishments/results of this program have been good. As general comments, the project has been doing well in rapid identification of failure modes of its bit designs and weaknesses in the application and then moving forward to the next development iteration - around 40 bits have been tested according to the presentation. The technologies and stinger bit developed in this program would potentially overcome the technical barriers but I would be more convinced if the new bit can be tested in the hard rock formation instead of conventional oil and gas wells.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23527

Score: 3.0

Comment: Not much detail was given here but the management of the project appears to be reasonable given that the researchers were able to design, fabricate and test a relatively large number of bit configurations. (I seem to recall the presenter mentioning 14 bits having been made and tested during the presentation?) Given the magnitude of the investment it may have also been prudent to introduce performance milestones at various junctures of the project that could also have served as evaluation points to determine if continued funding of the effort is justified based on accomplishments of the work and revised expectations of the potential performance of the experimental technology.

PI Response:

Reviewer 23433

Score: 3.5

Comment: The approach being employed by the investigators, of rapid cycles of testing, evaluation and improvement is seen as a particularly effective strategy in the present case. While our understanding of the mechanisms involved in the wear or fracture of cutting tooth materials is evolving steadily, the practical considerations involved in obtaining an optimal balance between rate of penetration and rate of wear (both steady-state abrasive wear and fracture damage due to shock loading) are still too complex to allow a purely theoretical approach to displace a program of experimental testing. Thus a rapid cycle of test - evaluate - redesign - re-test is seen as a very efficient way of making progress.

PI Response:

Reviewer 23478

Score: 2.8

Comment: This project is moving forward well, but there are only minimal indications of decision points and/or milestones within the course of project management. On the other hand, there has obviously been adequate coordination between Novatek and Oil Field Service Companies so as to get the prototype bits field tested. There are also appropriate plans to commercialize the bits in 2012 as well as to gain bit exposure in geothermal and EGS environments in 2012.

I would not say that numerous management improvements are needed, but the activities fall slightly short of those needed to score a 3.0 (Good).
PI Response:

Reviewer 23529

Score: 3.0

Comment: The project management is seen to be effective and well carried out. It would better if the project can put more effort on identification of EGS test fields where the hardware can be further validated on hard rock. The budget doesn't seem to be adequate with respect to the remaining tasks.

PI Response:

STRENGTHS

Reviewer 23527

Comment: The research team has extensive experimental drilling experience and strong capabilities for evaluating the performance and condition of drilling hardware components.

PI Response:

Reviewer 23433

Comment: The project is being carried out within an organization that has a solid reputation for making regular improvements in diamond bit technology, particularly in regard to the diamond materials themselves. Progress on the present project is consistent with this track record. Overall, the basic concept of the conical "stinger" bit tooth appears to be very promising, while the execution of the program, based on the short cycle test – improve – re-test approach is allowing a rapid improvement in test results.

PI Response:

Reviewer 23478

Comment: The primary strength of this project is the well documented experience of Novatek and its excellent connections within the drilling industry. This allows the company to efficiently design numerous versions of the Stinger bit and to test and have tested the products in the Labs and in the field. Once the optimum bit design has been achieved, this project will contribute to ROP and Bit life extensions and thus save time and money when drilling deep, hot, high pressure wells, both hydrothermal and EGS.

PI Response:

Reviewer 23529

Comment: Expertise on drill bits design and tests

Risks have been controlled and mitigated

PI Response:

WEAKNESSES

Reviewer 23527

Comment: As mentioned earlier, a complimentary analytical effort may have been beneficial to the project, particularly in the design and post- experimental evaluation efforts of the project.

PI Response:

Reviewer 23433

Comment: As soon as organizational issues can be resolved, trial bits should be run in a geothermal well.

PI Response:

Reviewer 23478

Comment: The main weakness is that 98% of the funds have been spent to date without having any bits tested in geothermal or EGS environments. The project is only 85% completed, but has only 2% of the funds remaining. So far, the lab and field test results in the Oil patch have been quite encouraging, but the real tests, in hostile conditions, remain ahead and need to be done in 2012!. Furthermore, the suitability for use of Stiner bits in Roller Cone bits still appears to be questionable. Will there be money enough to design new versions that will be acceptable for this purpose? Also, it remains to be seen whether Novatek can convince drillers to try the required low WOB/high RPM protocol needed to optimize stinger bit performance.

PI Response:

Reviewer 23529

Comment: Weaknesses are minor at this point. But as aforementioned, the reviewers would have more confidence on the outcomes of the coming year if the program could have tested on hard rock formation.

PI Response:

IMPROVEMENTS

Reviewer 23527

Comment: Nothing to add to what has already been said.

PI Response:

Reviewer 23433

Comment: It was noted above that the conical inserts behave extremely well if the indentation direction is directly parallel with the cone axis. This view is reinforced by the drop/impact test results. If it is possible to make a conical insert in which the cone axis is somewhat inclined to the axis of the cylinder that provides the insert anchoring surface in the bit, it would be possible to arrange the cone axis of the insert to be more nearly parallel to the hole bottom. Ideally, the cone axis direction might be inclined so that it is directed parallel with the actual tooth trajectory into the rock i.e. pointed along a spiral path with pitch equal to the bit advance per turn. This may be a too simplistic view, however, as the rock below the penetrating cone will be stronger than that above, then requiring that the cone axis be directed somewhat below the purely spiral direction.

PI Response:

Reviewer 23478

Comment: The only improvements that come to mind are: 1) get busy using bits in geothermal wells (hydrothermal and EGS) as soon as possible, and 2) attempt to collaborate with scientists familiar with modification of diamond molecular structure and/or creation of other super-hard, tough materials so as to help overcome the impact-related problems with Stingers and inserts in Roller Cone bits. Achievement of ROP increases greater than 3 times the current ROP should be an expanded goal.

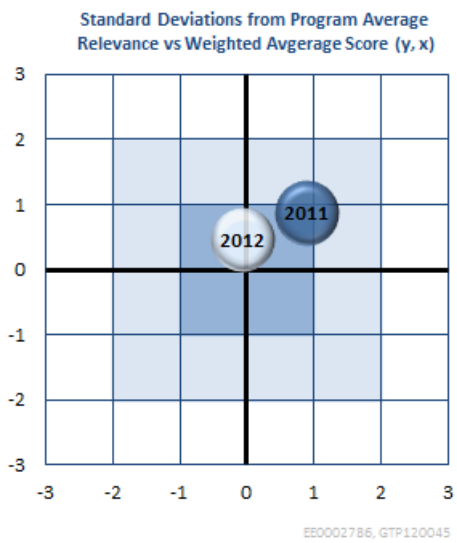
All of this will have to be done with only 2% of the originally allocated funds available!

PI Response:

Reviewer 23529

Comment: Reviewer did not provide comments for this criterion.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002786
Project: Complete Fiber/Copper Cable Solution for Long-Term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells
Principal Investigator: Lowell, Mark
Organization: Draka Cableteq USA
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23525

Score: 4.0

Comment: The relevance and impact of this project is extremely high, since a successful project will lead to the commercialization of the necessary high-temperature fiber and optical cable for data acquisition in supercritical environments. Such environments attack cable in myriad ways, and the investigator is anticipating all the forms of attack, and is taking measures in the design of the cable to defeat those attacks.

PI Response:

Agree.

Reviewer 23568

Score: 4.0

Comment: Developing fiber optic and copper cable to 300°C is essential to logging and monitoring geothermal wells.

PI Response:

Agree.

Reviewer 23471

Score: 3.0

Comment: The development of a hydrogen-resistant optical cable for continuous monitoring of temperature in a high-temperature geothermal well is a key development needed for monitoring EGS stimulations and keeping track of fluid inflow/outflow zones. This alone would mark an important contribution from this project, but an additional aspect of this project is incorporation of a robust, fiber-optic system into a (more traditional) electro-mechanical cable, onto which an electronic pressure/temperature sensor can be attached. However, some aspects of this R&D effort were poorly motivated in this presentation, which would have benefited from a clear statement of the state-of-the art in the various areas under development. For example, efforts are now underway by other companies to develop fully fiber-optic systems for discrete measurement of temperature and pressure downhole; do these types of alternative approaches negate the need for a heavy electromechanical cable of the type envisioned here and, if not, why not? Could a single- or multi-mode fiber accomplish both the distributed temperature and discrete temp/pressure measurements needs of this system at lower cost/risk?

PI Response:

Yes, the alternative approaches could ngate the need for the electrical component of the cable. The electrical component could be left out. This work is not solely directed at a combined electrical and optical fiber cable. The advantage of the combined effort is that any option is covered. Yes, a single- or multi-mode fiber cable could accomplish the same end. It is not the objective of this project to determine the best measurement technique. The objective of this project is to develop an improved electrical and/or fiber optic channel.

Reviewer 23548

Score: 3.0

Comment: Important in that it addresses some key challenges observed in the deployment of fiber optic cables to date.

PI Response:

Agree.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23525

Score: 3.0

Comment: The investigator has been challenged with significant employee turnover due to sale and purchase of company, with concomitant reorganization. The technical approach on the modification of the fiber is extremely strong, with a thorough investigation made of "hydrogen darkening" of the cable, due to hydrogen attack on the primary dopant, germanium. Investigator has substituted fluorine as the dopant to change fiber index of refraction, and has achieved single mode (sharp dopant cutoff) as well as multimode (prescribed dopant distribution) fibers. Investigator has also developed a novel gel compound, to provide mechanical support to the fibers (i.e., preventing harsh fibre-to-fibre contact) in the cable. Investigator's company has been manufacturing cable for 25 years, and so, there is a wealth of experience the investigator brings to cable design.

Investigator had not checked for fluorine dopant migration long-term at 300 C. It is suspected that this will not be a problem, but it would be more assuring if the investigator would make this check.

Investigator had considered hydrogen embrittlement of the steel armor applied to the cable, but offers a very expensive alternative if embrittlement is an issue (nickel-based metal armor with no iron).

PI Response:

Agree. Checking for fluorine migration has not been checked. The current technical opinion within Draka is that the fluorine will not migrate, but emperical confirmation would be useful. This work may not be able to be done with remaining project funds.

Reviewer 23568

Score: 4.0

Comment: The three phase approach is eminently logical.

PI Response:

Agree.

Reviewer 23471

Score: 3.0

Comment: The technical approach seems to be sound, but with some challenges. Finding an ideal gel formulation seems to be one of these, with a viscosity that is so low at 300 degree C that it apparently would flow out the bottom of the encapsulating tube and offer inadequate mechanical support for the fiber. My sense is that this issue is still daunting, and is far from finding a solution. It is also not clear to me if a gel can ever offer the kinds of mechanical support they are seeking for long fiber-optic deployments, and I wonder if a more rigid (elastic/plastic as opposed to viscous material) might be better suited to this purpose. I am also concerned that the PIs have yet to converge on a final design for the main (armored) cable design, and are still considering options such as applying an outer, polymer coating to such a cable to provide corrosion resistance. However, these types of coatings are very sensitive to abrasion and getting “pinched through” or torn in going over sheave wheels, open-hole rugosity and internal upsets in a well casing/wellhead, and offer poor long-term resistance against hydrogen embrittlement. I think a better solution (which is probably beyond the budget for this project) would be to use a cable whose outer armor is constructed from a Ni-based super alloy (e.g., one of the Inconels or a similar formulation), which would offer superior corrosion and embrittlement resistance over the stainless steel armor being considered now.

PI Response:

A "non-convential" gel solution has been developed and is being submitted for a patent. More about this solution was not put into the presentation since it is still proprietary. Ni-based alloys are standard solutions and is used in the outer tube encapsulated cable (TEC) sheath. The armor strength member would be too expensive for this project.

Reviewer 23548

Score: 3.0

Comment: The approach should lead to a hydrogen-tolerant system that can be tested in the field.

PI Response:

Agree.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23525

Score: 3.0

Comment: Investigator has indeed produced cable prototypes on time, but is awaiting testing in a downhole environment.

PI Response:

Agree.

Reviewer 23568

Score: 3.0

Comment: The improved resistance of optical cable to hydrogen darkening is most significant. Maybe a closer interface with well-logging experts could more definitively resolve whether or not a strong steel sheath is necessary, or if the cable can be attached to a separate strain-relief steel cable. The field trial is yet to be performed, but all indications are that it should work well.

PI Response:

Agree. Discussions with well-loggin experts are underway.

Reviewer 23471

Score: 2.0

Comment: Development of the hydrogen-darkening resistant cable seems to be progressing well, and development of a high-temperature fiber coating and conductor insulation material is completed. My largest concern has to do with manufacturing and executing a trial deployment of the combined, heavy-weight fiber-optic/armored logging cable in a high-temperature geothermal well, an operation with which the operators (admittedly) have little experience and which appears to be lagging far behind schedule.

PI Response:

Agree. Discussions with well-loggin experts are underway.

Reviewer 23548

Score: 2.0

Comment: Overall good, but a lack of a downhole field trial is a concern, if the cable is expected to be soon marketed.

PI Response:

Agree. Discussions with well-loggin experts are underway. Field trials are being planned.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23525

Score: 3.0

Comment: Investigator seemed uncertain about details of data uploading to Geothermal Technologies Office data site.

PI Response:

Agree. I need help on this subject.

Reviewer 23568

Score: 3.0

Comment: I sympathize with the personnel problems due to the corporate buyout and with the difficulties scheduling field trial with partner AltaRock. I appreciated the forthrightness in the presentation of these difficulties and how they were overcome.

PI Response:

Agree.

Reviewer 23471

Score: 3.0

Comment: The project appears generally well managed, with good progress on most elements. The collaboration with Sandia on spectral transmission testing of the fibers represents a good industry/government-lab symbiosis. Project management has gone through some turmoil, due to changes in company ownership and reorganization, but appears to be under better control now.

PI Response:

Agree.

Reviewer 23548

Score: 3.0

Comment: Overall in good shape.

PI Response:

Agree.

STRENGTHS

Reviewer 23525

Comment: Investigator has long experience and deep expertise in cable design and manufacture.

PI Response:

Agree.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

I may have missed the need to more clearly state my invidual, team, or project strengths in the instructions to prepare this presenation.

Reviewer 23471

Comment: Reviewer did not provide comments for this criterion.

PI Response:

See previous response

Reviewer 23548

Comment: A testable system ready for downhole trials.

PI Response:

Agree.

WEAKNESSES

Reviewer 23525

Comment: Investigator does not have deep expertise in issues regarding the actual insertion of the cable into the well (i.e., passing the cable across sheaves, lubricators, seals, etc.) and the specific effects this portion of the environment might have on the cable.

PI Response:

Agree.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

I may have missed the need to more clearly state my invidual, team, or project weaknesses in the instructions to prepare this presenation.

Reviewer 23471

Comment: Reviewer did not provide comments for this criterion.

PI Response:

See previous response

Reviewer 23548

Comment: It may appear sensible to line up additional options for field trials for a variety of downhole conditions.

PI Response:

Agree, but project resources limit the number of field trials possible.

IMPROVEMENTS

Reviewer 23525

Comment: Reviewer did not provide comments for this criterion.

PI Response:

I may have missed the need to state project improvements in the instructions to prepare this presenation. One area not mentioned is working underway to extend performance beyond 300 deg. C. A partner for metial coated fibers has been selected with discussions underway to make and test cable prototypes.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

See previous response.

Reviewer 23471

Comment: Reviewer did not provide comments for this criterion.

PI Response:

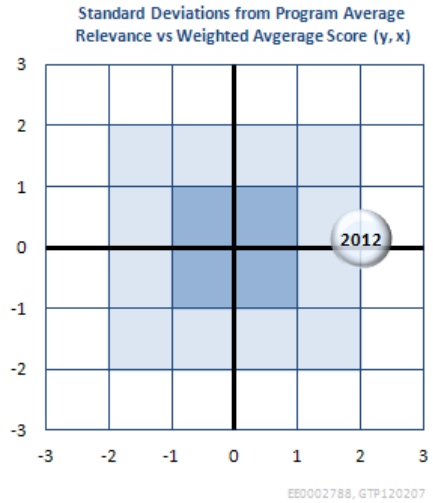
See previous response

Reviewer 23548

Comment: None.

PI Response:

See previous response



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002788
Project: Perforating System for Geothermal Applications
Principal Investigator: Smart, Moises
Organization: Schlumberger Technology Corporation
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23568

Score: 3.0

Comment: EGS requires well stimulation with predictable fracture size and orientation. This project examines stimulation using explosives. Not until the discussion was it made clear that these performations were not to replace hydraulic stimulation, but rather to enhance it in the near field of the borehole. The presenter should begin future presentations describing how this project complements hydraulic stimulation.

PI Response:

Reviewer 23471

Score: 4.0

Comment: This project has very high applicability to the problem of zonal isolation in geothermal systems. Other systems for zonal isolation are also under development by other groups, including the use of chemical diverters to plug fractures that have been opened during EGS shear stimulations so that treatment fluids can target different depth intervals of an open hole. These chemical diverter systems have the advantage that they can be used in open-hole intervals of a well, thereby gaining access to a greater proportion of the natural fracture population than would be the case for a cement-and-perf operation such as that envisioned here. However, chemical diverters will not work for hydrofrac treatments, because the porous and incohesive nature of the diverters means that the plugged fractures will readily reopen once the fracture propagation pressure is reached. Thus, only hard mechanical diverters (e.g., packer-type systems) or traditional case/cement/perforate treatments such as that enabled by this research will work when EGS treatments have to be accomplished from hydrofracing alone or through a frac-and-shear-stimulation (combined) approach. However, traditional perforating guns are very temperature limited, with charges that often detonate prematurely (at low impulsive energy) or not at all. Interestingly, the presenter did not seem to be aware of this important application of their research, and referred in his presentation to perf'ing extremely long cased-hole intervals, when in reality a staged perf-and-treat scenario over shorter intervals of a well would work best for an EGS system. Nevertheless, the relevance of this technology is very high, and I view this R&D project as providing an essential tool in the full spectrum of zonal isolation technologies that will be needed for successful EGS stimulations.

PI Response:

Reviewer 23548

Score: 3.0

Comment: The project is rather useful because it serves to address a fundamental gap for staged "stimulation/fracs/shear fracs" in high-temperature EGS wells, where zonal isolation is part of the well design. More generally speaking high-temperature perforation appears to be highly applicable to conventional geothermal wells, too.

PI Response:

Reviewer 23567

Score: 3.0

Comment: The successful development of this technology would provide a useful tool to the Geothermal inventory when exploring hard rocks. Low-temperature tools of this type are used in the Oil & Gas industry to facilitate oil and gas extraction but are not available for the high-temperature geothermal environments. The technology could be also explored for zonal isolation in addition to aiding well stimulation in EGS.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23568

Score: 2.0

Comment: The approach appears logical, but the description of the approach does not say what is new and novel nor does it include what criteria or how they were obtained to guide the project.

PI Response:

Reviewer 23471

Score: 4.0

Comment: This was a very solid presentation, with a logical and technologically rigorous approach. I wrote down a number of issues during the presentation about which I wanted to ask questions, only to discover that most of them were covered either during the remainder of the talk or during the Q&A period, in response to questions by myself or by other reviewers. For example, issues such as thermal stability of oil used in the firing head (including accommodating differential thermal expansion), the use of all-metal vs polymer seals (the latter being their primary focus now, with metal-on-metal being developed for high-pressure applications later), and charge penetration ability in hard rocks (which are

comparable to traditional HNS charges) had all been thought of ahead of time and were the subject of active research by this team. I was also glad to see that percussion-detonation (via pipe) and electrical detonation (via wireline) were both being given serious consideration, as wireline-perf operations can be a real cost- and money-saving alternative in geothermal operations.

PI Response:

Reviewer 23548

Score: 3.0

Comment: Very good, systematic, WBS-based approach.

PI Response:

Reviewer 23567

Score: 3.0

Comment: Systematic approach with clear work plan and met milestones.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23568

Score: 1.0

Comment: There is basically only self declared success and a statement "Due to the proprietary nature of this work all publications and presentations are STC internal."
PI Response:

Reviewer 23471

Score: 3.0

Comment: Good progress has been made in this project to date, although tasks still remain. Accomplishments to date include developing the ability to stack multiple guns, designing and testing a stable detonation cord jacket, and verification of effective energy transfer within the system. Remaining challenges include solving issues associated with explosive outgassing at high temps, and developing batch-to-batch consistency during the explosive manufacturing

process; the latter issue strikes me as the most daunting, although something that I presume is within reach given the contractor's expertise in this area pertaining to low-temperature systems . Given the solid "systems-level" approach being taken by this team and their attention to the key engineering details (including lab testing and field validation), there is a high probability that this project will be finished successfully and be made market ready.

PI Response:

Reviewer 23548

Score: 3.0

Comment: On track with promising results.

PI Response:

Reviewer 23567

Score: 4.0

Comment: Good progress has been demonstrated to date. High temperature stable explosive has been synthesized and tested at temperature. Successful higher-temperature testing will increase the value of the tool for geothermal. Transition of the explosive synthesis to higher-volume manufacturing has been completed meeting important commercialization milestone.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23568

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23471

Score: 4.0

Comment: Although it was hard for me to see “behind the scenes” and determine how this project is being managed, the presentation was one of the best organized talks I saw at the Geothermal Technologies Office Peer Review and gave me the impression that this project is being very well organized overall. The systems-level approach to this project, wherein each component is being developed, built and tested individually, and then integrated into a final package for testing, seems sound. I also like the coordination with Sandia National Laboratory on issues pertaining to explosive characterization at temperature and detonator reliability, which seems like a good use of Sandia’s expertise and a logical area for industry/government-lab cooperation.

PI Response:

Reviewer 23548

Score: 3.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23567

Score: 3.0

Comment: No issues with the management plan revealed. Field testing planned as part of the project. If possible, it could be beneficial to carefully and quantitatively evaluate technology value to geothermal during the field test.

PI Response:

STRENGTHS

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23471

Comment: This is a very strong project, for all the reasons outlined in my preceding comments. Although the technological challenges are significant, this was one of the best projects I reviewed and the project is well organized and technologically sound. Development of this capability is important to the future of EGS technologies, especially in

unstable rocks where long open-hole intervals are difficult to maintain and/or when hydrofracing is a key component of the stimulation strategy. I look forward to hearing more about this project at the next peer review, and hopefully being able to employ this technology in the field in the not-to-distant future.

PI Response:

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

WEAKNESSES

Reviewer 23568
Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23471

Comment: None that I can see.

PI Response:

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

IMPROVEMENTS

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23471

Comment: My only recommendation is that the PIs of this project reconsider how this technology might be most useful in EGS stimulations, as the rationale presented in the talk (lowering breakdown pressure so that hydrofracs can be carried out at lower pressure) is not really germane to geothermal systems. This is largely due to the fact that most high-temperature geothermal wells are already prefractured (in tensile mode) by thermal/cooling stresses during drilling, as shown by image logs in such wells, rending the in-situ tensile strength near zero. As I mentioned earlier, the greatest use of this technology is likely to be in zonal isolation, to enable creation of multiple stacked zones for a muti-stage stimulation and greater heat extraction per well, which is one of the real challenges facing current EGS developments in hard, low-porosity rock.

PI Response:

Reviewer 23548

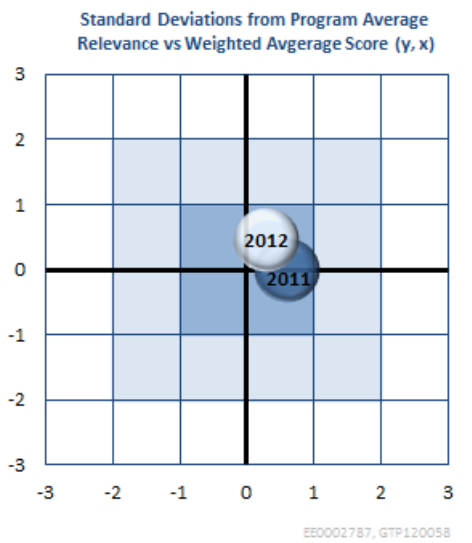
Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002787
Project: Multiparameter Fiber Optic Sensing System for Monitoring Enhanced Geothermal Systems
Principal Investigator: Challener, William
Organization: GE Global Research
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23527

Score: 3.0

Comment: This project is in general a good extension of the state of the art for distributed temperature measurement using optical fiber as well as development of pressure sensor technology for fiber applications in high temperature, geothermal environments. The utility of this technology has the potential to significantly improve geothermal production and field characterization operations in the future so has good programmatic relevance. While useful application knowledge was produced from the fiber optic field exercise, the path forward for geothermal application of fiber technology is still somewhat unclear if there was in fact fiber degradation due to hydrogen/temperature exposure as indicated. The dual focus on the fiber system and sensor development may have diluted resources and provided a more limited understanding of serious technical issues associated with each effort. A more singular focus on either fiber optic deployment in geothermal environments or fiber optic based pressure sensors may have provided more useful results to determine the best path forward for each area of investigation. The effort on developing both systems seems to have limited the investigation into the problems encountered for each area yielding somewhat inconclusive findings of critical technical issues.

PI Response:

This is indeed a large project with several goals. One goal was to test and evaluate commercialized technologies such as Raman DTS and Brillouin DTSS in a geothermal environment, which we hae succeeded at doing. Another goal was to select the best available optical fiber, use it to fabricate a cable, and evaluate its operation in a downhole environment. As the reviewer notes, the results of this test have been somewhat inconclusive. A 5 dB drop in signal amplitude was measured over the 5 week test. A downhole test of at least 6 months would be more apropriate for judging the long term stability of the fiber in a hydrogen environment, but that was outside the scope of this project (indeed, the contract specified that we would only prepare for a downhole test, while in actual fact we are actually completing two downhole tests during the course of the project). Finally, the third primary goal was to develop new sensors for pressure and temperature measurements. The results from this effort were somewhat delayed by fabrication difficulties, but will be reported over the next two quarters as the project is completed.

Reviewer 23521

Score: 3.0

Comment: There is a high demand for downhole tools that can work for an extended period of time in the harsh conditions characteristic to Enhanced Geothermal Systems. This project is addressing a field-ready fiber optic cable for temperature, strain, vibration and pressure sensing.

The relevance/impact of this research is spelled out clearly.
PI Response:

No response entered.

Reviewer 23519

Score: 4.0

Comment: The use of fiber optics for monitoring geothermal wells is highly valued by this reviewer. The potential for extending the fiber optic to supercritical temperatures is exciting. There is some confusion. The presentation said, "field-ready fiber optic cable and system for EGS up to 374 C and 220 Bar in the presence of hydrogen". Was this project funded as a supercritical project or an EGS project? I think it was funded as a supercritical project with a 374 C at 220 Bar minimum temperature.

Fiber optics were first researched back in the 1998 with the hopes of using Distributed Temperature Sensors (DTS) to track changes in the geothermal reservoir and for early detection of well problems such as cold water breakthrough.

Dick Benoit at Oxbow Geothermal paid for a number of optical cables to be placed in his wells. His interest and interest of other power plant operators provides evidence supporting the potential impact of this technology. Unfortunately, issues with hydrogen darkening of the fiber optic cable stopped all well deployment within the geothermal industry.

The need for a fiber optic solution has increased with time as new concepts in EGS power production. Now, the possibility of cold water short circuiting the EGS reservoir is a major issue.

The effort to develop a MEMS pressure sensor is valuable. In geothermal, pressure monitoring can record the response of the reservoir over time. Pressure informs the plant operator if the reservoir is being over produced or under-produced. Today, all pressure sensors (electronic or fiber) for temperatures over 200 C drift too much for use in geothermal reservoir monitoring.

Pressure is the most valued measurement in any oil well. As such, the oil industry has spent 100's of millions of dollars on any number of fiber optic pressure sensors. To my knowledge none of them have been accepted by the industry. In most cases, simple FBG base sensors lack sensitivity to track changes in the oil reservoir, while, interferometer based designs lack stability over time.

PI Response:

The original BAA specified 370 C and 220 bar as maximum test parameters. We have identified optical fiber with polyimide coating that should operate satisfactorily to 300 C and metallized fiber that should operate to 400 C or higher. We successfully fabricated a cable without inner fiber supporting gel that can also operate to 300 C. The MEMS pressure sensor was fabricated containing silicone oil that is stable to 232 C, although synthetic oils are available for use up to at least 400 C. Based on experience with low pressure MEMS sensors, this sensor should be extremely stable with time.

Reviewer 23568

Score: 4.0

Comment: High-temperature sensors and cable are highly relevant to geothermal well monitoring and logging.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23527

Score: 3.0

Comment: The overall approach seems sound, sequence of activities is reasonable and staffing support was excellent. The relative effort required for pressure sensor development versus fiber optic system is not entirely clear. It is hoped that more effort was spent on the sensor development than the fiber optic configuration. (Doesn't QUOREX already have a 300 deg C fieldable fiber system that could have been used?) An initial project schedule in the presentation material would have been useful for evaluation purposes. The field test focus of the project was important and was a good supplement to previous fiber optic field deployment investigations.

PI Response:

Pressure sensor development was handled by GE Sensing and the GE Global Research Center (GRC), involving ~8 people. Fiber testing and selection was handled by QOREX, involving ~2 people. Their experience in SAGD wells was invaluable for fiber cable design, but they had never previously fabricated a cable for a geothermal application. Downhole testing was handled by Sandia, QOREX, and GRC, involving ~5 people.

Reviewer 23521

Score: 3.0

Comment: The main focus of the project is to develop a fiber optic sensor cable for operation at high pressure high temperature in geothermal wells. The fiber uses pure silica core fiber with different coatings. Several tests are performed in the lab in order to determine integrity/degradation of the optical fiber. The technical/scientific details provided by the author are sound.

PI Response:

No response entered.

Reviewer 23519

Score: 3.0

Comment: The first objective of this project was to laboratory evaluate new high temperature fibers against hydrogen darkening when exposed to hydrogen gas at geothermal temperatures. This testing did show significant improvements in new fibers to resist the creation of hydrogen darkening (OH).

Testing continued in a low temperature geothermal well of 205 C. A higher temperature well would have been better, but this was a good start. The testing was well documented. The results were not without some surprises which supports the

scientific approach of this project. This well test was an update on new high temperature (HT) fiber optical cables inside a geothermal well.

PI Response:

No response entered.

Reviewer 23568

Score: 4.0

Comment: This project has an integrated approach to developing fiber-optic sensors to deal with the high-temperature environment of EGS. The fiber-optic pressure gauge is the more creative activity over developing a copper cable.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23527

Score: 3.0

Comment: Useful data was generated to this point in the project. The mechanical configuration of the FBG sensor looks like there may be repeatability issues associated with constraint of the spring from the pictures. It looks somewhat underconstrained against the end-washers. Might some of the drift in the reflectance measurements over time be due to shape changes of the spring loading system or mechanical relaxation effects due to tempering/creep?. Also, it was not clear if the fiber darkening issues were experienced both in the field testing and laboratory testing of the field cable.

PI Response:

The FBG sensor indeed has exhibited drift and repeatability issues. One additional package design remains to be tested before the end of the project, but in general this type of sensor seems to have definite reliability issues. Fiber darkening was measured in both the laboratory and the field test. The laboratory results indicated that the darkening was fully reversible.

Reviewer 23521

Score: 2.0

Comment: The progress seems to be in line with expectations. The optical fiber with silica core was fabricated and tested in the field, with good results. The hardware was integrated and tested, comparison with well log data is in good agreement. Pressure sensor seems to perform well, however, it was not very clear to me why the PI thinks that resonance tracking will be any different in the field, compared with lab experiments.
One important issue, present in quite a few other projects, is related to pressure and temperature determination. These quantities seem to be determined from the same parameter, i.e. the resonant frequency of an active element. Based on this,

it is not possible to separate the effect of pressure on temperature determination and that of temperature on pressure determination.

PI Response:

The reviewer is correct that the MEMS sensor requires an independent measure of temperature to accurately determine the pressure. Two temperature sensors were included in the cable for providing the temperature, the Raman DTS measurement and the FBG sensor. The latter exhibited drift and was not useful, but the former provided temperature measurements to +-5 C accuracy. This corresponds to a pressure accuracy of +-1 psi.

Reviewer 23519

Score: 3.0

Comment: This project pushed through to the deployment in a 205 C geothermal well. This is a significant accomplishment if nothing else was learned.

The fibers DTS readings were good with an approximate accuracy of +/-5C. The basic industry standard for electronics temperature tools is +/-1C. So the fiber is close. The PI reported that the fiber repeatability at temperature reporting was better than the +/- 5C accuracy.

The field test results reported that the DTS measurement was not affected by some small amount of hydrogen darkening detected in the optical cable. This might be a larger issue than realized by the PI. Hydrogen darkening has an exponential growth after about 180 C. This suggests that this fiber could see significant OH creation at temperatures above 250 C. Testing at supercritical geothermal temperatures inside a geothermal well may be the only means to validate fiber cable performance.

There are two potential reasons for the fiber darkening in the well but not in the lab. First, lab testing is generally done using hydrogen gas, H2. While in the well, free radical hydrogen can be found as a result of hot brine reacting with the tubing containing the fiber. Second, there is a potential for fiber to create receptors for hydrogen as part of a slow process where the fiber is under elevated temperatures AND strain. Generally, fiber being tested in the oven are left in a lose coil while fiber in the well must support its own weight.

In general, the difficulty in field testing fiber inside tubing continues to illustrate why fiber has found little market in well logging. The real valued application is in well monitoring. Once the fiber cable issues are resolved, drift and sensitivity of the pressure and temperature sensors need to be accounted for.

This project will end before pressure stability can be evaluated.

PI Response:

Excellent observations by the reviewer about potential hydrogen darkening effects that have not been observed in our field test but that will have to be considered in any long term deployment of fiber in very high temperature wells. Once the pressure sensor has been demonstrated, its long term stability will need to be resolved as part of a commercialization path. However, experience with these sensors in other, lower pressure applications lead us to expect excellent long term stability.

Reviewer 23568

Score: 4.0

Comment: The project has fulfilled its contract goals.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23527

Score: 3.0

Comment: A high quality project team was assembled and the project plan was reasonably well executed.

PI Response:

No response entered.

Reviewer 23521

Score: 3.0

Comment: Project management/coordination seems to be on track. Some delays here and there, but the overall outcome of the project not affected.

PI Response:

No response entered.

Reviewer 23519

Score: 3.0

Comment: It was clear from the presentation that the PI is directly involved in the project and holding a high level of personal integrity. I have seen fiber optic data modified to conceal issues with FBGs and DTS measurements. In one occasion, the PI (working for a different company) was recalibrating the fiber measurement every time the fiber DTS was run. This assured each well reading was the same as the one before. Naturally, this prevented the well owner from seeing any changes in their well over time and was of no value.

A suggestion; the PI should look for a partner with experience in placing and monitoring fiber optic systems in wells. This partner would come from the oil industry because only those companies have experience at fiber installation.

PI Response:

No response entered.

Reviewer 23568

Score: 4.0

Comment: The management kept the project on schedule.

PI Response:

No response entered.

STRENGTHS

Reviewer 23527

Comment: The project incorporated both "relatively" proven commercial fiber technology in combination with sensor development to facilitate the overall package development effort. Some useful field data was obtained to advance the understanding of fiber use in high-temperature applications.

PI Response:

No response entered.

Reviewer 23521

Comment: The development of an optical fiber that is not affected by hydrogen darkening and can be successfully used in the geothermal field is an important strength.

PI Response:

No response entered.

Reviewer 23519

Comment: This project is providing to the geothermal industry with an independent update on the performance of new high-temperature optical fibers. The efforts of the PI toward understanding the real issues of fiber optics deployed in a geothermal wells is highly valued.

PI Response:

No response entered.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23527

Comment: Nothing major.

PI Response:

No response entered.

Reviewer 23521

Comment: Pressure-temperature interdependence should be addressed.

PI Response:

See response under "Accomplishments, results, and progress."

Reviewer 23519

Comment: More testing of the fiber optic cable is required to better understand the creation of OH at higher temperatures. Testing needs to better simulate in conditions in geothermal well. Perhaps, only testing a real geothermal production well can be used to validate fiber and future fiber sensors.

It appears that stability testing of the MEMS pressure sensor will not occur within the funding time limit of this proposal. The chance of commercial success of the MEMS pressure sensor is poor.

PI Response:

The MEMS sensor will be tested downhole as part of this project, but long term stability will have to be evaluated in a follow-on commercialization path. There are always many obstacles to commercialization, but I believe this sensor has very good prospects.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23527

Comment: It may be beneficial to put to bed the issue of a fiber system capable of operating at 300 deg C so future focus can be placed on developing new applications of fiber optics in geothermal environments instead of continuing to split resources between dealing with fiber performance issues and sensor development. The technology appears to be close to widespread commercial use but the question of fiber degradation continues to present itself.

PI Response:

The reviewer is pointing out the importance of a long term test of the fiber cable and sensor(s) in a well that is at 300 C or higher. That is clearly one of the next steps after this project is completed.

Reviewer 23521

Comment: Pressure-temperature reading interdependence has to be solved, otherwise pressure and temperature determination is meaningless.

PI Response:

See response under "Accomplishments, results, and progress."

Reviewer 23519

Comment: If there are additional deployments in a geothermal well, the well should be hotter. Perhaps, talking to the Navy will help.

Testing for drift of the MEMS pressure sensor is a must for any hope at gaining a commercial market.

DTS systems are commercially available from a large number of service providers. I suggest, any DTS testing be done to qualify a HT fiber optical cable inside a geothermal well.

PI Response:

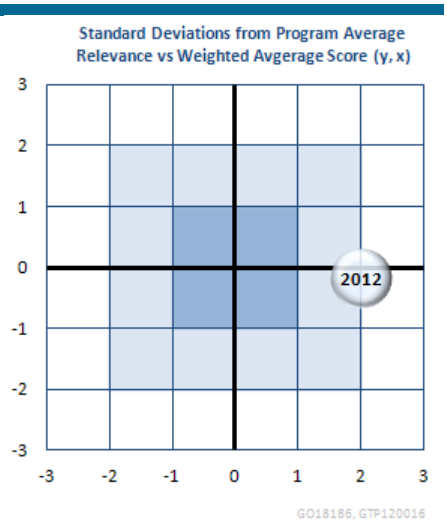
No reponse entered.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18186
Project: Detecting Fractures Using Technology at High-Temperatures and Depths
Principal Investigator: Patterson, Doug
Organization: Baker Hughes Oilfield Operation, Inc.
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23527

Score: 3.0

Comment: High temperature fracture imaging tools have great potential benefit to both hydrothermal and EGS geothermal applications based on their ability to provided descriptive information related to the wellbore and arguably near wellbore flow network. The availability of such tools in the commercial market is extremely limited. This project therefore represents a reasonable investment to enhance this capability in a potentially commercial capacity. From the technical perspective, the development of a high temperature borehole acoustic imaging tool is not unique to this reviewer's knowledge. A 280 deg C borehole televiewer was developed by Sandia as early as 1983 with modest improvements in temperature performance investigated and implemented periodically over the years. However, the Sandia tool uses a motor system to rotate a single transducer for comprehensive borehole coverage and this poses a significant limitations to both the reliability and upper temperature range of the device. By implementing a stationary transducer array that provides 360 degree circumferential coverage this project represents a reasonable advance of the state of the art that enhances both the potential use and reliability of such tools. The use of dewared, Low Temperature electronics will limit the utility of the tool, particularly given that expected logging speeds are only on the order of 10 fpm. This effective range of ~2,000 ft may nonetheless be sufficient for most potential applications.

PI Response:

Reviewer 23568

Score: 3.0

Comment: Fractures are the key to permeability in EGS. Therefore, developing an acoustic televiewer capable of 300 C is highly relevant. There are potentially competing methods, such as microformation logging or well responses to tides, but acoustic televiewer is the gold standard. There are, however, competing companies. It would have been useful to hear about the competition and what the strengths and weaknesses of this device are.

PI Response:

Reviewer 23548

Score: 3.0

Comment: The availability of a fracture imager is highly useful both, for EGS stimulation design and subsequent surveillance and workovers.

PI Response:

Reviewer 23567

Score: 3.0

Comment: Fracture imaging is important for efficient placement of injectors and producers in EGS systems. Successful completion of this project provides a valuable tool key to engineering or improving geothermal reservoirs.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23527

Score: 4.0

Comment: The development path for this project is well conceived and contains all elements needed to make the project successful. Design and testing tasks are appropriate and will promote prospects for project success. Resources appear to be reasonable for the level of effort required to achieve objectives.

PI Response:

Reviewer 23568

Score: 3.0

Comment: Pretty straightforward, which is good.

PI Response:

Reviewer 23548

Score: 3.0

Comment: The approach is methodical and should lead to a positive answer on the feasbility of such a tool.

PI Response:

Reviewer 23567

Score: 3.0

Comment: Innovation in high-temperature pressure seals, sensors array and system design creates an acoustic sensor capable to operate at high temperatures. Electronics could be upgraded in the future when new designs/materials are available.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23527

Score: 3.0

Comment: Component level development and testing performed to date are reasonable. To a certain extent this is to be expected for a company with a well established process and system for developing downhole tools. The development of the high temperature sensor package and interconnect assembly components are nonetheless noteworthy accomplishments.

PI Response:

Reviewer 23568

Score: 3.0

Comment: Very close to prototype testing in Q3 2012, so the jury is still out.

PI Response:

Reviewer 23548

Score: 2.0

Comment: While the project's goal is to "detect fractures using technology at high-temperatures and depths via a geothermal ultrasonic fracture imager GUFI" it is clear that the project will deliver at best various components and the general feasibility of a such a tool.

PI Response:

Reviewer 23567

Score: 3.0

Comment: The project appears to be on track and is almost completed. A full long term 300 C capability however was not achieved.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23527

Score: 3.0

Comment: Staffing for the project was excellent. The management of the project appears to have been conducted reasonably well.

PI Response:

Reviewer 23568

Score: 2.0

Comment: The planning seems to lag somewhat. They are at year three not having established a firm partnership to test the tool. Is it appropriate to have the acronym GUFI?

PI Response:

Reviewer 23548

Score: 2.0

Comment: The cost-time-resources planning resulted in the requirement for make-up funds by the project owner. Delays are not surprising considering the overly ambitious time plan of the project.

PI Response:

Reviewer 23567

Score: 4.0

Comment: The project was well planned and executed. Major decision points were identified at an appropriate place in the timeline. Funding added at the end to complete prototype build and field testing scheduled with Geodynamics and AltaRock suggests promising maturity of technology being developed.

PI Response:

STRENGTHS

Reviewer 23527

Comment: The organization performing the work has a successful track record for delivering quality product both to the Oil & Gas and Geothermal industries. The approach selected to obtain full borehole coverage will increase the potential capabilities of future acoustic imaging tools.

PI Response:

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23548

Comment: System components for a "GUFI" will be delivered.

PI Response:

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

WEAKNESSES

Reviewer 23527

Comment: No major weaknesses of note.

PI Response:

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23548

Comment: There will be no tool ready for testing.

PI Response:

Reviewer 23567

Comment: Electronics falls short at higher temperatures and may fail to fully utilize the potential of new high temperature acoustic sensor.

PI Response:

IMPROVEMENTS

Reviewer 23527

Comment: The use of dewared electronics will inherently limit the use of this tool. It would have been nice to incorporate high temperature electronics to eliminate the time constraints imposed on the tool by the use of low temperature electronics. It is also understood, however, if the necessary chip level components cannot yet be fabricated to meet the needed processing performance specifications required for the tool.

PI Response:

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23548

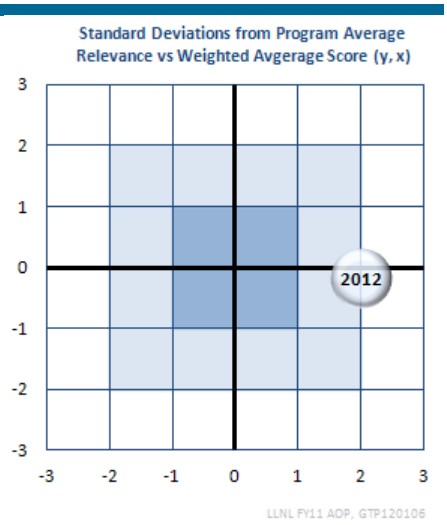
Comment: Should there be a next round of funds available for such equipment. It is essential that a tool ready for field testing will be delivered.

PI Response:

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: LLNL FY11 AOP 1
Project: Application of geothermally produced silica in Reservoir Management
Principal Investigator: Bourcier, William
Organization: Lawrence Livermore National Laboratory
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23397

Score: 2.0

Comment: The stated objective of this project is highly relevant as zonal isolation is likely to be a key technology developed that will assist in the deployment of EGS. If existing flow zones can be temporarily plugged while other zones are stimulated, one may be able to increase the flow rate between injection and production wells. Likewise, if short circuiting occurs, methods of diverting flow around these short circuits would be one effective way of increasing the lifetime of a reservoir. Therefore, the overall objective and premise of the project is highly relevant to the overall goals of the Geothermal Technologies Office. However, the project in its current state does not adequately address the knowledge gaps identified in the stated objectives. The project performers need to revisit the physical conditions that would be present in a real-world geothermal system that has a fast flow path (short circuit) or leak-off zones. These zones would have the highest rate of fluid flow and thus would have the fracture faces with the coolest temperatures in the reservoir. The silica gel that is being studied has faster gelation kinetics at higher temperatures rather than lower temperatures, and thus would result in faster gelation rates in areas of low flow. The areas of high flow (the leakage pathways and short circuits). Therefore, it seems this project needs to reconsider the use of this particular gelation pathway or reconsider the use for the silica gel as a diverter material. The presenter mentioned that this project was a result of having colloidal silica and needing a market for such. It does not seem that the project has adequately justified this use as a potential market.

PI Response:

Our goal is conformance control - diverting fluids to maximize thermal extraction, rather than using silica gel as a blocking agent during EGS stimulation. The comments of this reviewer are directed at the use of silica as a blocking agent for fracking. In that application the gel would need to sustain very high pressure, and then be readily removed after pressurization. While accurate for that application, the reviewer's comments do not reflect inadequacies for the intended applications of blocking fast paths, minimizing water losses, and reservoir modification to increase energy production - all aspects of "conformance control". The confusion is probably a result of the presentation being in a session on zonal isolation and a lack of clarity on this issue by the presenter.

The reviewer is correct in descibing a scenario of fast path blockage where the gel would form faster in the hotter zones and more slowly in the fast path itself. This is in fact a workable scenario given that gels in the hotter zones will more quickly transform to amorphous silica such that those fractures will re-gain permeability. The property of silica gels such that they can be "timed" to gel still allows us to emplace the gel into the fast path zone where it blocks flow as desired.

Note also that we have discussed this type of emplacement scenario with people experienced with water flooding of oil fields, an EOR application that has the similar goal of blocking fast paths for the water, but with the issue that any sealing material (cements and polymers) injected will also enter into the slow-flow fractures that are the targets for the water flood (and that you want to remain permeable). Their experience suggests that the fast paths dominate, most of the

cementing (gel) material ends up where you want it, and that the amount of blockage of the slow flow zones is minimal. They get more petroleum from the formation. We expect our systems to behave similarly. The gel will preferentially flow in the short circuit, because everything preferentially flows there.

As far as timing, recent experiments on the thermal stability of colloidal silica gels indicate that silica gels may be well-suited to preferentially block lower-temperature pathways, as the gels will not remain stable for long periods of time at high temperatures (1 week at 200 C, 3-4 hours at 300 C). So even if a high-T pathway is initially blocked by gel, since the gel is 80-90% water by volume, it will open up again as the gel precipitates amorphous silica. It is unclear whether the silica will form a crust on the fracture surfaces or will remain suspended in the fluid as particulates, but this is part of our scope and we will be investigating.

Reviewer 23412

Score: 4.0

Comment: This research has a high relevance to help conformance issues with geothermal, oil and gas, EGS, EOR and waterflood. One of the most innovative research applications I have reviewed.

PI Response:

No response entered.

Reviewer 23471

Score: 2.0

Comment: This project is potentially relevant to the problem of zonal isolation in geothermal systems, by developing chemical diverters to plug fractures that have been opened during EGS stimulations so that treatment fluids can target different depth intervals of an open hole. The diverter agents being developed here are derived from geothermal-production-produced colloidal silica. However, as noted in my other comments, my concerns about removing gel once it has formed (owing to its thixotropic rheology) and precipitation of silica (either amorphous or cryptocrystalline) from such a gel raises concerns about whether or not this approach will ever find widespread applicability as a diversion agent in creating multi-level EGS stimulations. For this reason, I envision that the greatest applicability of this approach might be in managing fluid flow/losses in convention geothermal fields far from injection/production wells, both along short-circuit pathways between wells or in plugging up “leaking boundaries” around the periphery of such systems.

PI Response:

Thixotropic rheology will actually be helpful in extracting the gel once it has formed, as agitation of the gel might allow it to flow again. Once the silica has deposited on the fracture faces as amorphous or cryptocrystalline silica, it will be difficult to remove. Our intention, however, has never been to use colloidal silica gel as a diversion agent in creating multi-level EGS stimulations - our main purpose has been, as this reviewer recommends, to manage fluid flow and loss in any (conventional or engineered) geothermal system along short circuit pathways and boundaries. So we agree completely with the last sentence of the reviewer's comments that the greatest applicability will be in reservoir management vs. EGS stimulation. This is the same point of confusion as the first reviewer (23397) so this was apparently not made clear in the presentation.

Reviewer 23526

Score: 3.5

Comment: This is high-impact work, and has the potential to make an impact on the industry. While they are targeting fast flow paths within the reservoir/EGS fractures, I think a bigger potential use is the plug far field fluid loss zones. We all speculate that fast flow paths can be created during EGS fracking operations, but history suggest that we can't get enough flow at all, regardless of how hot it is--refining and applying this technology to existing field with fluid loss issues may be a better match in the short term.

PI Response:

The reviewer points out that the main problem with EGS systems is not usually fast paths but instead low pemeability, so that diverting agents are not be needed. We agree that applications that use the gel to provide a barrier to water loss to fields having excessive fluid losses might be a more general application. Our goal really is to evaluate this inexpensive material for its applicability to any number of reservoir engineering applications, and identify those that are both important for resource recovery and are compatible with gel properties. Our work scope is designed to allow us to evaluate the variety of potential emplacement scenarios and identify the best use or uses.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23397

Score: 2.0

Comment: The overall rating for the technical approach is mixed between the modeling and laboratory efforts. The laboratory efforts seem well-designed and they are attempting to gather the appropriate information. For colloidal silica to be used as a diverter material in geothermal reservoirs, the necessary data are the kinetics as a function of temperature, SiO2, pH, and salinity. These are the key parameters that would govern the ability for gelled colloidal silica to serve as a diverter. The laboratory methods seem appropriate and adequate; however, more data on the stability at high temperatures needs to be gathered. The modeling efforts to this point are inadequate. As shown by the laboratory experiments, the gelation times vary with temperature from days to minutes. These times decrease with increasing temperature. The model thus far does not account for this temperature dependence. Additionally, the modeling efforts have not been designed to test the stated objectives of the project. If short circuits and leakage pathways are to be filled with the gelled colloidal silica as a diverter material, then the initial conditions of the simulations should reflect the need for a diverter material. The simulations presented not only have no significant heterogeneity that would indicate a short circuit or leakage pathway, but they do not have cooled surfaces that would result from an increased flow rate compared to the slow paths.

PI Response:

The reviewer notes the need for extending the gel model to higher temperatures. The experiments at high temperatures are currently underway, and have from the start been one of the key outcomes of this project.

As far as the modeling, the numerical model presented does include heterogeneous fractures (roughness) and accounts for flow and transport of both heat and mass. A description of the physical basis of model is provided in the slides. The thermal test that was presented, where the gel deployment allows the system to regain some of the heat that it has lost, is a direct application of the fully coupled model. We have postulated an exponential decay (a conservative assumption) of the gelation time as function of temperature for that exercise because we were initially limited to 25 °C experiments.

Currently, the relationship between gelation time and temperature (presented on slide 9) is implemented directly into the code, and will be further refined as more experimental data is obtained. The uncertainty of the gelation time at high temperature will be used in subsequent simulations to evaluate the impact of uncertainties of the gelation time on gel deployment location. Furthermore, the final implementation will also reflect the initial brine conditions in the reservoir: the equation given on slide 8 will be generalized to include temperature (such as the one given on slide 9 for a specific sol chemistry).

We agree regarding the short circuit conditions. We have 3 objectives (applications) for the silica gel: 1) to enhance thermal production by obstructing high flux and cooled regions, 2) minimize injected water losses to formation, and 3) remediating short circuit scenarios. We are currently investigating the 3rd objective. The initial conditions will reflect a short circuit scenario. First we will run the code to create the conditions to be remediated, record the extracted heat, and then we will deploy the gel in a fully coupled (flow, heat and mass) system and record the extracted heat post-gelation to assess where we have a thermal enhancement. The results of the short circuit scenatios will be presented at the GRC 2012 meeting. At the current state, the results are encouraging. We are also developing a protocol to show that an actual gel deployment at a specific site is successful.

Reviewer 23412

Score: 4.0

Comment: This project has adequate technical approach to determine how the product with behave and how it should be deployed.

PI Response:

No response entered.

Reviewer 23471

Score: 2.0

Comment: This project combines laboratory testing of silica gel gelation times (as a function of temperature, pH, salinity and SiO2 content) with numerical 3-D simulations of gel emplacement in single fractures and fracture networks. The scientific approach in these two areas is rigorous and is yielding interesting results, paying full attention to details such as gelation rates, mechanisms and kinetics, rheological behavior of colloidal silica before and after gelation, and effects of resulting rheological/flow laws on gel emplacement and stagnation in fractures. Although I have concerns about the effect that rapid gelation times might have on the accuracy with which gels can be emplaced at distance from an injection well, geochemical/thermal controls on gelation times are being addressed in this study. More importantly, I am concerned about whether or not these gels can be removed from a fracture or fracture network once they form, which may seriously limit the utility of using silica gels as near-wellbore diverter agents in EGS stimulations. Thus, flow-through experiments in realistic geothermal reservoir rocks at high temperatures and fluid pressures will be necessary to examine the kinetics of silica precipitation on fracture walls and possible deleterious effects that this would have upon fracture permeability in situ.

PI Response:

As far as the comment on chemical effects, we share the same concern and are planning tests to determine how silica gel-rock reactions might affect gelation rates. We will carry out ambient flow-through tests in and would like to do flow-

through experiments at high-T and P but would require additional funding. These tests would address the issues of overall material strength, and methods for removal, both physical and chemical or chemically-aided.

For the comment on emplacement of gels at distances far from the injection point, we agree that the gelation times at typical geothermal temperatures of 200-250 C may be too short (although we are still gathering these data). But we do have some additional controls available. We can increase flow rates to deliver the silica gel to more distant locations; we can inject the silica at lower temperature in order to retard the gelation; and we can use chemical additives to delay gelation. In some fields it may be possible to inject directly into the desired areas using existing wells.

Any approach to minimizing water loss is shown in slides 12 and 21. In these simulations the silica gel is deployed such that it creates an outer ring hydraulic barrier that includes both the injection and a far away extraction well. We have demonstrated the process for a smooth fracture (slide 12) and a representative rough fracture (slide 21). The latter shows that despite the complexity of the flow field (velocities and meandering) and the distant location of the extraction well the silica gel can be effectively deployed to enclose both wells with a hydraulic barrier that minimizes the water losses to formation.

Finally, the mechanical properties of a mature ripened gel at different silica concentrations and different aging times will be assessed experimentally. We have planned shear and tensile strength mesurements on standard coupon sizes. Obtaining the shear and elastic moduli of the gel can establish the maximum fluid pressures and in situ stresses the gelled silica can maintain, whether the intention is to leave the gel intact or to break it up and remove it to reactivate gel-isolated areas. These mechanical experimental tests will be used for design purposes only, no modeling is planned for the current year. Temperature will also be a major factor on the strength of silica gel, but determining mechanical properties of a gel at high temperature will likely be difficult and would require additional time and resources.

Reviewer 23526

Score: 3.5

Comment: The approach appears sound and well thought out. The team are using a number of tools to attack the problem, namely laboratory experiments, theoretical evaluations, and numerical modeling. I don't think all of the physics are yet completely understood, so the results require scrutiny, but the approach is strong and commendable.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23397

Score: 3.0

Comment: The accomplishments, progress, and results to this point in the project is adequate. The laboratory experiments have collected a significant amount of information about the kinetics as a function of a number of parameters, and some preliminary simulations have been performed. The planned work in FY 2012 should include model improvements that address the need for temperature-dependent kinetics; however, they did not as presented at the Merit review.

PI Response:

The experiments and model improvements that deal with T-dependencies are underway - due to fiscal scheduling, the Merit Review presentation was due approximately two weeks after receiving the first FY2012 money, so we could only present the results of the first year of the study.

A temperature-dependant gel model is a project goal and will be completed and incorporated into the flow model.

Reviewer 23412

Score: 4.0

Comment: Accomplishments and progress was very well presented.

PI Response:

No response entered.

Reviewer 23471

Score: 3.0

Comment: The project has been successful in meeting its basic research goals. Modeling and simple (see through) lab testing shows that silica gel may have some efficacy in reducing thermal breakthrough and short circuiting between injection and production wells (at least for flow in the single rough and smooth fractures) and may also be helpful in limiting peripheral water losses at the outer boundaries of such systems. Modeling of 3-D fracture systems is underway to extend these results to more realistic geothermal reservoir applications. However, further work will be needed before it can be demonstrated that silica gels are good materials to serve as flow diverters in EGS systems. It is not clear how the gel would be removed once it has been emplaced in the fractures, especially given the thixotropic nature of such gels and the possibility that such gels might break down and form fracture sealing materials (quartz/amorphous silica) that would be very difficult to remove.

PI Response:

No response entered.

Reviewer 23526

Score: 3.5

Comment: Once again I think this project progress is commendable -- the balanced approach makes it easy to recognize incremental advances. The numerical models developed fit with and utilize theoretical work and laboratory experiments, and are being used to reexamine what else need to be studied.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23397

Score: 3.0

Comment: Thus far the project management has been good. Variances in schedule due to the timing of funding have been addressed and the performers have been able to manage a number of important collaborations. One area for significant improvement in the management of this project would be to identify some milestones and a Go/No-Go decision point. The project should be evaluated for its ability to truly address the stated objective and both the laboratory and modeling aspects of the project need to focus on that objective.

PI Response:

We do have milestones listed in our FY12 plan. The go/no go decision will be an outcome of our last FY12 milestone to pick and evaluate a site. Cost and predicted energy performance data that result from that exercise should to a large extent tell us whether this technology has merit and whether or not it should be field tested.

Reviewer 23412

Score: 4.0

Comment: Project management and coordination with research collaborators and industry collaborators has taken place.

PI Response:

No response entered.

Reviewer 23471

Score: 4.0

Comment: The is well managed and coordinated, and has accomplished the intended work plan for Year 1 and is beginning Year 2 activities. The PIs have engaged UC Santa Barbara and UC Irvine to carry out mesoscale lab testing on problems related to fracture flow and blocking behavior of silica gel, which are important to the success of this project.

PI Response:

No response entered.

Reviewer 23526

Score: 4.0

Comment: This is a difficult area to evaluate/score. The project is well integrated with industry and the scientific community. I would have like to know more about their coordination with CSIRO and ORMAT. From a budgetary perspective, the project seems to be frugal considering they are conducting laboratory experiments which can be time consuming in relation to the quantity of results.

PI Response:

No response entered.

STRENGTHS

Reviewer 23397

Comment: The stated objective of this project is highly relevant as zonal isolation is likely to be a key technology developed that will assist in the deployment of EGS. If existing flow zones can be temporarily plugged while other zones are stimulated, one may be able to increase the flow rate between injection and production wells. Likewise, if short circuiting occurs, methods of diverting flow around these short circuits would be one effective way of increasing the lifetime of a reservoir. Therefore, the overall objective and premise of the project is highly relevant to the overall goals of the Geothermal Technologies Office. The laboratory efforts seem well designed and they are attempting to gather the appropriate information. For colloidal silica to be used as a diverter material in geothermal reservoirs, the necessary data are the kinetics as a function of temperature, SiO2, pH, and salinity. These are the key parameters that would govern the ability for gelled colloidal silica to serve as a diverter. Thus far the project management has been good. Variances in schedule due to the timing of funding have been addressed and the performers have been able to manage a number of important collaborations.

PI Response:

No response entered.

Reviewer 23412

Comment: This project has leveraged other mineral recovery from geothermal fluids.

PI Response:

No response entered.

Reviewer 23471

Comment: This is a scientifically interesting project, employing a solid combination of lab testing and numerical flow modeling. This project demonstrates the potential application of colloidal silica for management of flow fields within existing geothermal fields, to more effectively mine heat from fractured rock by blocking “short circuit” flow paths and by limiting peripheral fluid losses from such systems.

PI Response:

No response entered.

Reviewer 23526

Comment: Balanced approach--the mix of theoretical, laboratory, and numerical. It is clear the project has been well thought out from conception.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23397

Comment: The project in its current state does not adequately address the knowledge gaps identified in the stated objectives. The project performers need to revisit the physical conditions that would be present in a real-world geothermal system that has a fast flow path (short circuit) or leak-off zones. These zones would have the highest rate of fluid flow and thus would have the fracture faces with the coolest temperatures in the reservoir. The presenter mentioned that this project was a result of having colloidal silica and needing a market for such. It does not seem that the project has adequately justified this use as a potential market. As shown by the laboratory experiments, the gelation times vary with temperature from days to minutes. These times decrease with increasing temperature. The model thus far does not account for this temperature dependence. The simulations presented not only have no significant heterogeneity that would indicate a short circuit or leakage pathway, but they do not have cooled surfaces that would result from an increased flow rate compared to the slow paths.

PI Response:

No response entered.

Reviewer 23412

Comment: No apparent weaknesses.

PI Response:

No response entered.

Reviewer 23471

Comment: Uncertainties remain about the efficacy of using silica gel for temporary flow diversion in EGS systems, due to difficulties in removing gel from fractures once gelation has occurred or concerns about silica gel breaking down at high reservoir temperatures to form potentially fracture plugging amorphous silica deposits. In either case, the fracture plugging effects of colloidal silica may not be readily reversible.

PI Response:

No response entered.

Reviewer 23526

Comment: The project needs to consider what happens to the gel as it reacts geochemically with the reservoir and fluid, especially as the gel precipitates.

PI Response:

We have done initial static aging experiements at high temperature and we have not observed major geochemical reactions, though we will investigate this in more detail. We are planning on conducting dynamic (flow-through using crushed granite) experiments at ambient temperature to investigate this further, and with continued funding, may be able to conduct dynamic flow-through experiments at high temperature.

IMPROVEMENTS

Reviewer 23397

Comment: If short circuits and leakage pathways are to be filled with the gelled colloidal silica as a diverter material, then the initial conditions of the simulations should reflect the need for a diverter material. The planned work in FY 2012 should include model improvements that address the need for temperature-dependent kinetics; however, they did not as presented at the Merit review. One area for significant improvement in the management of this project would be to identify some milestones and a Go/No-Go decision point.

PI Response:

No response entered.

Reviewer 23412

Comment: No improvements are recommended.

PI Response:

No response entered.

Reviewer 23471

Comment: Reviewer did not provide comments for this criterion.

PI Response:

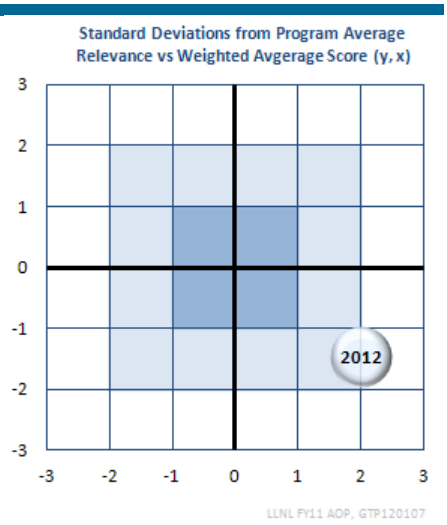
No response entered.

Reviewer 23526

Comment: Can the team develop/quantify the precipitation/mineralization process of the gel, and then incorporate this behavior into the numerical model?

PI Response:

Good idea. This is do-able but not without some good empirical data. There are chemical kinetics models for these processes but they would need to be backed up by a good suite of test data with realistic fluids and rocks in order to be trusted. We certainly can also explore the problem numerically.



Review: 2012 Geothermal Technologies Office Peer Review
ID: LLNL FY11 AOP 2
Project: Modeling of thermally induced spall of brittle geomaterials
Principal Investigator: Lomov, Ilya
Organization: Lawrence Livermore National Laboratory
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23433

Score: 1.0

Comment: The investigator proposes to develop a computer model that will describe the behavior of rocks under the type of stresses characteristic of thermal drilling. The main motivation is said to be that it is difficult to carry out real experiments on thermal drilling under the conditions found in deep geothermal wells. However, the investigator does not indicate to what extent the conditions in deep wells cause differences in material and other properties that are expected to make the drilling behavior different from that found near the surface. It may be that some properties are indeed influenced by the increased stresses at depth, but there is no indication that this is actually so, whether such differences have been measured (and how), and in what way they will influence such practical parameters as the drilling rate of penetration. If it does indeed become possible to show that, for whatever reason (based on the modeling results), the rate of penetration at depth is indeed lesser or greater than at the surface, can anything actually be done about it, and how will this information be used to increase the efficiency of drilling?

A large amount of work (both experimental and theoretical) has been done on thermal drilling over the years, and many different configurations of drilling equipment have been tried, with heating methods ranging from electrical to flame to laser. Many combinations of thermal fluid and temperature have been tried, resulting in effects from spallation to rock melting. The reviewer wonders if the proposed modeling work will suggest a new approach. In the reviewer's opinion, the major problems in thermal drilling now reside not in understanding how the rock is spalled or melted, but in developing the drilling hardware and operating procedures necessary to survive the high-temperature downhole conditions.

PI Response:

Deep wells conditions are dramatically different from near-surface conditions. First, there are large lithostatic stresses which is impossible to reproduce in the lab sample with a few feet diameter, since it requires high-pressure devices. The borehole opening futher complicates the insitu stress field, making it even harder to reproduce in the lab, which requires different compression in axial and radial directions and different positions. Second, thermal conditions are different in the field and lab conditions. Third, rock cores tested in the lab are usually extracted near surface, and there is large amount of work that indicate that rock quality increases with depth and can influence the rate of penetration.
What few deep field scale thermal spallation drilling tests have been conducted indicate that there are substantial differences between drilling at depth and at the surface - both in terms of drilling rates and spall sizes. However, due to the costs and efforts involved it is not a simple matter to determine the source of these differences - are the changes due to the changing lithology, borehole conditions, drilling temperatures, flow rates or some other factor. Teasing apart these different contributing factors may be impractical, costly, time consuming and potentially physically impossible in lab or field studies - but can be simulated with relative ease with a well calibrated model.

While PI agrees that general mechanisms of thermal spall are understood, our understanding of the processes involved remain largely emprirical - precisely because of a lack of modeling in this area. Thus there is no guidance to where thermal spallation drilling would be most benefitial. For example: what parameters are important in controlling drilling rates and under what conditions? Do rocks remain drillable under hundreds of bars pressure and elevated temperatures? There are no answers for such questions now. Unsuccessful attempt to drill an expensive well in unfavorable conditions can severely undermine the effort to develop this technology even if the drilling equipment is available.

Reviewer 23412

Score: 2.0

Comment: This project will have future relevance if the boring spallation system is functional. Numerical modeling of the spallation system is unique only to spallation and not other rock penetrating systems but could probably have a change in scope to include other systems.

PI Response:

Field and laboratory studies of thermal spallation drilling have delivered drilling rates two or more times faster than conventional drilling systems in hard basement rocks. Hence it is clearly offers a potential alternative to conventional drilling systems at least in some rock types. Numerical modeling will help to identify rock fields where spallation systems are likely to succeed and be more effective than conventional drilling.
The numerical modeling developed under this project will also have other geothermal applications - for example thermal damage to well-bores and stimulation of geothermal wells.

Reviewer 23480

Score: 2.0

Comment: The relevance of this project appears to hinge on the acceptance of thermal spallation drilling for geothermal wells. TSD is still in the early development stages and is not commercially available for geothermal drilling. This project succeeds as the TSD system succeeds. Given the current status of TSD development and acceptance by the geothermal industry, the impact of the project is problematic. There is also the question of whether the modeling is essential to the performance of spallation drilling systems. However, the modeling could have application to other geothermal issues/processes. The PI should look at trying to model hydraulic fracturing which is essential to EGS reservoir creation. Rock fracturing is a grain scale process, and the propagation of that fracturing through the rock mass is a vital piece of information for understanding reservoir geometry and productivity. Another useful modeling application would be erosion/corrosion of metal surfaces, both at the surface and downhole.

PI Response:

Modeling is essential because it can guide the TSD drilling to the reservoirs where it is likely to be most effective, and improve the performance of thermal spallation drilling in specific rock types - both of which will lead to faster acceptance of the technology.

Reviewer 23526

Score: 3.0

Comment: The project aims to quantify geomechanical behavior of spalling in geologic media to support thermal spallation drilling. As we all know, drilling costs are the bane of the geothermal industry, so any advances in drilling technology are important, and this project has the potential to contribute to this area. I don't know about the exportability of market penetration of the results. As it seemed in the presentation, this work directly supports Potter Drilling, but it is unclear if it could support others.

PI Response:

The effort is aimed to help all entities which are interested in the spallation drilling technology. This will be achieved both by improving undestanding of favorable conditions for spallation drilling as well as providing software tools for the industry.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23433

Score: 2.0

Comment: The scientific approach is well presented, and the preliminary results shown so far are interesting. Clearly, the investigator has invested a great deal of talent and energy into the development of the model. The reviewer would, however, like to have seen a more detailed description of how real mechanical and thermal properties are introduced into the calculations. For example, all fracture processes involve the expenditure of energy to create the new fracture surface. This energy is ultimately consumed in the creation of new surfaces and/or in the movement of dislocations, the formation of crystal twins and so on in the crystals that are near to or at the growing fracture face. These processes are typically stress and temperature-dependent, so in a good model, the energy required to create new fracture surfaces will usually vary considerably with changes in temperature and confining stress. How this information will be incorporated into the model, and where the actual physical numbers will be obtained is not clear. If real physical data of this type are not incorporated into the model, it will be only a little less empirical that the empirical work that the investigator says has been done so far and must be superseded. In short, the model may be highly developed in terms of the modeling of geometry and continuum mechanics, but may be short on the materials science.

All of the above comments are relevant to the work and approach proposed. As was noted in the previous section, however, the reviewer wonders if the real problem to be solved in thermal drilling is not understanding how the rock is destroyed, but in developing equipment to survive the very harsh conditions downhole.

PI Response:

The full description of the material model used has not been presented in the review due to slide limitations and time constraints. They are well documented in the peer-review literature (i.e. see Vorobiev, O.Y., et al., Simulation of penetration into porous geologic media. International Journal Of Impact Engineering, 2007. 34(4): p. 721-731.) and have all attributes of a complicated state of art material model for geologic media: pressure dependent yield strength, partial associativity, Lode angle dependence, temprerature and structural softening, damage, strain-rate hardening, porosity, water saturation. Authors developed this model for more than a decade. The apparent simplicty of the model comes from the calibrating approach developed by analyzing a lot of rock data, where most of the parameters can be scaled by the few eseential ones, which represent rock compositions and quality.

Reviewer 23412

Score: 3.0

Comment: The technical approach is good but it hasn't advanced very well since the project started in 2010.

PI Response:

Most of the progress was focused not in advancing the approach, by getting simulation results which would demostrate the value of the approach to the industry.

Reviewer 23480

Score: 3.0

Comment: The modeling mathematics are sophisticated, and Voronoi cells offer a means of simulating the grain texture of real rock. The PI refers to two scales: grain and "system"; grain scale is straightforward, but the actual extent of the system scale is uncertain and not obvious from the presentation material. Implicit in the presentation was the coupling of these scales to translate the large forces generated by the spallation nozzle head (mesoscale) to the crystalline surface of the rock (microscale). The PI should take care to assure that the scale transition does not modify the underlying physics. EODYN apparently includes a number of rock properties (specific heat, poisson's, temperature) which have been lumped into an "internal friction coefficient", presumably a measure of spallability. If possible, these parameters should be modeled separately within the Voronoi cells, since they can differ substantially among rock-forming minerals. For instance, the PI has modeled granite as quartz, orthoclase and plagioclase to derive a Voronoi cell. But granite also includes 5-10% ferrormag minerals (mica, hornblende) which tend to have considerably smaller grain sizes than quartz and feldspar in granite. These minerals also have different physical properties (specific heat) which could have an impact on fracturing. At the system scale, the in situ stress field and the hoop stress around the wellbore could be determining factors in fracture propagation. If GEODYN includes in situ stress, bulk rock porosity and permeability, the model results should be more realistic (i.e., defensible).

PI Response:

The complexity of the model grow as the project matures, so we will study the dependence of the spallation on the properties of the minerals. In fact, we tried to represent in situ stress, porosity and compositions to be as close to reality as possible. We did not consider rock permeability, but it could be included in the future.

Reviewer 23526

Score: 3.0

Comment: The approach, as presented, is difficult to quantify. The presenter discussed a number of different simulation codes, and mentioned things like "multi-physics" and "multi-scale", but it wasn't clear to me how this was being accomplished. The initial slides mentioned ROPs on the order of 30 ft/hr with TSD, and one would assume that the modeling is trying to quantify this number, but perhaps al the results weren't brought together well at the end, and it left me wondering what truly has been accomplished. One important suggestion follows along with what the presenter stated was using "CAD design vs. Trial and Error", it would be beneficial to evaluate more than pseudo-representative grain size distributions, but also things such as macroscopic heterogeneity (e.g., open fractures, quartz-filled fractures, pores, etc) and also jet/nossle designs.

PI Response:

PI agree that effects of fractures, pores, etc. can be important in spallation drilling. In fact, Potter Drilling field work confirms that. This features will be included in the simulations as the project matures,

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23433

Score: 2.5

Comment: The work done so far is very interesting. The investigator has done a good job of developing the model, and explains clearly what has been achieved. Overall, as noted above, the model development seems to have made more progress in describing the geometry of the system - the distribution of grain shapes and sizes, for example, - than in developing the physics and mechanics of the failure process. During the presentation, the investigator stated that these processes are very difficult to model in detail (agreed), so some sort of global averaging procedure must be followed and the model has to be adjusted to make it behave correctly. This then rather spoils the appeal of the project, because it seems that although a great deal of effort has been expended on getting the geometrical conditions correct, one is still reduced to employing a semi-empirical approach to the materials science.

PI Response:

The project leverages the physics and mechanics of failure which was already in GEODYN code, thus the review presentation did not include this aspect of the modeling effort.

The mesoscale modeling effort is not spoiled by averaging. The semi-empirical approach will be employed to provide simplified tools to industry partners, since they may be interested in running these tools not to undestand undelying science, but to evaluate how engeenering parameters (like nozzle shape) can affect drilling.

Reviewer 23412

Score: 2.0

Comment: Boundary conditions have been selected and sensitivities have been selected to determine the best conditions for the spallation system to operate. The slow progress of the numerical modeling is probably due to slow progress of the spallation system.

PI Response:

The presented results were achieved with one year of effort and met all of the stated deliverables. During that year, the models were developed for separate 1) grain-scale simulations, 2) the system-scale simulations and 3) particle-transport simulations. Analysis was begun using the grain-scale model, and work was commenced on coupling the three independent models - a goal for the second year of funding. In addition to meeting all deliverables for the project, the work produced three papers and three oral presentations (one invited) and one poster presentation.

The reviewer is vague on what he/she regards as slow progress and hence, their comment is difficult to address. Nevertheless, in our opinion, meeting the project milestones, working ahead of schedule, and disseminating the results of the research, do not constitute slow progress.

Reviewer 23480

Score: 3.0

Comment: The accomplishments are minimal as apparently this project has just received funding in March 2012. Taking this timeframe into account, reported results are satisfactory. Given the computational tools at hand, additional results should be forthcoming quickly. The PI was able to replicate the grain size distribution from spallation experiments, adding credibility to the model. The other results, such as damage patterns and the influence of rough and smooth surfaces, suggest the model is performing properly. One result, showing a decrease in damage with depth (pressure) is counter intuitive and needs to be addressed. The PI does not give any units for "damage". The model is supposed to be predictive, but what is the PI trying to predict? Spallation drilling is a function of rock type, crystal size, and conditions at depth. These factors are not known a priori, so the model cannot make accurate predictions of spallability without a pre-existing well in place. Perhaps the PI should use the model to establish bounding conditions for spallation of various rock types under various downhole conditions. The PI states he is on track for all FY12 goals and deliverables, but he doesn't state what those are or when they will be accomplished.

PI Response:

In fact, the main finding of the project is that damage as a function of depth is not a unique function, it depends on rock type as well. The low-internal friction coefficient rocks show increase of damage with depth, which is consistent with limited experimental obervations of Potter Drilling. The damage measure is unitless. Usually is is measured from 0 to 1, and extensions of no-damage zones (0) and full-damage zones (1) give good metrics for quatittative comarisions of simulations under differen conditions.

While rock type, crystal size and conditions at depth are not exactly known downhole, geophysical data can be collected and interpolated from existing holes. This can put reasonable bounds on aforementioned properties. The one of the main project goals is to establish effects of downhole conditions to spallation of various rock types.

Reviewer 23526

Score: 2.5

Comment: This is the hardest to quantify, as it wasn't clear how all the pieces come together on the project. It is clear that progress is being made, but how near to the end goal is uncertain (because I wasn't sure what the goal is....)

PI Response:

The goal of the project is to extrapolate drillabilty of the various rocks under lab conditions to drillability under downhole conditions. The parameter space is very big, so the project has commenced by evaluating the sensitivity of the system to changes in what are regarded as the principle driving parameters (temperature, depth, microstructure).

PROJECT MANAGEMENT/COORDINATION

Reviewer 23433

Score: 3.5

Comment: The project management is relatively simple, since it depends essentially on the work of one investigator. Progress is satisfactory so far. The referee notes that the work and results are being discussed and further developed in contact with the Potter Drilling company. This company appears to be happy with the progress that is being made.

PI Response:

No response entered.

Reviewer 23412

Score: 3.0

Comment: The project management and coordination is good. The PI has plans to perform sensitivities.

PI Response:

No response entered.

Reviewer 23480

Score: 2.0

Comment: Management factors, especially coordination, are minimal. Potter Drilling is the only point of coordination, which is reasonable since Potter is the only commercial entity for geothermal spallation drilling. Perhaps the PI should look to non-geothermal sources for information. Spallation drilling was the primary means of drilling blast holes in the taconite mines of the Mesabi Range. Browning Engineering used spallation to drill a 1000 ft well in the Conway granite. Some of that work may still be ongoing and could be pertinent to this study. Given the narrow focus of this study, at present there appear to be no management challenges.

PI Response:

Browning and Linde-Corp developed systems for thermal spallation drilling in taconite mines and deep well drilling. Their commercial interest in spallation drilling ended shortly after completing the wells drilled in the early 1980's. A Los Alamos program into spallation drilling ran out of funding around 1985. In 1996, a Sandia National Laboratory Report found that the only evidence of on-going commercial efforts in thermal spallation drilling was a single patent application by a British company for a downhole separator.

Reviewer 23526

Score: 2.5

Comment: I was a little uncertain as to the overall goal of the project. The presenter spoke a lot about multi-scale and multi-physics approaches, but never brought all the pieces together. I would expect a more cohesive picture of the overall

process, and how it really supports the program. The project began in November 2010, so this should be more clear. I also wasn't clear on the schedule, or if costs are in line with accomplishments. The presenter stated less than $30K has been spent, this doesn't seem possible given the level of details presented. I am not convinced that a clear vision exists to get the project to its final goal, what the goal may be.

PI Response:

The project spent $350K in FY11. The research was multiscale and multiphysics in a sense that there were multiple processes (fluid flow, heat transfer, solid deformation and damage) addressed on grain-scale and system scale. Bringing all pieces together in a single simulation is a major effort, and it is a longer-term goal. Usually it requires multi-million dollar investments. The level of funding of this project warrants a different approach to multiscale: incorporate knowledge gained at the grain-scaled modeling to the reduced-order system-scale model.

STRENGTHS

Reviewer 23433

Comment: The major strength of the project lies in the very complete and careful construction of the geometrical aspects of the model. Significant work has also been done on developing the physical and mechanical criteria that govern the thermal spallation process. The investigator is developing simplified models that are intended eventually to be released to organizations that are actually developing practical drilling devices.

PI Response:

The complex geomechanical models had been developed before the start of the project, so probably they were not emphasized enough in the review, but they are essential for the project success.

Reviewer 23412

Comment: The PI has the skills to complete this project.

PI Response:

No response entered.

Reviewer 23480

Comment: Strengths are included in discussion of evaluation criteria. A significant strength to highlight here is the GEODYN code which has a proven record of performance as a fluid/mechanic simulator. The modeling capability is robust and can include a number of rock constitutive properties.

PI Response:

No response entered.

Reviewer 23526

Comment: It seemed clear to me that all of the individual work is of the highest quality technically, and the software tools indeed seemed to be very powerful. Judging by how the damage of the material was simulated, their formulation for damage must be strong--the authors should consider publishing their formulation and stabilization methods.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23433

Comment: An inherent limitation to all modeling activities is that the model only reflects the influence of those parameters and processes that the modeler believes are of importance (and therefore are incorporated into the model). If some unforeseen or unimagined physical process is in fact occurring in the real world, then the model will not reflect its influence, and the results may be quite misleading. This is the fundamental failure of the classical Greek approach to science, in which it was important to develop concepts rather than to make experimental observations. In the present case, it is not clearly explained how the model results will be compared with observations in the real world, and hence it is not clear how the results can be validated.

Even supposing that the predictions of the model can be confirmed, and it can be shown how various external parameters and the properties of the material being spalled affect the performance of a thermal drill, it is not evident whether any insights can be obtained to enable better equipment or operating conditions to be developed. There is, after all, no way of changing the properties of the rock to be drilled, and extensive work has been carried out over many years to discover what rocks are easily drilled or not, and what are the best devices (lasers, flames, electric arcs, ...) to be used.

PI Response:

Opposite to the Greek approach to science, the development of spallation drilling since the 1970s has been conducted via an Edisonian approach: try it and see what happens. That may work for lightbulbs, but the cost of a single deep well trial is far more expensive than this project.

There is no way of changing the properties of rock to be drilled, but there is a choice to start investements in well in California or Colorado, for instance. Despite many years research, only rules of thumb are known for the rock types (brittle nonporous are the best), but current drilling systems pose question far beynd that: depth dependence, rock joints, hole stability which are to expensive to answer with a simple Edison approach.

Moreover, there are drilling parameters that can be controlled - borehole pressures can be modified with different drilling mud-schemes, the drill temperature, flow rate and standoff distance can be controlled, the shape and design of the drilling nozzel can be changed. However, none of this matters if there is no insight as to what is needed to improve drilling rates.

As we have already mentioned subsurface conditions are a different beast from the laboratory, and in any case it is too expensive to test 1000's of different designs. For this reason traditional drill bit developers rely on computer aided design to help create new drill bits. There is no reason why the same should not be true in the design of thermal spallation drilling systems.

Reviewer 23412

Comment: The project is being performed to only have one unique solution for the spallation system.

PI Response:

See response to the comment below.

Reviewer 23480

Comment: A project weakness is that focusing solely on spallation phenomena limits the utility of the model. The model could be used for other geothermal applications. The project is not mature enough for significant weaknesses to become apparent.

PI Response:

The modeling framework is very generic and it could be used for other geothermal applications. The spallation drilling has been chosen as an important enabling technology for EGS.

Reviewer 23526

Comment: I believe that I have described the weakness I see in previous categories, but let me summarize here: It seemed clear to me that the work is of the highest technical quality, but I was unclear regarding how all the parts (codes and participants) are being integrated.

PI Response:

The main focus of the project is to help undestanding the physics of spallation drilling. The project has strong ties with Potter Drilling (integrating participants). The integration of the codes is planned, but is a longer-term goal.

IMPROVEMENTS

Reviewer 23433

Comment: As noted above, more effort should be devoted to modeling the physics and mechanics of the rock failure processes. The reviewer wonders if it is worth modeling the effects of fluids such as water in the pore spaces of the rock. This may, however, be unnecessary in view of the expected low porosity and permeability of many typical geothermal reservoir rocks. If the model could be used to show how, in a real situation, it predicts drilling results that are different at depth from those observed at surface, this would be a real achievement.

In general, thought should be given to comparing the predictions of the model with real experimental results at as early a stage as possible.

PI Response:

Permeability seems to be important for thermal spall of highly porous materials (concrete). Some experimental research by Potter Drilling suggests that it is not as important for granite, which is of the most importance for geothermal applications. It is important to confirm this theoretically, but has been left for future research.

There is very little experimental data available and the project tries to use it to every extent possible (particle size distribution, fluid temperature required to start spallation, drillable rock types).

Reviewer 23412

Comment: No improvements are recommended.

PI Response:

No response entered.

Reviewer 23480

Comment: Suggested improvements are included under evaluation criteria. The project would benefit from applying the modeling techniques to other geothermal problems.

PI Response:

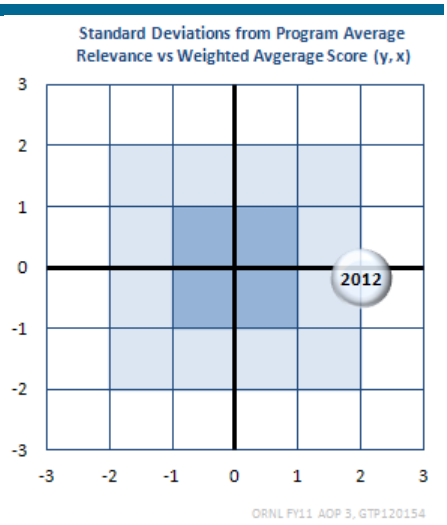
The PI agrees that the modeling framework is applicable to modeling of the wide range of geothermal processes.

Reviewer 23526

Comment: Please see individual comments.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: ORNL FY11 AOP 3
Project: Evaluation of Corrosion/Erosion of Casing Materials Under Extreme Conditions
Principal Investigator: Jy-An Wang, John
Organization: Oak Ridge National Laboratory
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23433

Score: 3.0

Comment: Casing corrosion and the associated erosion problems are of great importance in geothermal well operations. Corrosion is an issue in geothermal wells because of the almost universal presence of high temperatures and corrosive brines except for injection wells. The need to produce high volumes of hot fluids (generally at much greater rates than in oil or gas wells) correspondingly causes problems with erosion and associated cavitation damage. Unfortunately, since these problems are specific to the geothermal industry, and less important to the much larger hydrocarbon industry, suppliers of well tubulars have generally given lower priority to corrosion and erosion issues. Carrying out research and development of materials that can stand the particular conditions in geothermal wells is therefore not a task that can be left to the customary suppliers of wellbore tubulars. Hence the importance of the present project.

PI Response:

No response entered.

Reviewer 23412

Score: 3.0

Comment: Most casing designs are mechanical designs for tensile and internal yield. Very little attention is given to extreme flow and corrosive atmospheres. All field developments will only consider the number of wells required to deliver fluids for power production and not consider the extreme service the wells will be subject to and the resultant failure.

PI Response:

No response entered.

Reviewer 23480

Score: 2.0

Comment: The project seems to have evolved two dissimilar objectives, based on cavitation processes. The study of erosion/corrosion in casing materials is an area of considerable interest to geothermal developers because of the cost impact of deploying/replacing casing. This problem is well known in the industry and has been studied extensively over

many years. The PI should be aware of this work as it bears on his study. The PI has developed a testing apparatus using laser-induced cavitation which can enable the study of corrosion/erosion at an accelerated time scale. This should facilitate evaluating casing materials, especially new alloys, before deployment downhole. The PI also proposes using the cavitation process to initiate hydrofracturing in rock for purposes of increasing surface area for heat exchange. If made to work at an appropriate scale, this approach could have significant impact on EGS reservoir development. Use of the apparatus for laboratory-scale experiments on hydrofracing would have marginal impact. The PI needs to decide where the emphasis of his project should be placed.

PI Response:

The primary objective of the current project is cavitation/erosion study of casing materials. There is no doubt that we will focus our effort in this area. On the other hand, we see the cavitation-based hydrofracking as a promising concept for EGS development. Therefore, we will continue to pursue the latter by seeking additional opportunities.

Reviewer 23474

Score: 4.0

Comment: EGS well conditions are challenging for many materials, and an important material system in these well is the well casing itself. The geothermal well environment includes both high temperatures and a corrosive chemistry that results in scaling and degradation. Because of this, the well casing is expected to be replaced every five years. However, a recent EGS well by Geodynamics (Cooper Basin of Australia) had to be re-cased after just two years of service time.

The goals of this project are to (1) develop test procedures for characterizing the well casing under simulated conditions and (2) evaluate the casing materials so that the degradation can be understood and considered in future EGS applications.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23433

Score: 2.5

Comment: The approach selected has been to develop laboratory screening tests and procedures to enable the rapid and simple screening of candidate casing materials. This is an efficient approach that should allow the speedy evaluation of a wide range of candidate materials. The reviewer notes, however, that the investigator has limited his investigation of casing erosion to that induced by cavitation. The reviewer is not aware of the relative importance of erosion by cavitation as compared with erosion by particle impact (viz. sand or rock debris) and it may be that this is insignificant, but it would seem nonetheless worthwhile to devote some effort to particle-induced erosion mechanisms.

PI Response:

The reviewer provided a very good suggestion to include investigation of particle-induced erosion on casing materials. The PIs will try to include such effort in our follow-up studies.

Reviewer 23412

Score: 3.0

Comment: The scientific approach is good but only showed results for carbon and SS.

PI Response:

Due to the limited funding received in FY12, our research effort primarily focused on carbon steels and stainless steels. Howerver, we expect to expand our characterization horizon to include more casing materials such as composites and Ti if the project can be continued.

Reviewer 23480

Score: 2.0

Comment: The approach involves the use of an experimental cavitation apparatus for initiating erosion/fracturing of material surfaces. The approach is reasonable for studying erosion/corrosion in casing materials, and the apparatus is capable of circulating geofluids and varying temperatures. However, no plans are presented for developing a statistically signifcant experimental database on a variety of casing materials. This would seem the only effective way to evaluate materials. Is this work being left to others? The effort seems to be solely on developing a testing apparatus. While the use of geofluids provided by industrial collaborators is important, care must be taken that the geofluids are representative of the wide range of compositions found in nature; in particular, they should be free of contaminants, notably dissolved oxygen, which can influence the experimental results. Chemical corrosion from the use of geofluids does not appear to be factored into the experimental design. While useful for casing materials studies, the apparatus has limited utility for hydrofracture experiments. Details about a new apparatus, designed for hydrofracing, were not forthcoming.

PI Response:

The original plan was to evaluate a variety of casing materials to compose a database with statistically meaningful representation. The research deviated from its original plan due to unsufficient fund received in FY13. We plan to include more materials for testing after receiving additional financial support.

We agree with the comment regarding possible contamination in the industrial provided geofluids. We will perform a careful experimental design to minimize the contamination issue, for example, by boiling the water samples prior to testing in order to reduce dissolved oxygen.

Cavitation-assisted hydrofracking is not included in the scope of the current work. But we believe it is a novel concept that may benefit the DOE EGS program. Therefore it is worthwhile exploring. However, it is in a proof-of-concept stage and we would like to continue this effort by developing a separate research program.

Reviewer 23474

Score: 3.0

Comment: The development of characterization tools, as well as the application of the characterization tool, are organized in a logical manner. To date, a prototype chamber has been developed for corrosion/erosion testing in geofluids. The system includes a pulsed laser source, a pumping system, and sensing/monitoring capabilities. Testing thus far has included the evaluation of stainless steel and carbon steel materials. The carbon steel exhibited signs of corrosion damage

whereas the stainless steel appeared to have cavitation erosion (surface pitting). It should be noted that the project team has obtained geofluids from ElectraTherm, Inc. (Reno, NV) to use in these studies. Concrete samples were tested in distilled water and the results showed cracking in these materials.

The team has designed a high-temperature test chamber that will also used a pulsed laser to evaluate casing materials under conditions that more closely approximate EGS well conditions (i.e., high temperature and with geothermal fluids). That system has not yet been tested.

PI Response:

Detailed design of the high temperature test chamber is complete and various parts are ordered. We hope to assemble and test this unit in our next effort.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23433

Score: 2.5

Comment: Results obtained are satisfactory. The investigator made the point that a possible future use of cavitation might be to induce microfracturing and a resultant increase in hole roughness. It was suggested that the increased roughness in the walls of geothermal boreholes might increase the heat flow from the surrounding rock into the well. The reviewer is skeptical that this will be a significant effect, in view of the low conductivity of the reservoir rock. The reviewer is inclined to believe that the limiting factor in heat transfer to the well will be the rate of heat diffusion through the bulk of the reservoir rock, and that borehole surface roughness (particularly at the level produced by cavitation) will not be significant.

PI Response:

No response entered.

Reviewer 23412

Score: 4.0

Comment: Accomplishments and results are laboratory apparatus and measurements.

PI Response:

No response entered.

Reviewer 23480

Score: 1.0

Comment: The experimental apparatus appears to work well, with erosion pitting observed in various metal and concrete samples with the circulation of distilled water and geofluids. However, the results are qualitative, largely subjective, and have not produced conclusive findings of use to industry. A statistically significant experimental data set must be

developed, but there is no indication that will be done. The study was to have produced a "protocol", but there does not appear to have been much progress in that direction. By definition, a scientific protocol is "a predefined written procedural method in the design and implementation of experiments. Protocols are written whenever it is desirable to standardize a laboratory method to ensure successful replication of results by others in the same laboratory or by other laboratories." (ref: Wikipedia) The PI seems to consider the testing apparatus as the protocol rather than the testing procedure. A protocol based on the laboratory's testing apparatus would be difficult to replicate in other laboratories. The focus of this project appears to have shifted away from materials testing and toward hydrofracing technology. Other than the design of a hydrofacing apparatus, progress in this area appears minimal. Application for a patent on the pressure-pulse process used in the cavitation apparatus is notable.

PI Response:

The objectives of the current project included both the development of apparatus and testing protocol. As pointed out by the reviewer, a working protocol needs to be based on a statistically significant experimental data set. To date, we have tested some common casing materials including carbon steels and stainless steels. However, our testing effort has been limited by the current budget issue (no funding received in FY12). We completely agree with the reviewer that a practical protocol needs to be developed for industrial end users and we hope this can be realized should we receive sufficient financial support in FY13.

Reviewer 23474

Score: 4.0

Comment: The project appears to be making good progress. It was funded as a two-year effort and this review is for the first year. The test apparatus was designed, fabricated, and used in the first year to conduct tests on a few casing materials. More testing on concretes would be good to see so that the lifetimes of the casing materials can be evaluated.

Based on the results to date, as well as recent observations of EGS well casing degradation in Australia, the ability to predict the lifetime of the casing will be very valuable. This testing could be further enhanced by the use of well fluids obtained from a specific location.

PI Response:

We would like to include more tests on concretes and cements as well since they are critical materials for geothermal well construction.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23433

Score: 3.5

Comment: The management approach appears efficient. The reviewer notes that the investigator has adopted an approach in which small scale experiments may be used to evaluate a range of materials in rapid fashion. The reviewer also notes that the investigator has made use of existing equipment (lasers) in his experiments.

PI Response:

No response entered.

Reviewer 23412

Score: 4.0

Comment: Project management and coordination has been adequate.

PI Response:

No response entered.

Reviewer 23480

Score: 3.0

Comment: The project is well-organized, and the use of Gantt charts is commendable. The list of collaborators is impressive, but their role in guiding the project is ill-defined. They appear primarily interested in using the testing apparatus. The PI showed resourcefulness in dealing with the loss of funding for the second year.

PI Response:

We will strengthen our ties with existing collaborators by increasing the communication volume, data exchange, and collaborative experimental effort.

Reviewer 23474

Score: 3.0

Comment: The PI has done a good job of managing the work at Oak Ridge National Laboratory (ORNL) and interacting with the Geothermal community in general. The design and construction of the test apparatus was done entirely at ORNL. The interactions involve in-kind contributions through which geothermal fluids have been obtained for use in the testing of well casing materials.

The project appears to have been hindered by the unavailability of FY12 funds. It was not clear whether those funds would be made available, and if so when.

PI Response:

No response entered.

STRENGTHS

Reviewer 23433

Comment: This is an efficiently planned and operated project, and addresses a well defined requirement. Casing damage by corrosion and/or erosion is not a problem that is common in the petroleum industry, at least in the range of conditions

encountered in geothermal wells. It is therefore worth while for the Geothermal Technologies Office to devote some research activity to this issue, particularly for the range of conditions found in geothermal wells.

PI Response:

No response entered.

Reviewer 23412

Comment: This project has highlighted the importance of flow regime being included in casing design.

PI Response:

No response entered.

Reviewer 23480

Comment: The testing apparatus works well and delivers a large pressure pulse to the sample. This should allow the testing of a broad range of sample materials.

PI Response:

No response entered.

Reviewer 23474

Comment: The project addresses an important need for future EGS applications, and specifically the testing of well casing materials. The ability to predict the lifetime of these materials will be important for energy production applications, and the performance of the casing may vary depending on the well conditions. The team has already shown that geothermal fluids can be used in these tests.

The PI has involved others in the Geothermal community in this work. While the technical work is all done at Oak Ridge National Laboratory (ORNL), the participation of the other companies is a good indication of the value and relevance of the project.

Finally, several technical papers have been given (or are scheduled to be given). This is a good way to get the results from the National Laboratory into the public domain.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23433

Comment: The development of a cavitation generator is interesting and valuable, if cavitation damage is a major source of casing wear. However, erosion by solid particles entrained in the flow is also a major source of damage, and the

investigators should give some thought as to how to devise a test procedure to evaluate resistance to particle-induced erosion.

The idea of investigating and possibly selecting protective coatings to resist corrosion and/or erosion could be attractive under some circumstances, but the reviewer feels that this approach has high inherent risk. It is in the nature of coatings that small holes or other defects inevitably occur (particularly in the downhole environment where occasional rock fragments are entrained in the brine or steam flow.) Under such circumstances, attack will occur preferentially at the unprotected location, resulting in rapid degradation and possible perforation of the casing. While such damage may be easily detectable in piping used in surface locations, where leaks can easily and quickly be seen and remedied, leaks down hole are difficult to detect and much more difficult to seal. For this reason, lower priority should be given to the evaluation of coating materials, unless they are in some way self-repairing.

PI Response:

We agree with the reviewer that particles can be a potential source of erosion damage. This could be a good target for our future research effort. For material evaluation, we will give higher priorities to testing of bulk materials.

Reviewer 23412

Comment: The project has no apparent weaknesses.

PI Response:

No response entered.

Reviewer 23480

Comment: The project's focus is split between two rather dissimilar objectives.

PI Response:

The primary objective is to develop a casing material evaluation apparatus and protocol. This will also be true for our future effort.

We also believe the cavitation-hydrofracking concept is worthwhile exploring through a new/separate research project.

Reviewer 23474

Comment: Some correlation of the test data to either previous experience or other test methods would be valuable. This could be done with a previous well casing material (and associated well fluid) to show how corrosion/erosion can be predicted.

PI Response:

We would like to pursue this good suggestion through collaboration with our industrial partners.

IMPROVEMENTS

Reviewer 23433

Comment: The desirability of investigating particle impact erosion as a wear mechanism was noted above. In addition, it is known that the effects of cavitation on metals are increased if the metal is already under stress. The shock wave resulting from liquid jet impact (the Munroe jets generated by bubble collapse) can induce widespread yielding if the material being eroded is at a significant fraction of its yield stress. This might be a worthwhile area for future investigation, since materials in service are rarely unstressed.

PI Response:

Sample holders can be modified to pre-stress samples. The stress states can be determined in advance. Cavitation damage of stressed samples will then be studied and compared to those in a stress free condition.

Reviewer 23412

Comment: No improvements are recommended.

PI Response:

No response entered.

Reviewer 23480

Comment: The project would be improved by refocusing on either the testing protocol for casing or the hydrofracing process for EGS development. Absent the infusion of new funding, those objectives should not be pursued in parallel.

PI Response:

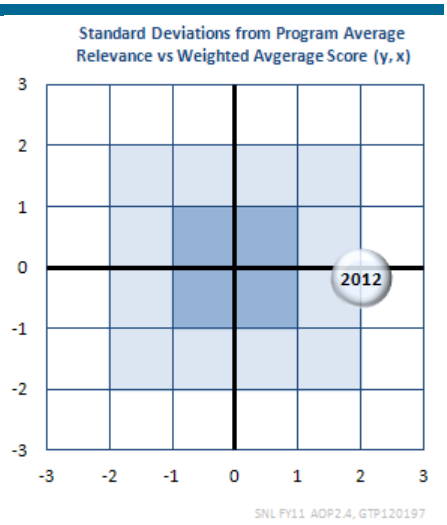
We will focus on development of testing protocols for casing materials. The hydrofracking concept will be pursued as a new initiative should additional funding be available.

Reviewer 23474

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: SNL FY11 AOP2.4
Project: Development of a Multichip Module(MCM) to Enhance High Temperature Accelerometer Measurements
Principal Investigator: Lindblom, Scott
Organization: Sandia National Laboratories
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23521

Score: 3.0

Comment: This project is addressing the need for high temperature downhole electronics. More specifically, the development of a MultiChip Module (MCM) designed for accelerometer measurements. The Relevance/Impact of research is high and aligns well with the Geothermal Technologies Office's missions and goals.

PI Response:

Concur

Reviewer 23401

Score: 3.0

Comment: Useful technological advance IF commercialized.

PI Response:

Sandia is pursuing IP protection for the module and will address external licensing opportunities in the future.

Reviewer 23568

Score: 3.0

Comment: While maybe realistic, the 250°C goal seems modest compared with the 300°C seen in many other Geothermal Technologies Office projects. Although the goal is modest, the accomplishment is better.

PI Response:

We chose the 250C temperature target because it is above the current signal conditioning circuitry for high temperature accelerometers can operate, but still within the operational range of all required materials and electronic components. In addition, while the actual lifetime will have to be confirmed through testing, these modules should operate at 275C for an extended period of time.

Reviewer 23567

Score: 3.0

Comment: High-temperature seismic tools collecting data from geothermal wells are of importance for the detection and location of rock fracture events while the well is being stimulated and can used for monitoring of the well after completion. These tools, if realized, in a small footprint, capable to fit in the existing tool body, compatible with most widely used cabling and providing high sensitivity will enable efficient data collection.

PI Response:

Concur

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23521

Score: 3.0

Comment: The scientific/technical approach is well defined. The MCM is designed to perform all amplification and filtering needs for a single temperature accelerometer. It is claimed that the circuit uses novel techniques to minimize noise floor. However, there are no technical details provided.
This project seems to be 'riding' on another project by Sandia ("Base Technology and Tools for Supercritical Reservoirs"), dealing with a very specific task of that project.

PI Response:

Per the DOE's guidance to PIs, we did not include any information that is copyrighted, proprietary, or confidential in the presentation.

In addition, this project is unrelated to the "Base Technology and Tools for Supercritical Resevoirs" project. As a portion of that project Sandia does plan to produce an analog MCM and digital MCM that will form the basis of a high temperature pressure, temperature, collar counter tool. The charge amplifier MCM from this project is specifically targeted at high temperature seismic tools, which is not a component of the base technologies project.

Reviewer 23401

Score: 3.0

Comment: Good design ideas but lacks path to commercial utilization.

PI Response:

While Sandia does not have a specific industrial partner at this point, we do plan to offer this technology for licensing once final testing is complete and the IP is secured.

Reviewer 23568

Score: 3.0

Comment: The project approach is a straightforward progression through the design, fabrication and testing of a high temperature charge amplifier circuit at both the board and MCM levels.

PI Response:

Concur

Reviewer 23567

Score: 2.0

Comment: The approach utilizes commercially available electronic components. The MCM system may be limited in sensitivity due to the input stage noise at high temperatures - above 225 C. As this can be considered as the technical barrier, a simulation or noise analysis could be performed to reduce technical risk.

PI Response:

I agree that input stage noise from the opamps will limit the sensitivity of this circuit. The design team would have liked to perform a noise simulation, but the high temperature electronics manufacturers do not release SPICE models for their parts. An attempt to mitigate this issue was made by choosing the lowest input noise high temperature opamp available and choosing a topology that does not have resistors in the input signal path, thus eliminating thermal noise and the effects of opamp input current noise. During testing of the completed MCM we plan to characterize the input noise floor of the circuit to determine sensitivity.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23521

Score: 3.0

Comment: In terms of accomplishments, the project seems to be in line with expectations, especially for such a low-funded project. Design of the MCM is complete, with fabrication and testing underway. Design, fabrication and testing of the charge amplifier is complete.

PI Response:

Concur

Reviewer 23401

Score: 4.0

Comment: On track with goals.

PI Response:

Concur

Reviewer 23568

Score: 3.0

Comment: The progressive steps in the approach have been completed.

PI Response:

Concur

Reviewer 23567

Score: 3.0

Comment: A breadboard version of the multi-chip module prototype has been completed and tested successfully at room temperature and 225C. Prototype test result matches simulation very well. Output stage driver is desirable, but didn't fit in the footprint of the MCM assembly.

PI Response:

Concur. The output driver is a nice functionality due to the fact that it enables tools that do not require downhole A/D conversion or digital communications. However, at the funding level for this project we were not able to add this part of the system into the MCM.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23521

Score: 3.0

Comment: Project management according to plan. There is a collaboration with industry for MCM construction/fabrication.

PI Response:

Concur

Reviewer 23401

Score: 3.0

Comment: Meeting targets.

PI Response:

Concur

Reviewer 23568

Score: 2.0

Comment: Although they evidently accomplisheed their goal in a technical sense, IP issues defuse the accomplishment.

PI Response:

To date the goals of this project have been met as evidenced by the board level results shown in the presentation. MCM testing results will be made available in the final report for this project.

Per the DOE's guidance to PIs, we did not include any information that is copyrighted, proprietary, or confidential in the presentation.

Reviewer 23567

Score: 3.0

Comment: The project is mostly complete. A slip in the schedule was observed caused by the delay in MCM fabrication but did not lead to any significant scope change.

PI Response:

Yes, there was a slip in the schedule, but it resulted in no additional cost to DOE.

STRENGTHS

Reviewer 23521

Comment: Targeted electronics for specific sensors is definitely needed in the geothermal community. This project is developing just that, targeted for accelerometer measurements.

PI Response:

Concur

Reviewer 23401

Comment: See other remarks.

PI Response:

N/A

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

WEAKNESSES

Reviewer 23521

Comment: It is difficult to determine the scientific/technical approach due to 'blank' statements in the Scientific/Technical Approach Section. More specifics related to the materials used would have helped.

PI Response:

Per the DOE's guidance to PIs, we did not include any information that is copyrighted, proprietary, or confidential in the presentation.

Reviewer 23401

Comment: Unclear if any industrial collaborator is prepared to put this innovation to work.

PI Response:

Once the IP is secured we plan to offer this design to an industrial partner for licensing.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

Reviewer 23567

Comment: High-temperature performance of the combine sensor MCM system.

PI Response:

The high temperature performance of the MCM/accelerometer system will be characterized during testing of the completed MCM.

IMPROVEMENTS

Reviewer 23521

Comment: The project seems to be progressing just fine, especially related to the level of funding. I have no recommendations related to improvements, other than providing more technical details.

PI Response:

Per the DOE's guidance to PIs, we did not include any information that is copyrighted, proprietary, or confidential in the presentation.

Reviewer 23401

Comment: See other remarks.

PI Response:

N/A

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

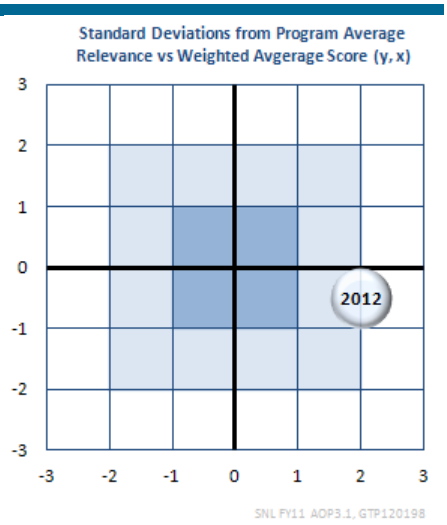
N/A

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A



Review: 2012 Geothermal Technologies Office Peer Review
ID: SNL FY11 AOP3.1
Project: Enhanced High Temperature/High Speed Data Link for Logging Cables
Principal Investigator: Lindblom, Scott
Organization: Sandia National Laboratories
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23521

Score: 3.0

Comment: The development of high-temperature electronics are important to the geothermal community and, also, to the oil industry. Electronics performing specific tasks, in a well-defined module is an interesting approach and deserves attention.

PI Response:

Concur

Reviewer 23527

Score: 3.0

Comment: Signal processing is not really my area of expertise, but the relative advancement of data transfer rates achieved in this project for the modest associated cost is arguably a good investment. The need to increase data transfer rates in high-temperature applications has significant programmatic relevance if the geothermal industry endeavors to use some of the more sophisticated subsurface characterization tools already prevalent in the Oil & Gas industry. The goals of this project are still orders of magnitude below lower temperature capabilities but this is a step in the right direction.

PI Response:

We agree that the results (and goals) of this project are orders of magnitute below lower temperature capabilites. To date, no hardware/software changes have been made to Sandia's existing downhole electronics. We have identified data encoding and filtering algorithms that can be implemented with today's suite of high temperature electronics that will allow an additional increase in data rate. In addition, through modifications to the downhole electronics we can optimize the performance of the uphole receiver by implementing adaptive equalization methods.

Reviewer 23525

Score: 2.0

Comment: Investigator is developing uphole electronics that can extend the bandwidth of simple linewire cable from 2x to 4x above that currently achievable. This will have impact both in short term and long term. In the short term, the project allows higher data rate communication on simple linewire to low-functionality electronics downhole. In the long term, the project allows for communication to new, high-temperature downhole instrumentation that is unlikely to have

sophisticated functionality due to use of avant-garde electronics (SiC and others). It is true that there exist certain commercial solutions that provide higher bandwidth communication, but these depend on more sophisticated downhole electronics. In this project, uphole electronics are made more sophisticated so that lower communication functionality is demanded of downhole electronics. For very high downhole temperatures, this is likely to be the right middle- and long-term approach. This effort, however, requires the particular cable to be calibrated, and indeed, a specific length of cable extended for the research approach to be successful. A follow-on project could be defined in which the cable calibration is automated. But the reviewer must ask the question: Is this effort one that is better suited to industry? And, given the direct approach taken, might this work be easily achieved without government funding?

PI Response:

We have already perfomed additional investigation into the feasibility of automated cable characterization (adaptive equalization) and believe it is possible with modest changes to the downhole electronics.

Given Sandia's long history of work with high temperature electronics we believe this effort is appropriate for a government funded R&D laboratory. While many companies in the oil & gas and geothermal industries are developing "high temperature" tools, the vast majority are doing so utilizing low temperature electronics and heat shields. The goal of this project is to optimize wireline communications for tools that are built with only high temperature components, which makes the electronics design much more challenging and time consuming. For example, a variety of electronics manufacturers sell low temperature MODEM chipsets that could be integrated into a wireline communication system with minimal effort. These chipsets do not have high temperature counterparts, and therefore innovative solutions must be developed for high data rate tools built to run without a heatshield.

Reviewer 23567

Score: 3.0

Comment: Improved wireline transmission will allow higher bandwidth link to support high temperature tools generating high data rates. High-temperature tool electronics significantly lacks in data processing power and suffers from physical size limitations when compared to Low Temperature electronics. An improved data link with increased bandwidth not requiring new cables and wirelines will enhance high-temperature tools capabilities.

PI Response:

Concur

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23521

Score: 3.0

Comment: Good scientific/technical approach. The role of both downhole transmitter and uphole receiver is spelled out clearly. However, no information related to the high temperature electronics is provided. This project seems to also 'ride' on a more healthy-funded project at Sandia.

PI Response:

To date, there have been no modifications to the high temperature electronics for this project. We first wanted to increase the data rate using Sandia's existing downhole electonics from the DWD program to demonstrate that communication improvements were possible utilizing only changes to an uphole receiver. We have identified modifications to the downhole electronics that could be implemented with existing high temperature components given additional funding.

This project is separate from other projects at Sandia, and the work performed to date has not utilized funds from any other project. That said, we would not hesitate to apply the positive results from this project to other current or future efforts that require high speed communications with our downhole tools.

Reviewer 23527

Score: 4.0

Comment: Given the available resources, the tasks and objectives associated with this project were appropriate with a reasonable level of technical impact achieved. It was a relatively small effort but still pursued well defined development and testing objectives. The hardware and software development tasks represent a suitable approach to achieving project objectives. The testing tasks were also reasonable.

PI Response:

Concur

Reviewer 23525

Score: 2.0

Comment: The investigator puts forward a simple technical approach: A filter is installed in the uphole electronics with the inverse transfer function of the linewire loss curve. This filter then "equalizes" the response of the cable for all calibrated frequencies and nominally, will remove the deleterious effect of early cable bandwidth roll off (i.e., cable has 10kHz bandwidth, this approach boosts signal above 10kHz to make the cable to appear flat in response to frequencies 2x or 3x higher). The output of this filter is then amplified, and digital coding/decoding performed. This is an elementary approach, but it was well implemented.

It was slightly surprising that the first iteration of the uphole equalizing electronics was actually a class project sponsored by the investigator at Harvey Mudd College, and was completed by undergraduates. In phase 2 of the project, investigator proposes to "adjust" the design (but make no major modifications) to extract some performance improvements.

PI Response:

We agree that the uphole electronics use a conceptually simple approach, but given that the downhole electronics utilize a very simple encoding scheme a more complicated approach is not necessary. The uphole system is designed and constructed in such a way that future modification to the downhole electronics can be accommodated with relatively simple changes to software, and will not require a major hardware redesign. In addition, while theoretically simple, the implementation still has many disparate pieces and was not trivial.

The phase 2 work for this project is complete, and the modifications to the initial Harvey Mudd College design yielded the following performance improvemnets: 1. 400 kbps over a single conductor cable almost twice as long (~9000 feet). 2.

600 kpbs over 5000 feet of single conductor cable. (This result is calculated because we do not have a 5000 foot cable at Sandia.)

The characteriation of the initial work as a "class project" is a bit misleading. The Engineering Clinic program at Harvey Mudd College is an intesive year long program at a first rate institution that exceeds the traditional "senior project" in scope and technical difficulty. The students have multiple meetings weekly with their professor and corporate sponsor to ensure the project is on schedule and the technical goals are being met. The work performed by the students is much more commensurate with a graduate level project than an undergraduate project. In addition, Sandia was motivated to engage Harvey Mudd College in this effort as a means to expose very bright undergraduate students to the field of geothermal energy research.

Reviewer 23567

Score: 4.0

Comment: Digital encoding for reducing noise and improving signal in combination with filtering is a viable and solid approach. The approach is an enhancement without the need to modify data transmission infrastructure with ability to reconfigure the system for optimal performance.

PI Response:

Concur

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23521

Score: 2.0

Comment: The team showed relatively good progress. There is still quite a bit more work to do. Did not see any data/results at high temperature.

PI Response:

Correct, we have not performed any high temperature testing during this projet because the downhole electronics are from Sandia's DWD program. The electronics were temperature tested both in the laboratory and the field during this program.

Reviewer 23527

Score: 4.0

Comment: Given the limited resources involved, the demonstrated data transfer rates were commendable. A useful signal processing approach was achieved and the possibly for extending the techniques to more variable conditions (longer cable lengths, different cable configurations, etc.) is apparent. This project in general represents a reasonable incremental advance of the state of the art.

PI Response:

Concur

Reviewer 23525

Score: 2.0

Comment: The investigator is achieving good research progress and has shown results where cable bandwidth is extended 2x and 3x. Goals for the project seem to be a 4x or 8x improvement in cable bandwidth.

PI Response:

Since the peer review we have made some additional achievements in bandwidth improvement. (see results stated in the response above.) To achieve performance improvement approaching 8x we will need to make changes to the downhole electronics. Many of these changes have been investigated, but will require additional funding to implement in hardware.

Reviewer 23567

Score: 3.0

Comment: Bit error rate measurement results have been demonstrated and maximum transmission rates have been evaluated. Fidelity of the filtering calibration needs to be proven in the field at high temperature as the cable spooled out in the well. A distortion of the filtering calibration could possibly affect maximum achievable bandwidth enhancement.

PI Response:

We agree with the reviewer's statement that the system should be proven with a field test. Field testing was not part of the scope of this project. With additional funding we can make changes to downhole electronics and perform a field test to verify the entire system.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23521

Score: 3.0

Comment: The PI seems to handle the project just fine, including some external collaborations. I think the focus of the project should be more high-temperature oriented, which I did not see from the presentation provided by the PI.

PI Response:

The original intent of the project was to focus equally on both the uphole (low temperature) and downhole (high temperature) sides of the communication system. However, as the project evolved we continued to find ways to adjust the uphole system in order to increase the data rate without any modifications to the downhole system. We feel that the uphole system is now at a point to where, with additional funding, we are ready to make changes to the high temperature downhole system. Many of the proposed changes have been initially investigated and were presented during the peer review.

Reviewer 23527

Score: 3.0

Comment: No major issues here. It might be nice in the future to involve service companies in order to obtain feedback on the technical approach so that it can be evaluated against industry practice.

PI Response:

Concur. With additional funding we would like to engage service companies in order to ensure the Sandia system is not in conflict with current (proprietary) industry solutions of high speed data transmission.

Reviewer 23525

Score: 3.0

Comment: Investigator did not mention project management to any great length, but has shown to be basically on time and on budget.

PI Response:

Concur. Given the relatively small scale and singular focus of this project Sandia did not need to invest heavily on project management.

Reviewer 23567

Score: 3.0

Comment: The project is being supported by collaborative work in Harvey Mudd College. Some issues have been encountered in subcontracting subsystem development but have been timely resolved.

PI Response:

Concur. We were able to identify issues with the Harvey Mudd College system and correct them to optimize the performance of the uphole receiver.

STRENGTHS

Reviewer 23521

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

Reviewer 23527

Comment: An advancement of the state of the art was achieved with a very modest financial investment.

PI Response:

Concur

Reviewer 23525

Comment: The approach of the investigator has some merits: Enhancement of performance of uphole electronics to compensate for diminished performance of cable and/or downhole electronics.

PI Response:

Concur

Reviewer 23567

Comment: Proposed solution is based on the existing wireline solutions and will cause insignificant cost to implement.

PI Response:

Concur. The current system, with no modification to the downhole electronics, provides a very cost effective means of increasing the data rate.

WEAKNESSES

Reviewer 23521

Comment: There are no high temperature tests performed.

PI Response:

No high temperature tests have been performed on this project because the downhole system is made up of electronics that have been heavily tested (laboratory and field) through Sandia's DWD project. Most of the work to date has been performed on uphole electronics that will not be exposed to wellbore temperatures. Sandia has investigated and proposed modifications to the downhole electronics that if additional funding is received will be tested at temperature.

Reviewer 23527

Comment: No significant weaknesses.

PI Response:

N/A

Reviewer 23525

Comment: The approach of making a fixed filter to "equalize" cable response to higher bandwidth seems artificially limited. The reviewer wonders why some sort of auto-equalization wasn't attempted in the first place.

PI Response:

While the fixed filter approach is limiting, although not completely, we chose to implement this type of equalizer because we estimated we would be successful within the confines of the project's limited budget. Testing and optimization of an adaptive equalizer would require the ability to unspool and spool the cable in a well environment, which would have been cost prohibitive for this effort.

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A

IMPROVEMENTS

Reviewer 23521

Comment: The project is relatively close to the end, with few funds left. I hope some data related to high temperature survival of the electronics will be provided.

PI Response:

High temperature survival of the downhole electronics used in this project have been documented though the results of Sandia's DWD project. We have investigated and documented changes we can make to improve the performance of the DWD electronics, which we will implement should additional funding be granted.

Reviewer 23527

Comment: It would be useful to know what new tool capabilities have been enabled by the achievements of this project for perspective. A target data transfer rate for the geothermal industry would also be useful to help guide R&D efforts. In other words, how do signal-processing researchers know what data transfer rates are needed to enable new tools? Yes, any increase of the data speeds is beneficial but there should be more context in the discussion that drives target speeds that deliver new capabilities.

Service company feedback is also encourage to help guide evaluation of progress and future development.

PI Response:

This is an excellent comment and a shortcoming of this project. We chose the data rate improvements based off of what would have enabled higher resolution data for Sandia's microseismic tool that was completed in FY11. However, industry engagement would have been useful to settle on a target data rate value for high temperature tools others may have in

development. As a component of future work Sandia may do in this area, we will engage outside interests to determine an industry data rate.

Reviewer 23525

Comment: Reviewer wonders if the project, when completed, should not be extended and industry allowed to pursue this route of investigation without government funding.

PI Response:

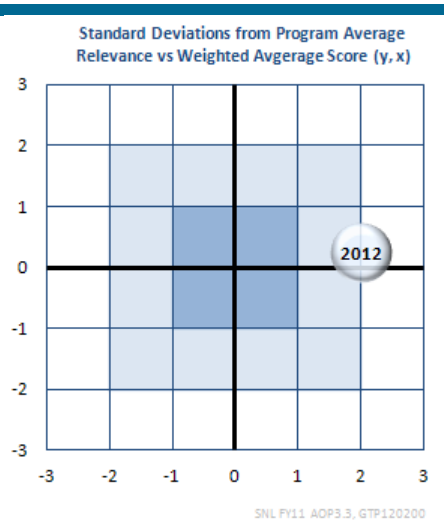
We agree that once the research on this project is complete an industrial partner should be found that can take it further down the path of commercialization. This is the goal of many of the R&D projects undertaken in the Geothermal Research Department at Sandia.

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

N/A



Review: 2012 Geothermal Technologies Office Peer Review
ID: SNL FY11 AOP3.3
Project: High Temperature Downhole Motor
Principal Investigator: Raymond, David
Organization: Sandia National Laboratories
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23521

Score: 3.0

Comment: The Geothermal industry is in great need of high temperature downhole rotation solutions for drilling geothermal wells. Commercially available downhole motors can't survive the extreme temperatures present in a geothermal well. If successful, the downhole motor can have a great impact on directional drilling. However, I'm not sure about the interest of Geothermal community in directional drilling, especially for Enhanced Geothermal Systems (EGS).

PI Response:

The PI concurs that there is a great need for high temperature downhole rotation solutions as current technology PDMs (positive displacement motors) cannot survive the temperatures of geothermal wells. Drilling plans are often modified as a result with side-tracks occurring higher in the hole in lower temperature regions, followed by surface rotation, with few options for correction when the well path deviates. Reliable, robust, high temperature downhole rotation solutions are vital for improved geothermal resource recovery.

Reviewer 23568

Score: 4.0

Comment: The ability to drill cost efficiently at high temperatures in multilaterals from a single drill pad is extremely important for EGS development. To do this requires a hydraulically operated downhole motor to replace Positive Displacement Motors, which are currently limited to 177 C. Therefore, developing a downhole motor for EGS temperatures is a technological game changer.

PI Response:

The PI concurs that successful development of a high temperature downhole motor is an enabling technology for EGS development. This capability would allow multilateral completions from a single well pad to allow concentrated energy extraction and conversion. A high temperature downhole rotation component will generally give rise to improved directional drilling control authority resulting in preferential targeting of geothermal features.

Reviewer 23548

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

Reviewer 23567

Score: 3.0

Comment: The directional drilling made available at high temperatures will significantly aid the accuracy of geothermal well construction. This project is important for developing EGS technology and demonstrating EGS development in rocks with peripheral drilling capability.

PI Response:

The PI concurs that the directional drilling capabilities to be realized with this technology will foster improved geothermal wellbore construction. It is an enabling technology to demonstrate EGS development in preferred fracture scenarios, much as rotary steerable subs have enabled extended reach drilling in the hydrocarbon industry. As noted by the reviewer, improved directional drilling capability is also needed for developing and demonstrating companion EGS technologies.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23521

Score: 3.0

Comment: The technical approach is sound, at least to a reviewer outside this field. I would like to see the patent that will come out of this and learn more details about the technical approach.

PI Response:

Details regarding the technical approach used in the high temperature downhole motor can be disclosed upon verification of the patent application filing.

Reviewer 23568

Score: 3.0

Comment: The approach is built around three tasks culminating in a proof-of-concept motor. A key development step was to build a Dynamometer Test Station to demonstrate the torque specifications in the first task are met as part of proof of concept.

PI Response:

The development of the Dynamometer Test Station is vital to supporting an objective, scientific evaluation of the concept. The dynamometer test capability is needed in support of validating the concept to TRL-3 (Technology Readiness Level), an experimental validation of the characteristic proof of concept.

Reviewer 23548

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

Reviewer 23567

Score: 3.0

Comment: The technical approach is generally sound, but due to the proprietary nature not enough information provided to judge the quality of the approach accurately. Room temperature testing of the prototype should be supported by high-temperature testing and reliability evaluation as much as project scope allows.

PI Response:

Proprietary information was not included at the direction of DOE wherein they advised not to include any information that is copyrighted, proprietary or confidential. The PI acknowledges that this obstructs an objective evaluation of the technical approach.

When originally proposed to DOE, Sandia noted that high temperature environment operation would be verified in an out-year with validation of design intent to be realized near-term at low temperatures. Actual high temperature testing has been proposed for a follow-on year of the project.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23521

Score: 2.0

Comment: Tasks 1 and 2 advanced to TRL-2 and Task 3 is in the Proof-of-Concept stage. Accomplishments, Results and Progress seem to be on track.
However, I'm not sure the team proposed any experiments related to High Temperature conditions in laboratory setting (Task 3). While demonstrating the functionality of the motor at room temperature is important, the final goal of this project is a high temperature (HT) motor and the team should take this into account.

PI Response:

The prototype concept will first be demonstrated at room temperature to validate the concept. The exclusion of low temperature tolerance elastomer and polymer materials will provide the design basis for high temperature operation. Follow-on years of the project will certainly address high temperature testing. The functionality of the motor will be environmentally qualified at the high temperatures to be expected in geothermal regimes in an out-year of the project.

Reviewer 23568

Score: 3.0

Comment: Everything but the actual proof-of-concept motor test has been accomplished. So the final jury verdict is still to be determined. There appears to still be a gap in proving out substitutes for elastomers in production motors.

PI Response:

The proof of concept testing will confirm the design basis for the elimination of elastomers in production motors. As noted by the reviewer, this characteristic testing will establish the final verdict on the viability of the motor concept.

Reviewer 23548

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

Reviewer 23567

Score: 3.0

Comment: The project team is well qualified for this project with good progress made on demonstrating the concept and establishing testing setup and testing procedure.

PI Response:

The PI concurs that the project team is well qualified as comparable developments have been successfully pursued using programmatic resources.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23521

Score: 3.0

Comment: Not sure the team has enough time to complete the work, especially demostration in a HT environment.

PI Response:

As noted, high temperature testing will occur in follow-on years of the project as this is the manner in which the project was proposed to DOE. The high-temperature capability of the candidate motor operation is realized through the elimination of elastomers and polymers from the baseline design. However, critical function evaluation testing at high temperature is certainly necessary to evaluate the influence of high temperature fluids on power transfer, evaluate the

influence of differential thermal expansion on motor performance, and investigate native component hardware material performance at elevated temperatures.

Reviewer 23568

Score: 4.0

Comment: The accomplishments are high in relation to budget because this project has synergy with other projects.

PI Response:

Synergy with other projects is primarily realized in facility and capital equipment resources. It is important to note that significant progress has been realized to date in developing a prototype design concept in support of the characteristic proof of concept testing to be completed.

Reviewer 23548

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

Reviewer 23567

Score: 3.0

Comment: With the plan for this new technology to be broadly available in the future to service companies a novel valuable tool addition is likely and practical.

PI Response:

The intent is to demonstrate the concept via the subject programmatic plan. Once intellectual property is secured, Sandia will seek out a commercialization partner and work towards licensing the subject technology. This will ultimately lead to development of a novel valuable tool with service company support.

STRENGTHS

Reviewer 23521

Comment: The project addresses the need for High Temperature Downhole Motors.

The team has a patent submission in works.

PI Response:

As noted under the impact of research section above, development of a high temperature motor is central to improved geothermal resource recovery. Furthermore, intellectual property protection sustains the drilling services industry; it is important that the patent filing be pursued prior to open disclosure.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

WEAKNESSES

Reviewer 23521

Comment: No High Temperature experiments planned in the three tasks of the project. This is mentioned in the future activities, but it is not clear to me what funds will be used for the proposed work.

PI Response:

High temperature testing was not part of the original work scope. Funding for support of high temperature testing will be proposed to DOE in a follow-on year of the project.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

IMPROVEMENTS

Reviewer 23521

Comment: The focus of the project is the development of a High Temperature Downhole Motor, but I didn't see much work/tests performed at high temperatures.

PI Response:

As noted herein, the design basis of the motor establishes the high temperature capability of the concept via elimination of elastomers and polymers. High temperature qualification testing will be addressed following a successful demonstration of the proof of concept testing.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response as reviewer did not comment.

Reviewer 23548

Comment: Reviewer did not provide comments for this criterion.

PI Response:

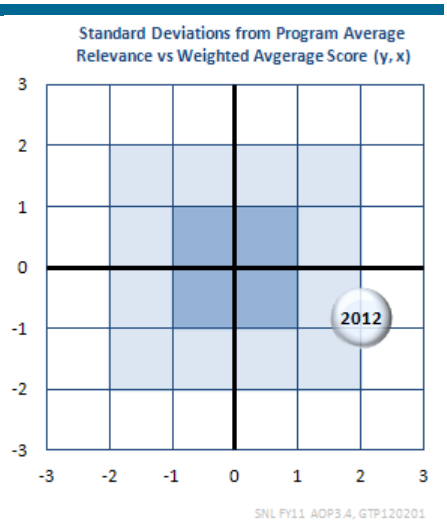
No response as reviewer did not comment.

Reviewer 23567

Comment: An early focus on evaluation of motor materials at high temperatures and establishing high-temperature testing capability in the dyno setup should significantly reduce technical risks and provide feedback for motor improvement.

PI Response:

The PI concurs that early attention to high temperature evaluation is needed. However, as stated herein, incremental development as originally proposed will first address evaluation of the concept at low temperature to establish viability. Development efforts thereafter will accelerate towards high temperature qualification to reduce technical risks and provide critical feedback into development of a high-temperature specific motor solution.



Review: 2012 Geothermal Technologies Office Peer Review
ID: SNL FY11 AOP3.4
Project: Auto-Indexer for Percussive Hammers
Principal Investigator: Su, JiAnn
Organization: Sandia National Laboratories
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23433

Score: 3.5

Comment: Hammer drilling has particular advantages for the drilling of hard, abrasive rocks. In the first place, concentrating the available down force on the bit into a series of discrete impacts rather than applying a steady down force enables the bit to apply (momentarily) a much greater peak force than the steady state value. This is important when penetrating hard rocks. Secondly, since the bit teeth penetrate the rock in a direction parallel with the hole axis, there is relatively little sideways movement of the bit teeth, i.e. minimal scraping movement along the hole bottom. This reduces the abrasive wear of the bit teeth. For both these reasons, hammer drilling is a preferred method for penetrating hard, abrasive rocks. One requirement for the efficient action of a hammer bit is that it should be rotated slightly (indexed) between impacts so as to avoid having the bit teeth repeatedly contact the rock at the same position. The proposed program achieves the desired indexing action by providing a separate sub behind the hammer that causes the hammer and bit to rotate.

PI Response:

I agree with the assessment of the relevance/impact of the research. Thanks for the comments.

Reviewer 23412

Score: 3.0

Comment: The air hammer has been in use in mining applications and limited in the oil and gas industry mainly because it was not invented there and also there are safety aspects of drilling with air in potential hydrocarbon atmospheres. The air hammer should have some application with geothermal drilling. The advantage of the auto indexing or rotating and hammer action was identified for directional control of the tool face. I would think that orientation of the tool face with intermittent torque would be difficult.

PI Response:

The auto indexer rotationally indexes the bit face to allow drilling. It is not intended to control the tool direction or orientation. That will have to performed with another tool. Sorry for any misunderstanding.

Reviewer 23480

Score: 2.0

Comment: The relevance of this project is predicated upon the widespread use of percussive hammer drilling. Currently this is not the case, and although some experts point to hammer drilling as the best means of penetrating hard rock, the PI does not present information supporting the general adoption of this drilling system by industry. Although this project may succeed in achieving its objectives, the impact of that success may prove minimal.

PI Response:

The reviewer is correct in that percussive hammers have not been widely used in geothermal drilling. That is something that this project, along with the high temperature hammer development hopes to change by giving drillers more options for accessing geothermal resources.

Reviewer 23519

Score: 1.0

Comment: Pneumatic hammers are known to increase the drilling rate in hard rock as used by the mining industry. The proposal suggests the use of pneumatic hammers will offer benefits to future EGS well drilling with the addition of an indexing tool developed under this program. Hammer drilling with an indexing tool should improve performance (ROP) in drilling hard rock and provide a means to allow directional drilling.

This program is extending the operating range of an indexing hammer in hot geothermal resources by increasing the operating temperature. The new design eliminates all elastomers and makes use of dry lubricates to increase the operating temperature. It appears, these developments are considered valuable IP by Sandia. The details of this work were not presented at the program review because Sandia has not protected it's IP position.

The use of hammers can in some circumstances, within geothermal drilling, "could" offer faster and more cost effective drilling in hard rock over conventional top drive, roller cone drilling.

However, the risk of failing to realizing the cost savings and/or the risk of expensive equipment lost in the hole will continue to prevent the use of pneumatic hammer drilling geothermal. The use of pneumatic hammer technology in EGS directional drilling is valued by this reviewer, however, there isn't any information provided on how this technology will support horizontal drilling in a manner which reduces operational costs.

PI Response:

It is well known that pneumatic hammers are among the most efficient methods of drilling holes in hard rock, and the ability to provide downhole rotation will help to enable directional drilling using the technology. However, we realize that downhole rotation is but an enabling technology and it is not the only factor in realizing that capability. Other aspects of the drilling operation will have to be improved and developed as well.

With respect to the issues around IP, due to the open nature of the meeting we followed DOE guidance that did not include any information that is copyrighted, proprietary, or confidential in the presentation.

The argument for using hammers (and thus downhole rotation) is explicitly directed at lowering the costs of wells. While hammers do not work in all conditions, where they are applicable they easily outperform roller bits in ROP as well as tool life. This was discussed at last year's Peer Review and provided to DOE in the draft white paper last year. The primary goal is to give drillers more options for accessing geothermal resources. Risk is always present in well construction and I would challenge the assertion that in hard rock environments hammer based systems are inherently riskier and more costly than more commonly used technology.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23433

Score: 3.5

Comment: The approach to the problem of indexing is sound. The method has been to provide a separate sub to be mounted above the hammer unit that provides the rotary motion. In this way, the two functions are separated mechanically, so that, in principle, the indexing device can be mounted behind a range of hammers from different manufacturers. The rotary motion appears to be achieved by the use of a down-hole air driven rotary vane motor. Such motors are very robust, and well suited to use in extreme environments. It was not made clear how the vane motor motion is converted into the necessary stop/go motion required for indexing so the reviewer is unable to comment on this feature of the design.

PI Response:

Per the instructions for the review presentations, proprietary information relating to the conversion of motor motion into bit indexing was omitted. However, the author will be willing to present that information once the IP issues have been settled.

Reviewer 23412

Score: 2.0

Comment: The presentation was sanitized of proprietary information necessary to understand the scientific or technical approach.

PI Response:

Per the instructions for the review presentations, proprietary information relating to the conversion of motor motion into bit indexing was omitted. However, the author will be willing to present that information once the IP issues have been settled.

Reviewer 23480

Score: 2.0

Comment: The summary and presentation material do not explicitly define the "auto-indexer" or explain how it works. The approach appears to be to improve existing technology to enable/facilitate performance in geothermal drilling. Listing the pros and cons of the tool is commendable. A table showing the current state of art for performance and the expected improvement would also be helpful. Although functional requirements for the tool are identified, the means to be used in meeting those requirements are not explained. An engineering diagram of the tool and a schematic of how it fits in the BHA would be helpful.

PI Response:

Per the instructions for the review presentations, proprietary information relating to the conversion of motor motion into bit indexing was omitted. However, the author will be willing to present that information once the IP issues have been settled.

I agree with the reviewer that an engineering diagram of the BHA would have been helpful

From top to bottom:

Drill string -> Auto Indexer -> Pneumatic Hammer -> Bit

Reviewer 23519

Score: 3.0

Comment: The auto indexer power section testing on the Sandia dynamometer test station is good. Dynamometer testing provides for hardware characterization at a reasonable cost and over various operating conditions.

After testing on the dynamometer is complete, the power section will be integrated with the rest of the auto indexer tool, and tests will be conducted at the Sandia Geothermal Test Range. I'm unfamiliar with the Sandia Geothermal Test Range. The peer review summery suggests the basic tool operation can be tested using rock samples. Given the limited funding for this project, such testing seems reasonable and should result in some reportable results. This testing may also point out any major design deficiencies at low cost to the program.

Unfortunately, these proposed tests are at the major component level and at low temperatures and without exposure to high pressures and caustic fluids. There are no actual details of test results evaluating dry lubricants or processes which have eliminated elastomers. The project lists the corrosive environment of geothermal wells as being a major impediment for the use of hammer drilling in EGS wells. There doesn't appear to be any planned testing or evaluation of HCL or H2S testing of the indexing tool or pneumatic hammer.

The lack of testing or evaluation of materials used by Sandia researchers in the construction of testable systems leaves this reviewer reluctant to provide this project with even a nominal evaluation as to the scientific approach. I personally feel Sandia is doing a much better job at addressing the technical issues than is being presented here. Attempting to protect IP by withhold test data and basic design considerations for dealing with corrosive fluids, high pressures and high vibration as seen in real geothermal drilling has resulted in a poor score.

PI Response:

I appreciate the comments. The current goal for development is to test the basic functionality of the tool. The reviewer is correct in that the environmental testing will be important to evaluate the overall effectiveness of the tool. Those types of tests will require finding suitable test wells and opportunities to exercise the tool in those environments, which may be a challenge given the scope and budget for the project.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23433

Score: 3.0

Comment: Work done so far has involved the initial design, selection of materials and preliminary testing. This appears to have gone well, although the dynamometer can only deliver air to the motor at 90 psi, which is eventually expected to function with air at 350 psi. Thus testing has not been able to examine the full working range of the motor. The reviewer notes that the investigators have had some problems with heat treatments and coatings. See below for some suggestions for dealing with air motor lubrication problems.

PI Response:

Thanks for the feedback. Testing is underway.

Reviewer 23412

Score: 2.0

Comment: The project is 80% complete with the most important step of final prototype demonstration to come. The critical step of demonstration will determine the project the success of the project.

PI Response:

I agree. Testing and a successful demonstration will ultimately determine the success of the project.

Reviewer 23480

Score: 2.0

Comment: Construction of a working prototype for testing is important. The hardware for a final prototype appears to have been built, but assembly of the working model is ongoing. The PI may have been unprepared for some of the challenges inherent to upscaling the tool. Will the tool be tested in a dynamometer with sufficient pressure? Are there plans to field test the tool in a geothermal well? High-temperature operation is a valuable attribute--what is the maximum operating temperature? Eliminating the need for elastomers is a significant accomplishment.

PI Response:

The assembly of the working model was completed. I apologize for any ambiguity in that part of the project. There were some challenges in scaling the tool from the proof-of-concept. Most of those were in getting enough air to run the larger motor and it has been tested in the dynamomenter at pressure. The maximum operating temperature will be dependent on the final material selection. Currently, the materials are tempered at a minimum of 400°C which would be the limiting factor. Fielding the tool in a geothermal well will depend on opportunity and funding. The original project plan was only to demonstrate the basic functionality of the tool and drill some shallow holes.

Reviewer 23519

Score: 2.0

Comment: There are too few technical details in the program review to consider results. It would have been nice to identify some of the solutions in improving the design of the hammer. However, the report does state that the program is successful and within schedule.

PI Response:

The project is moving forward. We have hardware built and it is being tested. Unfortunately, we were unable to show more details at the peer review.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23433

Score: 3.5

Comment: This is a straightforward project from the management point of view, since it involves only one line of activity. Requirements for coordination with other players are therefore minimal. Overall, the project appears to be on track. A more challenging period may come soon when field trials must be arranged.

PI Response:

Agreed.

Reviewer 23412

Score: 2.0

Comment: With much of the technical information sanitized from the presentation, it is difficult to assess the management and coordination

PI Response:

Much of the coordination is internal and working with the machine shops to get hardware built.

Reviewer 23480

Score: 2.0

Comment: The project appears to be managed entirely in-house at the laboratory. This approach has certain advantages for staffing and coordination, but also limits the extent to which expert technical support and advice is obtained. The coordinators/collaborators are listed as hardware suppliers, not the ultimate users of the technology. The ability of the project to move ahead seems to be limited by laboratory resources, such as availability of testing equipment. The data sharing plan is rudimentary, and perhaps stems from the pending patent application for the tool? According to the milestone chart, the project is about a year behind schedule---further slippages could occur, resulting in cost overruns.

PI Response:

The reviewer is correct about the design discussions. Much of the design discussions was internal. The data sharing is somewhat limited, but the design details will be useful for the technology program. There were some delays in getting the testing started, but things are moving forward.

Reviewer 23519

Score: 2.0

Comment: It appears that failing to identify and protect IP is a significant weakness in project management. Future Sandia PI should file documents with the Sandia or DOE legal offices to protect their first to invent rights.

Filling such documents takes only a few days.

PI Response:

Documents were filed to protect the IP, and we do not agree with the amount of time that the reviewer asserts. However, the status of the patent application is still uncertain.

STRENGTHS

Reviewer 23433

Comment: The project addresses a well-defined need in the area of improving the functionality of downhole hammer drills. The specific issue is how to make sure that sequential impacts by the hammer bit do not fall always in the same place but are indexed to land at locations at an optimal distance from the previous impact. The solution, to provide rotation via a separate sub, placed behind the hammer section, is a good one. It has the advantage of the sub being a piece of equipment separate from the hammer, and is therefore potentially able to be added to a range of different hammers. The engineering problems involved in the design appear to be of the conventional mechanical engineering type, although it may turn out that exposure to the high temperature down-hole environment may bring up unforeseen problems with lubrication. Overall, the reviewer judges that the project has a high probability of success.

PI Response:

Thank you for the comments.

Reviewer 23412

Comment: The project has strengths because it has produced a product.

PI Response:

Thanks for the comments. I like to point to the fact that we are developing an application-based tool.

Reviewer 23480

Comment: The elastomer-free motor and the torque performance of the motor are significant improvements in downhole tools and could have broad-based impacts beyond the auto-indexer application.

PI Response:

Thanks for the comments

Reviewer 23519

Comment: In addition of the PI's presentation, this reviewer sees hammer (and vibration drilling) useful for a fast and reasonably inexpensive means for drilling shallow temperature gradient wells of small diameter. These technologies can move a lot of rock in the compacted soils.

Hammer drilling should slightly improve performance (ROP) in drilling hard rock over roller cone, top drive drilling. Use of an indexing tool should provide a means to allow directional drilling.

In general, there is always value in creating more tools in the tool box when considering the future of EGS. Drilling will be a major cost component to future EGS projects.

PI Response:

Thanks for the comments

WEAKNESSES

Reviewer 23433

Comment: As noted above, exposure of the auto indexer to the dirty and high temperature down hole environment may give rises to problems of lubrication and excessive wear. It is not clear whether the investigators have given any thought to these questions, but if not, it may be worthwhile to do so at an early stage.

PI Response:

These are certainly challenges to address during the development process. Materials selection and durability are key challenges to this type of project.

Reviewer 23412

Comment: The weakness of the project is that the produced product has no indication of reliable operation at in situ conditions of temperature and it requires compressor pressure.

PI Response:

Those are valid points that will be addressed as part of future testing and development. The initial goal of the project is to establish the functionality and operation. Reliable operation under real conditions and temperatures will be addressed in future work.

Reviewer 23480

Comment: Specific design aspects of the tool are lacking, which prevent the reviewer from making an adequate assessment of operating characteristics and performance.

PI Response:

I understand the sentiment.

Reviewer 23519

Comment: Pneumatic hammer drilling at geothermal temperatures and depths is unlike to increase ROP enough to justify the cost.

PI Response:

The tool is designed to operate with conventional equipment, and at a given diameter hammers generally cost less than roller bits. We do not believe this a a more expensive option in most cases.

IMPROVEMENTS

Reviewer 23433

Comment: The question of lubrication of the air motor was noted above. If the prime mover in the sub is a rotary vane motor driven by compressed air, there is the potential for the air supply to be less than ideal under field conditions. Lubrication of conventional vane motors is by the introduction of oil mist into the air supply. In the present case, there is the risk of failure of the lubrication system, or the possibility of the accidental entrainment of water in the air supply. It would therefore be desirable for the vane motor to be able to run in the presence or absence of oil lubrication, and in the presence of water in the air supply. The reviewer has some experience of this problem in the past, when it was required to deal with the oil/no oil, water/no water situation in the small vane motors used to power hand tools. The solution involved changes to the motor vanes only -no coatings on the motor stator, which in the specific case was made of cast iron, and no other changes to the mechanical or material design of the motor. The vanes were changed from being made of a cotton-phenolic resin composition to ones made from a composition containing woven glass fiber, PTFE, a polyfluor alkoxy resin and additives that contained lead in various forms and concentrations. The reviewer would be happy to provide further information on the materials and how to manufacture such vanes, if needed.

PI Response:

Thanks for the very helpful feedback.

Reviewer 23412

Comment: Improvements can only be considered after the prototype has been tested.

PI Response:

Testing is underway. Thanks for the feedback.

Reviewer 23480

Comment: To be useful, the tool must work in a geothermal environment. Although the PI is performing tests, the conditions of those tests are not specified. Both laboratory and field tests should be done under geothermal conditions of temperature and fluid chemistry. An industry collaborator should be recruited now to assure the technology is commercialized in a timely fashion.

PI Response:

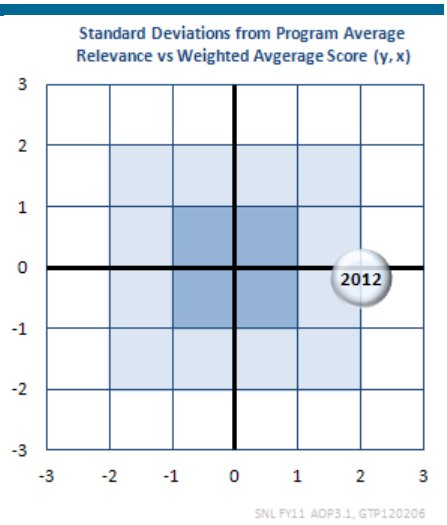
We have another project in which we are working with an industrial partner on pneumatic hammer development. We are looking to use this opportunity to work with an industrial partner on product development.

Reviewer 23519

Comment: Sandia needs to identify a means to protect its IP during Geothermal Technologies Office reviews.

PI Response:

The issue is being addressed. Thanks for the feedback.



Review: 2012 Geothermal Technologies Office Peer Review
ID: SNL FY11 AOP3.1
Project: Energetic Materials for EGS Well Stimulation
Principal Investigator: Blankenship, Doug
Organization: Sandia National Laboratories
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23521

Score: 3.0

Comment: Enhanced Geothermal Systems need good fracking technology, and the present project is addressing energetic systems that enable branching, far-field fracking and stimulating existing fracture, using solids, liquids and gases.

PI Response:

We agree! Thank you for the succinct summary.

Reviewer 23519

Score: 2.0

Comment: The most accepted method for EGS well stimulation is hydraulic fracturing. Hydraulic methods allow the use of local water sources. In general, local concerns over contamination of fresh water supplies are reduced by the use of water and sand when conducting well stimulation.

This project does provide a simple, perhaps less costly means for simulation of geothermal wells drilled inside existing hydrothermal geothermal systems. In this case, a well may have intersected the reservoir at a location with low permeability. The gas generated pressure could be to increase localized permeability or in cleaning out a damaged production zone.

In existing hydrothermal systems the concerns of the local population are less likely to be an issue. The goal of this effort is to develop environmentally safe energetic materials for stimulating EGS production. However, environmentally safe is not clearly defined within the goals of the project other than safe to transport over US roads using guidelines from the DOT.

The potential for energetic materials for use in large scale EGS projects is unlikely as well stimulation must reach out 1000s of meters from the well with large opened fractures. In short, I don't see a means for gas driven pressure stimulation to compete with hydraulic fracturing in future EGS power projects.

As such, this technology will compete with existing stimulation options for conventional hydrothermal geothermal systems and find limited use in large future EGS systems where large fractures over great distance are required.

There should be significant interest in this technology from the natural gas industry.

PI Response:

We "define" non-toxic in a general sense to mean not particularly toxic on a relative scale and not particularly hazardous to handle. We are NOT considering hazardous materials such as hydrazine, tetranitromethane, etc. The products of reaction of our systems are benign such as water and oxygen or nitrogen, water, carbon dioxide or light metal oxides and possibly chlorides.

Hydraulic fracturing is limited in application and performance. High rate gas fracturing has a different scope. It can reduce well bore permeability, create multiple fractures, and extend existing fractures. Multiple, repeated, stimulations can continue to increase the length of initial fractures. Additionally it is possible to inject energetic materials into the fracture where a subsequent energy release can take place. A direct cost comparison my not be accurate. Hydraulic fracturing could be done in a less costly manner but it cannot do what energetic materials can do. There is likely a place for both technologies, they are not competeing but synergistic.

We agree! There is the potential to eliminate the waste water generated in hydraulic fracturing operations.

Reviewer 23568

Score: 4.0

Comment: This project explores using novel high explosives technology for EGS stimulation. Given Sandia's expertise in explosives, this project is one they are best to tackle. In particular, the idea of explosives can lead to fracture networking to increase reservoir area exposed. The idea is to find a "designer" explosive to develop branching of far field fractures and/or stimulate existing fractures.

PI Response:

Well put. We used the words "tailored pressurization" but "designer energetic materials" are what we are developing.

Reviewer 23567

Score: 3.0

Comment: This project is advancing technology of directed well stimulation and may provide a solution for a tunable peak pressure and timing profile controlling fracturing and shear forces.

PI Response:

Exactly. A good summary of our approach.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23521

Score: 3.0

Comment: The current technique wants to position itself somewhere between High Explosives (HE) and Propellants (P), in terms of the fractures generated. The team intends to achieve their goal by a rapid increase in pressure to levels in

between those produced by HE and P. Additionally, they intend to tailor the newly developed energetic materials such that the pressure profile is initiating near well fractures and, additionally, propagates the fractures to the far field. Detailed analysis of the energetic materials is performed theoretically and experimentally, maybe.

PI Response:

Thank you for the excellent synopsis of the project.

Reviewer 23519

Score: 2.0

Comment: The approach is to formulate chemistry to provide a computer modeled burn rate, burn temperature and pressure impulse. Solid, liquid and gas materials are considered under differing deployment methods suitable for downhole use.

Perhaps, outside of the project planned budget, there are three additional topics which should have been considered.

First: What or who determines the requirement of energetic materials to be environmentally safe as used inside a geothermal well? The answer clearly varies from state to state but some effort to identify a process would aid in considering one or more of the down selected energetic materials.

Second: With explosive materials, the pressure pulse is expanding faster than the acoustic wave in a given material can travel. In short, there is less of an issue with confinement at increasing depths. Although, this research is claiming to be above propellant rates of expansion, some consideration should be given to discussions with other geothermal researchers as the deployment options and likelihood of well confinement at the zone of interest.

Finally: Some conceptual consideration should be given to what if events. For example, most (if not all) energetic materials degrade with temperature and time. What if, the deployment is held up in an upper section of the well? What if, there fails to be an ignition? What are the environmental issues if there is only a partial burn?

PI Response:

1) Rather than specify who determines what is safe, our approach has been to use relatively benign materials. In discussions with drillers the issue will be bringing a “new” material to the site and adopting appropriate handling procedures.
2) An excellent point. Ideally gas generation rates will be tailored to a specific formation with input from geothermal researchers.
3) Our systems are not typical of conventional CHNO high explosives. Our gas system is thermally stable at typical geothermal well temperatures, our solid system is an inorganic binary that is thermally stable and our liquid system is designed to function at "temperature" and be pumped to the fracture zone of interest. In general being hung up in the wrong position is not an issue. There is no ignition system required for the liquid system, the gas phase system can be vented to the surface if there is a failed ignition and for a failed ignition of the solid system it could be retrieved or allowed to "dissolve" in place. Partial burns are unlikely, but given the nature of the reactants we do not believe there will be any significant environmental issues.

Reviewer 23568

Score: 3.0

Comment: The approach is a straightforward division into solid, liquid, gas requirements. The rock mechanics science that motivates the underlying performance goals in pressurization rate was not clearly stated.

PI Response:

There are several dynamic processes occurring that will determine the nature of the cracking that occurs as the borehole pressure rises. The crack itself propagates at a rate dependent on the driving pressure and the opening of the crack mouth, but limited to about the shear wave speed which typically is 2 to 3 km/s. There is an extensive literature on the velocity of propagation of cracks in rock. Gas pressure in the crack rises as gas propagates into the crack at a speed ≅ sonic velocity as an upper limit. In addition to extending the crack, the gas pressure on the crack face results in a compressive stress normal to the crack plane which is initially tangential to the hole boundary. Near the hole circumference this compressive stress propagates at the velocity of an interface wave, a Rayleigh or more properly a Stoneley wave, with a velocity that is also ≅ shear velocity. As this compressive wave propagates, it tends to suppress cracking because a higher gas pressure is required to create a net tensile stress. A similar effect occurs due to the release wave generated when the newly-created crack's free surface relieves the tensile stress responsible for the crack's initiation. This has the effect of making the tangential stress more compressive, as the release wave propagates around the borehole boundary, and thus also suppresses cracking. The release wave's propagation speed should be also ≅ shear velocity, the same as the wave generated by the gas pressurizing the borehole. However, the release wave starts as soon as the crack forms, while the pressurization wave initiation requires that the gas propagate into the crack and exert pressure on the crack faces.Until the arrival of the relief and pressurization information via the propagation of elastic interface waves, the stress state will be the same as in the absence of the crack. At intermediate pressurization rates, there is an interplay between stress relief propagation and the crack gas pressurization rates, both of which suppress additional cracking, versus the borehole pressurization rate which tends to initiate more cracks, modulated by the azimuthal dependence of the crack initiation stress due to stress anisotropy. It is in this intermediate regime that interesting and useful effects may be achieved by controlling the pressurization rate.

Simply stated, at quasi static pressurization rates single cracks form and at rapid pressurization rates, on the order of 1-10 x10**6 psi/sec, multiple cracks form.

Reviewer 23567

Score: 3.0

Comment: The innovative approach investigates a complete suite of gas/liquid/solid systems platform with the goal to compare and evaluate their performance and capability relative to each other. The approach is planning to utilize energetic materials and is also addressing the need to control and minimize the damage which can be sustained by the well bore as a result of stimulation, but the mechanisms of deep fracturing to produce results similar to hydraulic stimulation are not obvious.

PI Response:

For a more indepth discussion please see the prior response. We are using rapid gas generation from energetic materials to conduct work on the formation similar to using hydraulic fluid and a pump. In this case the use of energetic materials allows for the energy release rate to be orders of magnitudes greater than for a hydraulic fracturing system. Simply stated, our peak power is much greater. With this approach we can generate multiple fractures to increase well bore permeability.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23521

Score: 2.0

Comment: This part is difficult to judge. There's only one slide dedicated to this section, without much data.

PI Response:

Per the DOE's guidance to PIs, we did not include any information that is copyrighted, proprietary, or confidential in the presentation.

Reviewer 23519

Score: 1.0

Comment: To date, computer simulation has been used to aid the down selection of energetic materials. Work with Purdue has been used to evaluate transportation safety factors. There are no examples of rejected materials to gage the evaluation criteria. There are no examples of environmentally unsafe or safe materials.

A liquid pump system has been developed. No data or discussion is given to its performance or even its operation.

PI Response:

Per the DOE's guidance to PIs, we did not include any information that is copyrighted, proprietary, or confidential in the presentation but to breifly elaborate:

"Undesirable" material examples: Neat Hydrazine, MMH, UDMH, tetanitromethane, TNT, Trinitrobenzene, interhalogens (Chlorine trifloride), nitrogen tetroxide, etc.
"Safe" Materials: hydrogen peroxide, oxygen, simple hydrocarbons, etc.

Pump system: 2500psi, 10gpm diaphragm injection pump was demonstrated with a HP gas generator at 99+% efficiency.

Reviewer 23568

Score: 3.0

Comment: The results align with approach; however, the field testing is yet to be done and will be the proof in the pudding.

PI Response:

We agree wholeheartedly, field testing is of paramount importance. In order to conduct meaningful field test we have made a significant investment in laboratory scale testing.

Reviewer 23567

Score: 2.0

Comment: Proprietary material systems are claimed to be developed in the course of the project without demonstration of supporting test data. Preliminary test data is highly desirable to evaluate technology potential and usefulness. Fracture depth, control and directionality measurements may turn out to be crucial.

PI Response:

We are moving from successful laboratory scale testing to shallow well bore testing. Data will follow.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23521

Score: 3.0

Comment: The project seems to be handled fine, including work performed by external collaborators.

PI Response:

Thank you. Our team at Purdue University and at the Energetic Materials Testing & Research Center are significant contributors to the success of the project.

Reviewer 23519

Score: 3.0

Comment: There appears to be an issue with IP when providing reviewers with information on Sandia projects.

Perhaps, part of managing the project is to file first to invent protection in a timely manor to allow for more open project discussions at Geothermal Technologies Office reviews.

Otherwise, all Sandia projects have reasonable coordination with information moving through the Sandia Geothermal Research Department. This project seams underfunded given the scope of work to determine environmentally safe. There is a lack of funding to validate the projects outcome.

PI Response:

Per the DOE's guidance to PIs, we did not include any information that is copyrighted, proprietary, or confidential in the presentation.Unfortunately filing is a timely manner is an issue as open presentation initiates a patent bar date clock.

We agree that the project is underfunded given the scope of the task at hand. We have tailored the sccope of the project to the funds available. Validation will require additional funding.

Reviewer 23568

Score: 4.0

Comment: The project is on track.

PI Response:

We are progressing towards our goals.

Reviewer 23567

Score: 3.0

Comment: Project is designed to compare several energetic material systems for stimulation with the goal to identify most promising for EGS construction. Downhole demonstration is planned; however, it was indicated that some test would not be possible to carry out in the current project scope.

PI Response:

Down hole tests will be conducted in shallow bore holes at EMRTC. Testing is limited in scope to the funding at hand.

STRENGTHS

Reviewer 23521

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23519

Comment: Computer modeling to down select potential test materials.

PI Response:

No response entered.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23521

Comment: No data/results to support the progress of the project.

PI Response:

Pump system: 2500psi, 10gpm diaphragm injection pump was demonstrated with a HP gas generator at 99+% efficiency.
Gas phase system: Ignition and propagation demonstrated. High pressure tests in progress.
Solid system: Materials identified. Test planning underway.

Reviewer 23519

Comment: Poorly defined objectives and no follow-on to validate the project's success.

PI Response:

Objectives:
Develop a family of energetic systems that are suitable for increasing well bore permeability, extend existing formation fractures and generate new fractures. Follow on will require additional funding.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23567

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23521

Comment: Data, results, data, results...

PI Response:

Per the DOE's guidance to PIs, we did not include any information that is copyrighted, proprietary, or confidential in the presentation.

Reviewer 23519

Comment: Assuming, my assessment of the potential use of energetic materials for use in large scale EGS projects is wrong, I suggest the following.

1. Increase the funding.

2. Cover the following questions

a. What does environmentally safe mean in a geothermal well? At least in one example.

b. Some conceptual consideration should be given to what if events. For example, most (if not all) energetic materials degrade with temperature and time. What if, the deployment is held up in an upper section of the well? What if, there fails to be an ignition? What are the environmental issues if there is only a partial burn?

3. Program for validation of the results in an geothermal well with instrumentation.

PI Response:

1) We wholeheartedly agree that funding should be increased.
2)
a. Environmentally safe means; not particularly hazardous to handle and no long term issues. For example, with the injection of hydrogen peroxide into a geothermal well, high pressures can be generated to produce fractures with the products of reaction only being water and oxygen. The same thing could be accomplished with hydrazine, but the toxicity issue would be insurmountable.

b. Our systems are not typical of conventional CHNO high explosives. Our gas system is thermally stable at typical geothermal well temperatures, our solid system is an inorganic binary that is thermally stable and our liquid system is designed to function at "temperature" and be pumped to the fracture zone of interest. In general being hung up in the wrong position is not an issue. There is no ignition system required for the liquid system, the gas phase system can be vented to the surface if there is a failed ignition and for a failed ignition of the solid system it could be retrieved or allowed to "dissolve" in place. Partial burns are unlikely, but given the nature of the reactants we do not believe there will be any significant environmental issues.

3) We agree that developing a program for validation is needed. This will require another step up in the funding level.

Reviewer 23568

Comment: Reviewer did not provide comments for this criterion.

PI Response:

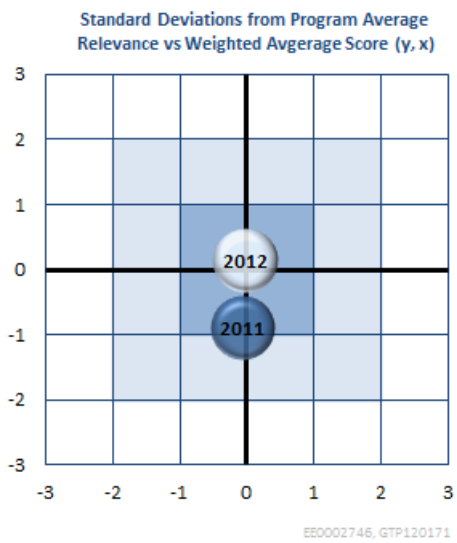
No response entered.

Reviewer 23567

Comment: Complete materials characterization for obtaining preliminary data of fracturing efficiency and estimation of EGS benefits.

PI Response:

We are in the process of materials testing and characterization.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002746
Project: Development of a Hydrothermal Spallation Drilling System for EGS
Principal Investigator: Potter, Jared
Organization: Potter Drilling, Inc.
Panel: High Temp Tools, Drilling Systems, Zonal Isolation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23527

Score: 2.0

Comment: The goals and efforts of this project are laudable. The focus on field demonstration of spallation drilling is the most pertinent project form for evaluating this technology as it has been investigated primarily at the laboratory level for over 20 years. Rapid demonstration or application of candidate technologies in field-like conditions should be a focus of this program, particularly given that a limited funding climate requires more selective identification and managing of R&D investments.

The above being said, the numerous issues associated with both the system deployment and rock reduction performance of spallation drilling technology does not appear to this reviewer to be the most effective use of programmatic funding if the objective of the program is to reducing the cost of drilling. The cost to further develop this method to a point of commercial viability is likely to be quite significant while the drilling method itself appears to have limited application. It is incapable of being used as a grassroots drilling method (from spudding the well onward), has limited lithological application and is not particularly well-suited to producing well bore dimensions amenable to efficient and effective installation of completions. The potential return on investment is likely to be quite small even when compared to the adaptation of conventional drilling technologies to function in hard rock applications.

PI Response:

Reviewer 23478

Score: 2.5

Comment: This project is quite relevant to the Geothermal Technologies Office goals and objectives because, if successful, it may significantly decrease drilling time and cost by increasing ROP and eliminating conventional bits that wear out rapidly under harsh hydrothermal and/or EGS conditions.
The impact on the geothermal industry as a whole would be modest, as this project addresses only the drilling sector of geothermal exploration and development. However, when (and if) in the medium term future, this technology proves to radically change all hard-rock drilling methods, then the impact will indeed be significant.

This project is somewhat akin to the Multihole Array drilling concept in that it touts its suitability for rapidly drilling numerous offsets from EGS wells and in this way to increase heat exchange and the chances of intersecting more fractures. Similarly, the thinking behind this project is somewhat "out of the box" and therefore fated to encounter many challenges related to materials, tools, down-hole conditions, etc.

The reason for the relatively low score is the impact level. It really can not be considered to be exceptional or considerable at this time.

PI Response:

Reviewer 23471

Score: 4.0

Comment: This project is highly relevant to the Geothermal Technologies Office goals. Reducing the costs of drilling through implementation of a hydrothermal spallation drilling technology could significantly reduce drilling costs through improved rate of penetration and (potentially) prolonged bottom hole assembly (BHA) life. Once successfully proven as a field technique, hydrothermal spallation drilling would also be very useful for drilling of multi-laterals off new or existing wells and could be used for hole-opening operations, to facilitate greater hydraulic communication with potential geothermal reservoir rocks.

PI Response:

Reviewer 23529

Score: 4.0

Comment: The basic objectives of the program are to build and test a prototype hydrothermal spallation drilling system with higher rates of penetration and limited bit wear and drill string fatigue. If successful, this system will reduce the drilling cost of EGS wells by approximately more than 15%, which aligns well with the EGS mission and has considerable impact on the commercial scale of deep, hard rock drilling. The program can also support the hydrothermal industry through the lower cost drilling of multilateral slimholes for resource-fracture identification as well as increasing productivity of wells by 50 – 200%.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23527
Score: 3.0

Comment: The approach is honest and reasonable given the objective of field demonstration of the technology. From what information I could glean from the presentation and summary sheet, the progression from laboratory testing to design to field prototype fabrication was very sensible. There seemed to be somewhat of a struggle associated with the integration of the surface and downhole equipment. This could perhaps have been handled a little more efficiently with additional expertise more familiar with some of the component technologies.

Did the earlier phase laboratory demonstration of spallation drilling incorporate hole cleaning and cooling fluid? If not, it is arguable that this interaction should have been studied some before proceeding to field trials. It is of course easier to see this in hindsight, but it is a question that can be reasonably asked.

PI Response:

Reviewer 23478

Score: 3.0

Comment: This project has been intelligently divided into four Stages and the Stages have then been further split into Tasks. The Tasks are designed to address specific challenges and each has a specific set of goals and objectives. The operations are well focused and have thus far resulted in numerous incremental successes and the identification of technical issues that will need more study in order to develop new approaches.

Given more time and money, it seems likely that work by both the proponent and the associates at Cornell University will be able to overcome and/or acceptably mitigate technical barriers and thereby improve drilling results. There are still several problems in the optimization of this technique. Potter is now seeking to generate higher temperature steam, mitigate the effects of cooling waters on the cutting surface, and control the on-ff-onn phenomenon that now characterizes the drilling progress. Centralization of the coiled tubing is also a challenge to be overcome.

PI Response:

Reviewer 23471

Score: 3.0

Comment: The technological approach being used by this group is innovative and potentially far-reaching. The thermo-mechanical stresses induced by the cutting jet are most amenable to rapid cutting in “hard” crystalline rocks (e.g., granites), which constitute a large proportion of the potential EGS resource base in the U.S. The use of down hole catalysts to drive the reaction has proven to be an effective approach, although one of the challenges now is modifying the bottom hole assembly for higher power output and greater reliability. Also, it appears that this catalyst approach limits their ability to vary power output during drilling, and ways to vary tool output during drilling should be investigated, as this might be advantageous to controlling cavity formation when ROP drops. Although not mentioned in the presentation, I encourage the PIs to employ borehole televiewer and resistivity tools (multiple depths of investigation) to diagnose the overall shape, roughness and damage state of the holes that they drill during test deployments and to ascertain the manner in which the spallation process interacts with pre-existing discontinuities in the rock mass (fractures, foliation and lithologic changes). By combining such an analysis with lab diagnosis of cuttings produced in these same zones, additional insights might be gained into the physical process at work at a variety of scales (sub-grain, grain and trans-granular) during cutting that will help them design a more energy-efficient and controllable process.

PI Response:

Reviewer 23529

Score: 3.0

Comment: The staged technical approach developed for this project is clear, well thought out and well organized. The earlier stages that demonstrated the scaled concepts of 1" and 4" diameter drilling bits have been successful and addressed several key technical barriers. The site preparation has been completed. The program is almost completed and just waiting for the field trails and the innovative heating technologies from partners.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23527

Score: 2.0

Comment: This project does more to demonstrate the complexities and difficulties associated with spallation drilling in the field than it does to demonstrate its potential value for reducing geothermal drilling costs. It is a fairly sensible demonstration of the readiness of the technology for commercial use. Although there were a few modest accomplishments such as eight feet of penetration in continuous drilling mode and reasonable rates of penetration in granite, it more clearly shows that there is much more work required to develop a system suitable for commercial use. The achieved rates of penetration, while slightly better than commercial roller cone technology, also do not do much to promote interest in this drilling method.

PI Response:

Reviewer 23478

Score: 2.5

Comment: Considerable tangible progress has been made with some quite notable accomplishments; rock can be drilled using spallation; an interim acceptable, but not optimum, BHA has been built; temperatures of 900 degrees C can be generated without a downhole ignition source (but a higher temperature will be necessary); cuttings can be recovered and water re-circulated; and rates of penetration up to 15 feet/hour (50% of the ROP goal) have been recorded.

However, considering that 98% of the allocated funds have been expended, this progress does not seem to be commensurate with the cost and this fact prompts a lowering of the score for this Criterion.

If the time available for this project is extended (as anticipated by the PI), the technical objectives may still be reached, but likely at costs well beyond the current budget.

PI Response:

Reviewer 23471

Score: 3.0

Comment: Producing an effective and reliable thermal spallation drilling technology is proving to be very daunting, and the PIs are to be congratulated on focusing so intensely on such an important yet challenging technology. I am impressed that they have carried out more than 15 field tests, even though only four to five were budgeted. The presentation fairly acknowledged the challenges faced by this project, which include maintaining a steady penetration rate (needed to avoid undue hole enlargement and cavity formation), avoiding flooding of the cutting face by cooling water (which retards the spallation process), and improving down hole tool life. The latter is a particular hurdle, since so far their latest system seems to be limited to a total penetration of 8 ft during continuous operation mode. Also, the PIs are encouraged to continue investigating the possibility of using a mechanical bladder or some sort of corrosion-resistant (Inconel/Rene41?) metallic diverter pedal arrangement – perhaps backed up by stiff yet collapsible centralizer fins tailored to the intended hole size – to separate the spallation zone at the bottom of the tool from the overlying cooling fluid circulation pathways. Once this problem is solved, it should be a easier to achieve the desired (high and steady) ROP. My sense is that their ultimate goal of achieving a penetration rate of 30 ft/hr in granite with a downhole tool life of 100 hrs will take some time to realize, and the path to commercial viability is not clear at present. However, I am hoping that this team will persevere in pursuit of this goal given the importance of this problem to the development of economical EGS systems and the Geothermal Technologies Office overall.

PI Response:

Reviewer 23529

Score: 3.0

Comment: The accomplishments and results of the program at this point have been promising in relation to the resources expended. The rate of penetration up to 15’-20’ per hour has been demonstrated. The capability of generating continuous high-temperature steam jet has been identified as well. Certain key challenges such as catalyst lifespan, premixed fuel/oxidant pre-ignition, and control and monitor of penetration have been addressed. The goal of design, fabrication, and field deployment of the hydrothermal spallation drilling system has been achieved.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23527

Score: 3.0

Comment: The project seems well managed and executed. Planning, scheduling and staffing were effectively coordinated with project objectives in mind.

PI Response:

Reviewer 23478

Score: 2.7

Comment: This project has been well managed from the outset with regard to achieving some technical goals and objectives and coordination with collaborators. The PI seems to be candid about reporting partial successes and failures and in identifying significant technical issues and/or barriers. There have been some significant delays and variances from the original plans/schedule and these have resulted in at least "moderate" impact to the overall project. However, corrective actions are reportedly in progress and problems are being attacked and hopefully mitigated.

The major management problem appears to be in cost over-runs; there is only 2% of the funding left and more than 5% of the project remaining to be achieved. (In my opinion, the project is not 95% complete as claimed by the PI. I would guess that is closer to 85-90% finished.....) This budget problem is the primary reason for the relatively low score given to this criterion. The PI is very openly upset about the fact that almost any minor adjustment to field procedures costs $50,000 or more and thus the all too rapid use of budgeted funds.

PI Response:

Reviewer 23471

Score: 4.0

Comment: The project is very well managed, with the entire company devoted to making this process work at all scales – theory, lab and field testing. I admire the dedication, technological savvy and perseverance displayed in sticking to this problem. The PIs have established a very effective collaboration with Cornel University on modeling and development of advanced (and hopefully more effective) heating systems, which should help them move forward on the technological front.

PI Response:

Reviewer 23529

Score: 4.0

Comment: The execution of the project is outstanding. Management of this project has been very effective towards the deliverables that were committed. Future plans are well organized on optimizing drilling performance and performing a demonstration for the geothermal community.

PI Response:

STRENGTHS

Reviewer 23527

Comment: The primary strength of this project is that it provides data that can be used for a more system-level assessment of a technology that has been proposed as a solution to geothermal drilling problems for over 30 years. This effort provides a much more complete appreciation of the complexities associated with transitioning laboratory technologies to the field.

PI Response:

Reviewer 23478

Comment: The strengths of this project are in its logically designed Stages and Tasks. These appear to be addressing challenges and objectives in an orderly fashion that is producing measurable results even if they are not exactly the results sought when the project began. The PI is taking small, measured steps towards the objectives and does not appear to be skipping any procedures that could save money, but jeopardize ultimate outcomes.

The project's involvement of Cornell University and Lawrence Livermore National Laboratory (LLNL) scientists and researchers in order to develop higher temperature devices and improved spallation models is an excellent idea that also strengthens the project. I'm not sure that the availability of expensive modeling of the effects of spallation in various geologic environments will materially improve the ultimate chances for success of this project. Success will be measured by improved ROP and ease of implementation eventually. (How much "Bang for the Buck")

PI Response:

Reviewer 23471

Comment: The hydrothermal spallation technique holds promise as a more rapid method for drilling in granite and similar hard rock formations amenable to the development of EGS. Various groups have tried to improve on traditional drilling

techniques using a variety of techniques for decades, and in spite of the challenges and remaining hurdles I hope that this effort will continue. This represents just the sort of high risk but potentially high return R&D effort that the Geothermal Technologies Office should be funding.

PI Response:

Reviewer 23529

Comment: Strong expertise on drilling system design;

Project is well managed and has good deliverables;

Good collaboration with right resources.

PI Response:

WEAKNESSES

Reviewer 23527

Comment: Nothing to add.

PI Response:

Reviewer 23478

Comment: The only weaknesses to date appear to be the complexity of the project and the resulting complexity of the procedures that will have to be involved during actual drilling operations. These will be emphasized and grow in magnitude as tests are conducted at ever greater depths and in increasingly hot, highly pressured and heat-tempered lithological environments typical of some hydrothermal and most EGS fields.

A comment should also be made about pre-project scheduling and budgeting. Neither enough time nor adequate money was allocated to achieve all of the objectives. These are not really true project weaknesses, but they can be considered project management faults.

PI Response:

Reviewer 23471

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23529

Comment: Weaknesses are minor at this point.

PI Response:

IMPROVEMENTS

Reviewer 23527

Comment: The budget associated with this project is quite large compared to typical the Geothermal Technologies Office efforts. It may have been beneficial to place Go/No-Go decision points earlier in the project to periodically evaluate whether there was any value in continuing the work if particular milestones were not met. This is fairly common in R&D efforts where both basic feasibility and transition to commercialization are being evaluated and there is a desire to limit funding exposure in the event where it is learned that key technical objectives are more difficult to achieve than originally envisioned.

PI Response:

Reviewer 23478

Comment: This is very difficult, because the project has been well run to date with the exception of time and budget-related short-falls. The only suggestion that I might make would be to have decreased the scope of this investigation and limited it to pre-drilling activities and then to have planning a second full project dedicated to field testing and deeper drilling in hostile geothermal environments. Accordingly, the present schedule and budget might have been adequate for the first "phase" and hopefully, successes in this phase would have facilitated the acquisition of additional funding with which to undertake the above-described "second phase" field work.

PI Response:

Reviewer 23471

Comment: The challenges face by this group in further developing and commercially implementing thermal spallation drilling are considerable, but not insurmountable. The PIs are encouraged to continue their work in developing enhanced

tool power output, improved tool reliability and more effective isolation between the hydrothermal jet (spallation) region and the fluid cooling/cuttings circulation stream. Use of advanced borehole imaging and other logging techniques in test holes drilled in the field may help better diagnose the rock failure process during spallation drilling and design a more energy efficient and controllable system.

PI Response:

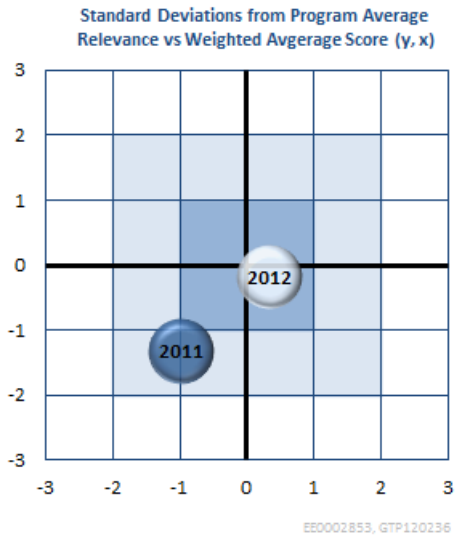
Reviewer 23529

Comment: It would be excited to see how the first field trail goes and how would the project address the issues at actual hard rock field. It will add great value to the geothermal community.

PI Response:

LOW TEMPERATURE AND CO-PRODUCTION DEMONSTRATION

Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002853
Project: Technical Demonstration and Economic Validation of Geothermally-Produced Electricity from Coproduced Water at Existing Oil/Gas Wells in Texas
Principal Investigator: Luchini, Chris
Organization: Universal GeoPower, LLC
Panel: Low Temperature and Co-Production Demonstration



RELEVANCE/IMPACT OF RESEARCH

Reviewer 23414

Score: 3.0

Comment: This was a neat idea that would have considerable economic viability if natural gas wasn't nearly free. The PIs have obviously looked under every rock to build the economic case. I was very impressed by Luchini's presentation and fielding of the reviewer questions. They got a 3 for relevance instead of 4 only because of the continually descending natural gas price baseline - something the PIs can't control I'm afraid.

PI Response:

Reviewer 23441

Score: 4.0

Comment: Luchini, et al. used in house and outside consultants to produce geophysical models that bound the reasonable expectation for the proposed site, given the limited nature and extent of the data available. Costs for this scooping have been minimal ($330K), hence, a high return on the investment by DOE.

The results presented orally suggested that 90% of the revenue stream would come from the by-product hydrocarbons in the reservoir fluids. This project should be of high interest to the Geothermal program, and at the same time, no specifics were shared as to what the actual revenue stream looked like. This needs to be part of "Economic Validation" and its absence makes it very difficult to evaluate the overall effort. The presenter stated that, "Everyone believes that subsidies will go away and they must compete against NG." Clearly, this is not possible. If the project stays viable, it would be in the interests of the Geothermal program to see this work effort through and secure some quantitative results. The high scoring in the absence of hard numbers supporting this effort reflects that belief.

PI Response:

Reviewer 23466

Score: 2.0

Comment: Researchers objective is to demonstrate that depleted Oil and Gas wells can be reworked so that the combination of hydro carbons and geothermal production economically justifies development. If this could be demonstrated it would provide a concrete example which could lead to the co development of thousands of Oil and Gas wells for a co produced market. This project is totally focused on showing that the economics can work and is attempting to use existing strategies and techniques to develop a path to economic success. This is more about selecting the right combinations rather than developing new technologies, an approach that mergers or combines existing techniques.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23414

Score: 3.0

Comment: The science done by the PIs was appropriate. The PIs grappled with a number of competing technical problems and did it quite well (almost making it look too easy).

PI Response:

Reviewer 23441

Score: 4.0

Comment: Projects will be assessed on the quality of the technical approach. While we are assured that all economic validation begins with quantity and temperature of produced brine, and amount of co-produce hydrocarbon, the program reviewers received no quantification of this. Here the justification is that these wells were never intended to be produced via high brine flow, little supporting measurements were done when the wells were initially completed to support high fidelity modeling. Industry experience must be substituted until at least one project has been completed in these kinds of wells. If the project stays viable, it would be in the interests of the Geothermal program to see this work effort through and secure some quantitative results. The high scoring in the absence of hard numbers supporting this effort reflects that belief.

PI Response:

Reviewer 23466

Score: 2.0

Comment: This process is driven economically and there is no effort to develop new science or techniques. Researcher is devoting attention to well selection including economics, technical factors, cooling water, transmission, political issues, power plant design, and overall economic performance. The objective is to build an economic model that will attract investors. It would be good to see what factors are being considered and how they impact the overall economics.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23414

Score: 4.0

Comment: I gave these guys a 4 because they encountered more than their share of unexpected obstacles, yet managed to change course and come up with useful results.

PI Response:

Reviewer 23441

Score: 3.5

Comment: This project is looking for at least 7-10 wells for 15 MW minimum. Presently, people are trying to give wells away. You can lock up resources when prices are low. They are working on reservoir models using industry approved resource appraisal methodology. Doing the Blackwell correction on wells finds that they should be at 340 degrees-F and when the appraisal is finished in the next few weeks the overall viability of the project will be clear. The DOD has a mandate on GREEN ENERGY mandate, so there is a market. This criterion will center around two areas:
1. Quality – TOUGH2 model was used with a variety of scenarios and they are running this in house with a modified code (they have expertise in such modifications).
2. Productivity – the level of productivity has been outstanding. At present, the project is trying to balance the geothermal side and the hydrocarbon side. It is clear that the HC will be sold, rather than using it as fuel on site. There is not enough for a two stage gas turbine plant and such a power plant will not be economical without at least 300MW. The project believes that it is reasonable to anticipate a 20 year lifetime before a casing collapse. The water balance is 200 gpm in the summer and positive in the winter.

PI Response:

Reviewer 23466

Score: 2.0

Comment: Researcher has developed geologic and economic models that allow rapid evaluation of a potential site. This model was used to select a site that has the best potential. Researcher is finding that a lower price of energy (electric and fossil fuel) has a very negative impact on economics. Also finding that use of the depleted well does not work economically unless some amount of oil/gas is produced and the geothermal aspect part of the project is a very minor in terms of economic contributions but adds significantly to cost.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23414

Score: 4.0

Comment: I particularly appreciated the efforts made by the PIs to reach out to investors and make a viable business case.

PI Response:

Reviewer 23441

Score: 4.0

Comment: The project is already considering the technical, policy, schedule, business and staffing issues in an exemplary manner.

PI Response:

Reviewer 23466

Score: 3.0

Comment: Research appears to be well coordinated with locating a good site and working through the issues of building a project. The use of Pratt and Whitney to provide a turn key plant frees the researcher to pursue economic aspects of the project.

PI Response:

STRENGTHS

Reviewer 23414

Comment: Market awareness.

PI Response:

Reviewer 23441

Comment: This presentation was a straightforward and clear analysis of the challenges to commercializing Geothermal power in the domestic market. The very low price of Natural Gas now makes it possible to deliver electricity to the Houston hub at $23-31/MW wholesale and with oil prices in the current high price range, it is the recovery of a high quality hydrocarbon phase from the condensate coming up with the reservoir fluids that provides the best justification for this project. Reportedly, this condensate could be used as gasoline.

PI Response:

Reviewer 23466

Comment: The strength of this project is that it attempts to use existing resources and infrastructure in a synergistic way. Its focus is on economics and not so much on science. It could be a catalyst to encourage development of the thousands of depleted oil wells.

PI Response:

WEAKNESSES

Reviewer 23414

Comment: None.

PI Response:

Reviewer 23441

Comment: Only those investors working with Universal GeoPower who are taking a very long-range view are staying involved. Two of these investors are Asian and the third company is in Denver. It might be hoped that a project making such significant progress would attract more domestic interest.

PI Response:

Reviewer 23466

Comment: The obvious weakness is that the project is attempting to use wells designed for one purpose for a different purpose. While the notion is attractive I think more science about how either the geothermal process is altered or the oil/gas production is altered so that the two can be combined in a supportive way might help this project. Most oil and gas companies would do this if it were profitable. So there needs to be something extra, maybe other secondary uses, maybe a combination of some filtering to help water sources or oil and gas separation. What the researcher has developed is useful because it shows that using an oil/gas well as a geothermal well is not as simple as putting a little power plant on the well.

PI Response:

IMPROVEMENTS

Reviewer 23414

Comment: None.

PI Response:

Reviewer 23441

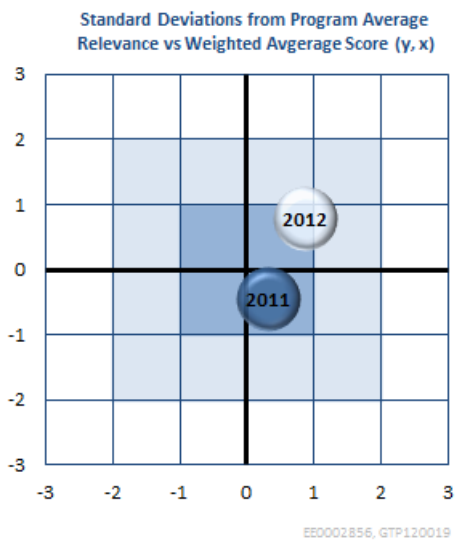
Comment: While TOUGH2 is a good a starting point, it would be helpful to learn what is available in private sector that might also be of predictive value.

PI Response:

Reviewer 23466

Comment: More science should be applied to modify how oil/gas and geothermal are combined.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002856
Project: Beowawe Bottoming Binary Project
Principal Investigator: McDonald, Dale
Organization: Beowawe Power, LLC
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23463

Score: 4.0

Comment: This project is about generating electricity from 205o-brine produced at a rate of 250 l/s. Used brine is reinjected back at 150o. This is a situation common to many other regions around US and around the world. Hard data on the levelized cost of electricity and experience on long-term questions such as the fouling of the heat exchangers and the aquifer temperature drop should be of relevance to projects in those regions. The lessons learned in the area of power conversion are also applicable in areas outside geothermal energy sector such as waste heat utilization etc.

It will be interesting when enough data are collected over a couple of years to observe the variation of power generation with extraneous factors such as the ambient temperature, the wet bulb temperature, the time between heat exchanger maintenance, etc.

PI Response:

O&M data will be provided for a period of 2 years.

Reviewer 23466

Score: 4.0

Comment: The use of ORC equipment to harness thermal energy that to date has been wasted, is an excellent demonstration project that pushes the industry to devise methods of extracting more thermal energy from the resource base. For example the Beowawe water is relatively clean, however pushing down the injection temperature creates a need to solve scaling problems, while showing that more of the thermal energy can be harnessed. The equipment installed is also modular and helps make an economic case for the development of smaller isolated resources.

PI Response:

No response entered.

Reviewer 23443

Score: 4.0

Comment: This project is demonstrating that the use of a binary system is capable of extracting additional energy from supposedly spent geothermal fluids before their reinjection. This has substantially advanced the Geothermal Technologies

Office mission. The range of extraction of useful energy is expanded. The economics indicate that the capital cost is about $2,000/kW.

PI Response:

Excluding the DOE contribution, the capital cost is approx $3200/kW.

Reviewer 23465

Score: 3.0

Comment: This project fits well with the DOEGP's mission and goals. The real benefit of this project was improvement of power plant efficiency by the addition of 1.8MW without drilling an additional production well. However, could have the additional 1.8 MW been gained by other minor power plant adjustments such as adjusting power plant operations or varying refrigerant composition with the change in ambient temperatures and season?

The cost of generating an additional 1.8MW net with $2 million from DOEGP, plus $2.4 million in match share equates to $4.4 million/MW. This is not counting O and M costs and other associated costs.

The project was well thought out and seems to have anticipated adjustments in plant operations to accommodate the bottoming cycle. Recognition should be provided for meeting the technical knowledge gap and plant adjustment challenges. This project addresses a market barrier for incorporating bottoming cycles to achieve efficiency gains. This however, is may not be technically or economically possible in many geothermal power plants.

When this review took place the project was essentially 98% completed and no information on the cost of electricity and levelized costs were provided to the reviewers.

PI Response:

Additional power generation from the main steam plant could not have been achieved without a costly investment in additional geothermal production and injection wells. The total capital cost, excluding the DOE contribution was approx $5.8M, or $3200/kW. To date, annual O&M costs have been approx $12K. These costs include labor, chemicals, makeup cooling water pumping, consumables, contracted services, and replacement parts. The cost of replacement refrigerant has not been included since those losses have been associated with extraordinary events and we are taking measures to guard against further such losses. We believe similar bottoming cycles employing waste heat to achieve efficency gains are technically possible in most geothermal facilities, but may not necessarily be economically feasible.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23463

Score: 3.0

Comment: The commitment of the PI to the project is indicated by their covering the budget overrun. Notwithstanding the extra investment made in the project, the presenter was frank and forthcoming about the project details providing a near-complete picture. The real value in this project is the performance of the power conversion equipment at very low temperature differences between the hot reservoir and the heat dump (in this case the wet bulb temperature).

The choice of the equipment supplier does seem reasonable. A Kalina cycle could also have been contemplated since it is, on pure thermodynamic terms, better suited to really low temperatures such as this one. One intriguing factor is the use of a shell-and-tube heat exchanger instead of a plate heat exchanger more commonly used in similar applications where a low pinch temperature difference is required.

PI Response:

The choice of heat exchanger type was left up to the Supplier; however, it is likely that a shell-and-tube heat exchanger may be a preferred choice due to the need for leak-free performance in refrigerant service.

Reviewer 23466

Score: 3.0

Comment: The installation of the ORC equipment is being done on a "safe" basis, one key parameter that would be good to understand is the point at which injection temperature begins to create too much resistance to heat transfer and fluid flow in the heat exchangers. What the project is doing is to select a "safe" lower limit which pretty much guarantees there will be very little degradation of heat transfer due to TDS coating the heat transfer surfaces or plugging the injection well. It would be good to understand where the issues begin and to begin some formulation of solutions. This might be easier to do in a small demo project that does not compromise expensive larger power producing equipment. The economic data gained from this project is important to encourage other investors to develop low temperature resources.

PI Response:

Prior to the initiation of this project, our main plant staff performed a study of the scaling potential of the low temperature brine. The results of this study provided the basis for the selection of the design exit brine temperature. In addition, during the ongoing operation of the binary facility, we continue to analyze test coupons from various locations to monitor scaling potential.

Reviewer 23443

Score: 4.0

Comment: The technical approach was well thought out and has proven to be successful. There was a considerable risk at the conception of the project in that several key components of the system had to be designed and fabricated from scratch. These components are, apparently, operating to design.

PI Response:

No response entered.

Reviewer 23465

Score: 4.0

Comment: The technical approach taken by the PI was rational, logical and deployed in a reasoned sequential manner. The project employed the right procedures, methods, equipment and contracted experienced engineering firms to design and install the bottoming unit, and getting the bottoming cycle to work correctly without interfering with plant operations.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23463

Score: 4.0

Comment: Answering one of the questions, the presenter distributed copies of the February 2012 Monthly Report they submitted to DoE. This report was more informative than the presentation slides in assessing the performance of the power plant. The relevance of presentation templates is probably something to take into consideration in future reviews. The need of compliance with the designated format may be constraining the presenters in providing relevant information in their presentations.

The year-to-date availability of the plant is given as close to 90%, which is very good for a newly constructed plant. The data collection on the costs and the outages also seem to be being carried out at a detail to provide a valuable resource over the two years of data collection as required by the DoE (as we understand of this requirement).

Since this is not an island grid, the plant is operating in a baseload generation mode. It would have been nice to have at least one load-tracking project to provide data on the dynamics and dispatchability of such geothermal plants.

The collected data did not seem to include the weather conditions. This may be available from other sources. It would be good to co-locate the local weather conditions along with the plant performance in a future database. This would make it easier to identify the variations of plant performance with the change in weather conditions, especially with the wet bulb temperature.

PI Response:

This geothermal facility is a "must-take" operating plant; therefore, it is base loaded. It is likely that if it were load dispatched, the binary would operate in that mode satisfactorily also. The monthly operating data provided to the DOE includes dry bulb and wet bulb temperatures. Since our heat source (brine flow and temperature) are relatively constant, we can monitor the performance of the binary plant heat exchangers by examining process side refrigerant data and net generation for a given set of ambient conditions. For example, a condenser which may have experienced some scaling would perform less efficiently resulting in higher expander back pressures.

Reviewer 23466

Score: 3.0

Comment: This project is installed and putting power online. Its a great project to visit and the data being collected over time contributes to encouraging other similar projects. It would be good to see specific performance data on the heat exchangers and any relationship between injection temperature and degradation of heat transfer. This project had an issue with the wet cooling tower during periods of high wind and cold weather. This should be highlighted as a lesson learned and any wet cooling tower in a high desert environment should be protected from freeze conditions as they are very likely to occur.

PI Response:

No response entered.

Reviewer 23443

Score: 3.0

Comment: The quality of the accomplishments is very good and the progress is on track to achieve the project goals. The productivity of the work has been problematic, as noted by the Project Manager. There have been significant cost over-runs due to the unfamiliarity of the team with the potential size and cost of transportation for some of the components.

PI Response:

No response entered.

Reviewer 23465

Score: 4.0

Comment: The project was successful as far as the technical aspects are concerned. All project tasks were completed and technical targets/goals were met on time. The project is 98% completed and operating with only minor reporting and fine tuning remaining.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23463

Score: 4.0

Comment: It was acknowledged that the project budget had been significantly under-estimated as Beowawe had no experience with installations of this sort, in particular, the cost of installation, including assembly and concrete for cooling tower, and shipping costs. This error seems to have been corrected at no additional cost to the DoE with the company covering the extra costs. This is a credit to the motivation of the recipient company. It is assumed that the divergence was due to underestimation and not an unexpected and rare isolated incident.

Otherwise, the project seems to have been conducted in accordance with the original timeline. It is now complete. It has achieved its initial objective of providing data to help assessment of the technical and economic feasibility of a power generation expansion at the existing Beowawe Geothermal Power Plant using the Low Temperature (205oF) brine, which was injected into the reservoir prior to the project.

PI Response:

Yes, the divergence of project completion costs relative to budget was due to under estimation.

Reviewer 23466

Score: 4.0

Comment: This project was installed on schedule and has responded positively to challenges during construction and commissioning. The issue with cooling tower freeze up was quickly resolved and the management team used a mix of in house and external resources to install and commission the project. This is a solid example of how to integrate new technology into an existing resource.

PI Response:

No response entered.

Reviewer 23443

Score: 3.0

Comment: While project management encountered significant problems, the PM was able to recover most of the potential delay by exceeding the proposed budget. Some of these problems may have been foreseeable, however, the recovery is commendable.

PI Response:

No response entered.

Reviewer 23465

Score: 4.0

Comment: The PI and project team is well qualified to conduct the indicted work. The project adheres well to DOE policy and objectives. The project was only slightly behind schedule but within acceptable time. The PI had the appropriate staff on board and contracted out with experienced subcontractors. The spending plan is acceptable in relation to project schedule. The PI included appropriate decision points for future deployment of work. The project was deployed in coordination with partners, and permitting agencies.

PI Response:

No response entered.

STRENGTHS

Reviewer 23463

Comment: A principal strength of the project is the commitment of the recipient to the project and the honesty with which the results are reported. This will make the results of value to others interested in similar applications.

PI Response:

No response entered.

Reviewer 23466

Comment: This project had reasonable and attainable goals. It is a very good demonstration in the sense that it applies technology that has been recently developed. The geothermal industry is much like the ranching business in the sense that ranchers are reluctant to be the first to try out a new method or technique, however once they see a neighbor try the method or technique successfully, the willingness to invest in the new technology increases. So this project provides concrete evidence that lower temperature ORC applications are robust and ready for market. Its important to keep collecting data and showing the economic benefit of the project.

PI Response:

No response entered.

Reviewer 23443

Comment: This is a very strong project that has to date achieved its technical goals. The addition of the binary system to collect additional energy from ostensibly spent geothermal fluid is innovative and provides important progress toward the Geothermal Technologies Office's goals. The important bit of data that will be provided during the operations phase is whether the additional revenue generated from the 1.8 MW of electrical power will pay for the capital plus the debt service costs.

PI Response:

Our economic analysis indicated that the rate of return was positive.

Reviewer 23465

Comment: The project met the DOEGP's mission and goals. The project met the stated technical goals and objectives. Project management team was strong and capably administered DOE and match share funds in a prudent and acceptable manner. The project was deployed in a responsible manner by experienced and competent technical staff and contractors. The project was completed on schedule with only a minor set back. The PI employed a well conceived project deployment plan.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23463

Comment: No weakness could be identified. Possible improvements are mentioned under the heading of "Improvements".

PI Response:

No response entered.

Reviewer 23466

Comment: The weakness of this project is that its conditions are not immediately applicable to most of the low temperature resources. Since the project used existing wells, no well work was required, which is the largest source of risk in geothermal projects. Many low temperature resources are well known and many have existing wells. However most of the lower temperature resources will require some amount of well work and some amount of electrical upgrades to harness the resource. There is no doubt that this project benefited greatly from the existing electric and well infrastructure.

The data being reported over time will provide concrete evidence of the economic success. It would be good to add some parameters that document the heat transfer performance as a function of injection temperature. Perhaps images of the heat transfer surfaces and reporting of the non dimensional heat transfer coefficient as a function of injection temperature (or temperature differential) -- something that allows one to reasonably select an aggressive injection temperature and extracting the maximum amount of thermal energy.

PI Response:

This project was designed to utilize the waste heat from an existing operation geothermal steam facility having a constant source of brine flow and temperature. The injection brine temperature was selected based on our best determination of a safe injection temperature such that scaling would not be a problem. We continue to monitor scaling potential during our ongoing operations. In this case, it is not possible to experiment with lowering the injection temperature since the equipment was designed for a specific brine temperature and practical performance limitations of this equipment would soon be reached.

Reviewer 23443

Comment: The major weakness was the inherent risk of having to design and fabricate new components. This weakness was overcome by the expenditure of additional funds, which may or may-not be proven to make the system economically viable.

PI Response:

No response entered.

Reviewer 23465

Comment: The cost of electricity on a kwh basis was not provided. The project levelized cost was also not provided. No O and M costs were provided. These costs should have been prepared for the PEER review. The cost of installing a 1.8MW bottoming cycle at $4.4 million/MW.

PI Response:

The total capital installed cost of the binary facility was $5.8M, excluding the DOE contribution. To date, the annual O&M costs have been $12K, excluding the cost of replacement refrigerant and major maintenance.

IMPROVEMENTS

Reviewer 23463

Comment: This comment really needs to be made after more results are collected on the performance of the brine heat exchanger but the rationale for this more expensive choice needs to be made in the project report. It is possible that the circumstances made a S&T HX the optimal choice. Those circumstances need to be explained. Since at least one other of the projects in the group is using a plate HX, it will be possible to compare the two types once data are collected at the end of the projects.

In terms of the thermodynamic cycle, a Kalina cycle could also have been contemplated since it is, on pure thermodynamic terms, better suited to really low temperatures such as this one. In fact, it is curious that across all of the Low Temperature projects only one of them has chosen to use a version of the Kalina cycle. I must emphasize that this is a point to be made on the entire program rather than this particular project only.

A possible improvement, which may be difficult now since the project is complete, could be to do some dispatchability tests pretending to run the plant in load-tracking mode. This would be of no benefit to the plant owner but would provide very valuable data for future employability of such plants in island grid applications.

PI Response:

The selection of heat exchanger type was a commercial decision by the bidding Suppliers for this application. We do not anticipate the ability to operate in a dispatchable mode, since the facility is a "must take" plant.

Reviewer 23466

Comment: Recommend adding to the reporting data parameters that document heat transfer performance.

PI Response:

Please refer to earlier response.

Reviewer 23443

Comment: This project is sufficiently far along the any suggested improvements should be filed under the category of "Monday Morning Quarterbacking."

PI Response:

No response entered.

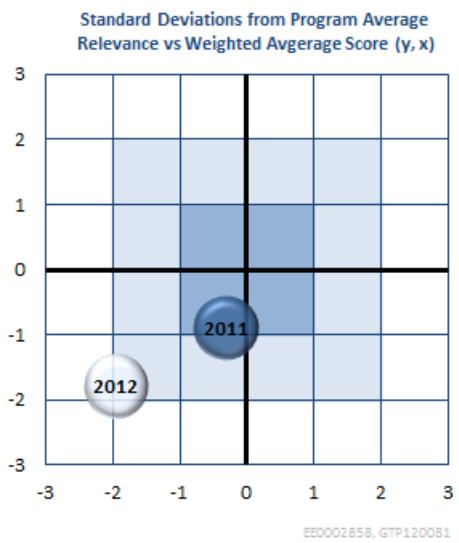
Reviewer 23465

Comment: It is unknown to this reviewer if DOEGP has any legal recourse for going after organizations that do not meet their stated technical or economic objectives. While this project is 98% complete, and actually performed and met all the stated objectives, this reviewer questions whether DOEGP can do something about projects that should have been terminated earlier.

It is recommended that all future power plant and low temperature co-production projects requesting funding should be required to provide DOEGP and PEER reviewers at a minimum economic data such as cost of electricity and levelized costs, and how they arrived at those figures. In addition all recipients should provide a life cycle analysis before the project is initiated and after the project is completed for comparison.

PI Response:

We have provided herein capital cost and O&M cost data. Cost data relating to energy revenue is proprietary.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002858
Project: Novel Energy Conversion Equipment for Low Temperature Geothermal Resources
Principal Investigator: Minor, Eric
Organization: Johnson Controls, Inc.
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23463

Score: 2.0

Comment: Apart from the generic relevance of doing another Low Temperature demonstration project, the presentation documents were not able to articulate the relevance and impact of this research project. The objective is "Develop equipment that generates electricity from low temperature geothermal resources at a cost at least 20% below that of the currently available technology".

It will be difficult to test project performance against this objective because (a) not enough information was provided on the innovations introduced with this design; and (b) the benchmark against this project competes is not adequately defined. A passing mention was made of the Pure Cycle engine as what this project would be compared against but this does not appear in any of the written documents. In any case, this is a smaller engine and without a recuperator. The comparison is not a valid one.

PI Response:

Reviewer 23466

Score: 1.0

Comment: Researcher is essentially using the same type machine as the Pratt and Whitney ORC machine and claiming this is a novel approach. When ask about what is novel, researcher indicates that using a counter flow heat rejection strategy is the novel aspect. There is a reason there is not a machine on the market that uses a counter flow strategy as described by the researcher, and that is that you can make more power when the coldest cooling water is used at each machine, whereas researcher claims more net power is developed by using a cascaded approach. The researcher's cascaded approach aligns the machines so that the hot fluid flows from the machines in a 1 -- 2 -- 3 -- 4 etc order so that machine one gets the hottest water, machine two the next hottest and so forth. The cooling water flows in the opposite order 4 -- 3 -- 2 -- 1 order so that machine 4 gets the coolest water, machine two the next coolest and so forth. This keeps the temperature differential relatively constant at each machine and does reduce the cycle irreversibility. However more net power would be made if every machine received cooling water directly from the cooling tower. There is no ambiguity here and no need to conduct an expensive experiment. The research could be simulated and done with a minimum of cost. Particularly concerning is that the researcher appears to believe this research is novel and will improve efficiency and reduce cost. The researcher also had very little in terms of quantifiable data that would substantiate claims.

PI Response:

Reviewer 23443

Score: 2.0

Comment: It is difficult to assess the impact of the research to date as this project is in its preliminary stages and there was no Project Plan posted with the Presentation slides. The overall goal of developing "better working fluids" and "improving heat cycle management" are commendable, but there is little information provided as to what these approaches may entail.

PI Response:

Reviewer 23465

Score: 2.0

Comment: This project qualifies under the defined DOEGP's mission and goals. If this project is successful, it will provide an alternative to a PureCycle binary system used for low temperature, small-scale geothermal power plants. The PI presented both technical and economic goals. The technical goal was to achieve design and deploy a 1.6MW binary cycle power plant. The economic goal was to commercialize their unit at 20% below the current state-of-the art.

It may address a significant affordability and technical knowledge gap, if it can back up its claim that it is 20% less expensive than a PureCycle system. Unfortunately, the PI did not provide any data or explanation on how this would be accomplished. The PI's presentation was incomplete and vague. It appeared that the PI did not want to provide information about their chiller system and left it to the PEER reviewers to ponder what their system was and how it operated. This Reviewer understood that the system consisted of two crossflow, chiller units with a two 800kW turbine-generators. The net electrical output was estimated at 1MW for the system with 600 kW for parasitic losses.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23463

Score: 1.0

Comment: Notwithstanding repeated questions from the Review Panel members for explanation on what is novel about this project, no satisfactory answer was forthcoming. It is not clear even what the design specs are. Rather than repeating a fuzzy target such as "20% better than the next best one", the efficiency and brine effectiveness at the design point needed to be quotable at this stage in the project. The comparison with alternatives will take care of itself if these numbers are indeed favorable as it is being claimed.

At the present, this reviewer has no foundations to judge the scientific/technical merit of the project.

The two claims to innovation are listed as (a) better cycle fluids; and (b) improved cycle heat management. No additional info is given on (a). During the presentation, it came out that the innovation in (b) is using standard York units in tandem in a counter flow configuration against brine. There is nothing innovative about this as most binary plants are designed in a similar fashion.

PI Response:

Reviewer 23466

Score: 1.0

Comment: This research lacks a defined path and relies on using sales pitches such as, "Johnson Controls leverages decades of experience in developing and manufacturing commercial chiller equipment . . . "

Researcher claims that a comparable machine will be developed that reduces costs by 20%, however there is no data to back up this claim, only claims of decades of experience, etc . . .

Researcher is using a 20% improvement that is not well defined. The claim is that its either a 20% improvement in efficiency over current design or a 20% in cost reductions but not both, an either/or proposition. Again no data backs up either claim, not a simulation, not a design -- only a claim. Usually efficiency improvements cost more money and the efficiency gains can quickly exceed the improved performance with substantial costs. The counter flow cascaded arrangement the researcher is claiming does maintain a relatively constant temperature differential, which will be smaller if the efficiency is improved and a smaller temperature differential will require a larger heat exchanger which will be more cost. So what the researcher is proposing to do, does not match the improvements being claimed.

PI Response:

Reviewer 23443

Score: 2.0

Comment: This criterion is difficult to evaluate as the technical approach is not described in any detail. York HVAC units are well-known and have been successful for years. However, the changes in application of a chiller unit to a geothermal power system was not discussed in detail.

PI Response:

Reviewer 23465

Score: 2.0

Comment: The technical approach taken by the PI is rational, logical and appears on its way to be deployed in a reasoned sequential manner. The project employed the right procedures, methods and equipment. Unfortunately, the PI did not provide enough discussion on the thermodynamic aspects of this project, and provided no comparisons with other small-scale systems.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23463

Score: 2.0

Comment: Research objectives are being met in the sense that it looks likely that there will be a plant installed on the OIT campus. It is not clear however how this will help the objective of generating "electricity from low temperature geothermal resources at a cost at least 20% below that of the currently available technology."

PI Response:

Reviewer 23466

Score: 1.0

Comment: Reseracher presented no concrete data that substantiates claims. Claim is a 20% improvement but no listing of efficiency or cost.

PI Response:

Reviewer 23443

Score: 2.0

Comment: The accomplishments are limited to the design and initiation of fabrication of a prototype system and the development of a "novel way of managing cooling water and brine flow" without providing any details.

PI Response:

Reviewer 23465

Score: 2.0

Comment: The project appears to be on a reasonable pathway to achieving their stated technical objective. However, the project has been in progress for two years and is only 34% complete.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23463

Score: 2.0

Comment: The project is on track towards a unit getting manufactured. Only one third of the budget is spent. Nevertheless, 2 is not a harsh mark because the objective is not to build any plant but to build one that is 20% better than the next best one. Some rigor is expected in defining how the benchmark is selected and how the comparison will be made.

PI Response:

Reviewer 23466

Score: 2.0

Comment: The lack of quantitative data limits the ability to evaluate management and coordination. Researcher has spent 2 years developing the design and that is reported to be complete, however there was no discussion of design during the presentation. The plan is to manufacturer and ship by October 2012. If design is complete I would expect to see predicted performance data, which was not presented. It also seems like most of this project is back loaded.

PI Response:

Reviewer 23443

Score: 2.0

Comment: The presentation hints as contractual problems that have delayed the initial time-line. Once again, the lack of information makes this a difficult criterion to evaluate.

PI Response:

Reviewer 23465

Score: 2.0

Comment: The PI and project team are well qualified to conduct the indicted work. The project adheres to DOE policy and objectives. The spending plan is acceptable in relation to project schedule. The PI included appropriate decision points for future deployment of work. The project is being deployed in coordination with partners (OIT), subcontractor (Barber-Nichols) and permitting agencies. It appears that the project is behind schedule.

PI Response:

STRENGTHS

Reviewer 23463

Comment: The strength of the project is that the end user is a university with substantial experience and interest in geothermal energy. There are expected to be significant spin-offs for the university in terms of education, maintenance of a green image, etc.

PI Response:

Reviewer 23466

Comment: If this project brings another manufacturer into the ORC market it will help create more competition and bring prices down. I believe that the researchers at Johnson Controls (who owns York), will develop a robust machine and that much of what was presented at the Peer Review was a sales pitch. I would not expect it to have the efficiency improvements claimed, but they do have a chance to reduce costs.

PI Response:

Reviewer 23443

Comment: This system is based on technology which has been used in millions of HVAC systems across the world.

PI Response:

Reviewer 23465

Comment: The project meets the DOEGP's mission and goals. The project is on its way to meet the stated technical goals and objectives. If successful, this innovative application could be an alternative to the PureCycle system. Project management team is strong and is capable of administering DOE and match share funds in a prudent and acceptable manner. The project was deployed in a responsible manner by experienced and competent technical staff and contractors. The project is well conceived project and had employed a reasonable, logical deployment plan.

PI Response:

WEAKNESSES

Reviewer 23463

Comment: It is difficult to identify any weaknesses because the presentation was nearly content-free.

PI Response:

Reviewer 23466

Comment: The fundamental premise of this research is flawed. The coolest water available should be used at each machine to net the most power. The cascaded approach promoted will not make as much power as providing the coolest water to each machine.
PI Response:

Reviewer 23443

Comment: The lack of information in the presentation and the lack of a Project Plan, made this a difficult evaluation. The presentation was more of a "sales pitch" than a discussion of technical data and innovation.

PI Response:

Reviewer 23465

Comment: The cost of electricity on a kWh basis was not provided. The project's levelized cost was also not provided. The PI did not provide any information on project life, O and M costs, corrosion or scaling problems.

The PI did not provide any data or evidence to believe that their chiller technology is any more efficient than the state-of-the art. No discussion was provided on its thermodynamic efficiency.

The system has a very high parasitic loss of about 38%.

The cost of installing a 1.6MW binary cycle for $2.17 million, assuming there are no other cost over runs.

This is another very expensive learning experience.

PI Response:

IMPROVEMENTS

Reviewer 23463

Comment: Similar to the remark for weaknesses, it is difficult to enter comments here because there presentation was not very informative.

PI Response:

Reviewer 23466

Comment: Recommend that JCI submit its design with predicted performance criteria included and projected cost. There may very well be some cost reductions and this could provide more competition in the market.
PI Response:

Reviewer 23443

Comment: Provide more information on virtually all aspects of the program. Johnson controls holds numerous patents that should protect the company from loss of significant technology.

PI Response:

Reviewer 23465

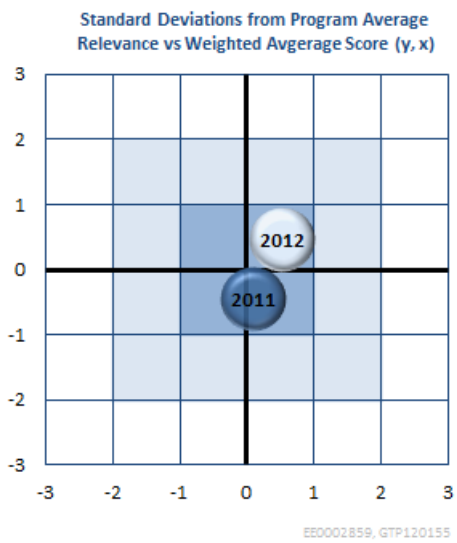
Comment: The PI should fully disclose any data or provide evidence that their chiller technology is more thermodynamically efficient or cost effective than the state-of-the art.

The PI should be required to provide cost of electricity on a kWh basis, levelized cost, and information on on project life, O and M costs, corrosion or scaling problems.

The PI should a market analysis for this type of unit. Provide a market projection of how many do they expect to sell, to who and by when.

The PI should be asked about how to reduce parasitic losses.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002859
Project: Osmotic Heat Engine for Energy Production from Low Temperature Geothermal Resources
Principal Investigator: McGinnis, Robert
Organization: Oasys Water
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23443

Score: 4.0

Comment: The success of this project will provide notable progress on the Geothermal Technologies Office goals by expanding the range of geothermal fluids that can be exploited for electrical energy production. This is an important project and is a unique approach to Low Temperature geothermal resource exploitation.

PI Response:

Reviewer 23463

Score: 3.0

Comment: This project is well outside the norm set by the other low temperature projects. The electricity is generated by exploiting a pressure differential generated by the salinity differences on two sides of a membrane. As the power is generated, the salinity is recycled by adding low-grade heat. In a separate publication, the PI claims that the resultant thermal efficiency of the engine is predicted to approach a maximum of 16% of Carnot efficiency, with practical efficiencies most likely in the range of 5–10% of Carnot efficiency. The temperature of heat used for the engine may be very low (40 oC with a 20oC ambient temperature).

This reviewer does not know if they can be realized but if they can, there will be very significant outcomes in utilization of low-grade heat (low-grade as in tepid water).

A mark of 3 is given rather than 4 because of the low likelihood that the project is expected to succeed. But then again, it might. A successful outcome, however unlikely, would have applications well beyond geothermal.

PI Response:

Reviewer 23466

Score: 3.0

Comment: The objectives of this project are to demonstrate the economic viability of an Osmotic Heat Engine using low temperature geothermal resources. The engine uses the thermal energy to "strip" or separate a salt from the from the working fluid. The concentration of the salt is used via a membrane to increase pressure and the pressure differential is used to drive a hydro type turbine. The advantages are a smaller turbine as compared to a vapor type turbine and the use of a concentration type differential to harness energy. The heat drives off the solute (salt) and its reused in the process. This concept is novel and its success depends on the economics of the different mechanisms and not so much the overall thermal efficiency. While the turbine will be obviously cheaper than a vapor type turbine, the membranes, the heat exchangers and storage system will all add cost. There is also a claim that the Osmotic engine will allow storage and can be essentially used as a battery to avoid low cost electric time periods and maximize high cost periods. This is also possible.

PI Response:

Reviewer 23465

Score: 4.0

Comment: This project qualifies under the defined DOEGP's mission and goals. This is a true research project that if successful could be a real game changer not in geothermal but in other energy applications where there is heat available and a lot of water. This project hinges on the capability of their membranes to accommodate a geothermal brine. Brines have different scaling and erosion characteristics. Brines with high TDS will render this membrane technology useless. However, there are some very low TDS brines that may work. The PI did not mention a target location to test this technology. The principle of this project rests on osmotic pressure differential and ion exchange between a geothermal fluid and pure water. This in theory may work in seawater systems but there is a huge difference in compositions between seawater and geothermal brines. To create the huge pressure difference in an osmotic membrane it would take a lot of water volume. Unfortunately, the PI did not provide any data or explanation on how this would be accomplished

The PI indicated that the osmotic membranes would have to withstand a positive pressure of 6,000 psi. The PI indicated the need for 10 million gallon above ground tanks but was not specific on the other details. The PI did mention that in their calculations indicate that it would take a pressure differential of 300 psi to generate 1kW at 50C. Using the PI's numbers, an above ground 10 million gallon system with a positive pressure of 6,000 psi would generate approximately 20MW. This technology has severe limitations, primarily because of the need for enough pure water and of less importance the need for a heat source.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23443

Score: 4.0

Comment: The technical approach is sound and the initial tasks of developing a pressure retarded osmosis (PRO) membrane and test module have, apparently, been successful. The Osmosis Heat Engine (OHE) system components have

been successfully tested. The development of the spiral wound membrane module will allow optimization of the pressure range of operation. The use of the NH3/CO2 working fluid has proven to be successful. This is one of the most innovative approaches that have been presented.

PI Response:

Reviewer 23463

Score: 4.0

Comment: The approach is described with rigor in the presentation documents as well as other publications of the PI. Especially pertinent is an article in the Journal of Membrane Science 305 (2007) 13–19 (A novel ammonia–carbon dioxide osmotic heat engine for power generation), apparently reporting on the outcomes of the PhD thesis of the PI.

The numbers seem to be adding up. The membrane unit generation (200 W/m2) is convincing. The project has the right approach in starting with component development and then trying to demonstrate the fundamental principle in small scale before building up a larger model.

PI Response:

Reviewer 23466

Score: 3.0

Comment: Researcher is following a three phase approach, (1) feasibility and design, (2) procurement, fabrication, and install, and (3) field operation. There is no ambiguity that the Osmotic engine will have a low thermal efficiency and while this is not as important as economic efficiency it is important in the sense that the osmotic engine needs to be relatively inexpensive, especially since the net energy will be low. My concern is that during the feasibility and design step there was no estimate of cost. Researcher is claiming a load following capability and while this is true, I suspect it will require extremely large storage volumes which could limit the project economically. Researcher is focused on the membranes and while this is key it might be the least expensive part of the osmotic engine. My point is that while this does allow extremely low temperatures we need to pay particular attention to the overall cost and I see little of that in phase I.

PI Response:

Reviewer 23465

Score: 2.0

Comment: The technical approach taken by the PI is rational, logical and appears on its way to be deployed in a reasoned sequential manner. It appears as if the PI employed the right procedures, methods and equipment. The PI did not provide a discussion on the where this technology would be tested in an EGS setting.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23443

Score: 4.0

Comment: While the accomplishments to date are confined to the development and testing of potential components, the quality of the results is high. Many of the components are already in use. This project is behind schedule and is incurring unanticipated expenses. However, there are components of the system that have been aided by the application of knowledge from Oil & Gas water treatment investigations and this should allow streamlining of some of the development activities.

PI Response:

Reviewer 23463

Score: 4.0

Comment: The membrane and the module have been developed. The next job is the system integration, which will hopefully prove the concept.

The spending also seems to be on tract reflecting the technical progress.

The existence of Alta Rock in the advisory team is important to maintain the geothermal focus.

PI Response:

Reviewer 23466

Score: 3.0

Comment: Researcher is well on track developing the engine component parts (stripper, membrane, module and turbine). Has shown very positive results for the membrane. Starting to assemble the pilot system. Researcher appears very competent and understands the issues.

PI Response:

Reviewer 23465

Score: 3.0

Comment: The project appears to be on a reasonable pathway to achieving their stated technical objectives. The project has been in progress less than two years and is only 45% complete. No explanation was given to the significant time delays.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23443

Score: 3.0

Comment: The project is behind schedule and has experienced unanticipated expenditures. The membrane and system optimization work should pay dividends during the fabrication of the pilot system. It will probably be necessary to extend the schedule in order to collect sufficient operations data from the pilot plant.

PI Response:

Reviewer 23463

Score: 4.0

Comment: Starting from individual components, e.g. the membrane and the module, optimizing their design individually, and then integrating them to a complete system with decision points after each component development stage provides for an orderly progress and this is also reflected by the control on spending while having achieved half of the project tasks.

PI Response:

Reviewer 23466

Score: 3.0

Comment: Researcher is building on competency in the water treatment market to accelerate development of membranes.

PI Response:

Reviewer 23465

Score: 2.0

Comment: The PI and project team are well qualified to conduct the indicted work. The project adheres to DOE policy and objectives. The spending plan was not discussed in relation to project schedule. The PI included appropriate decision points for future deployment of work. The project is being deployed in coordination with partner Altarock but did not mention what their role is. No discussion was provided regarding communications with permitting authorities.

PI Response:

STRENGTHS

Reviewer 23443

Comment: This system may be able to allow exploitation of lower temperature geothermal resources or could, possibly, be an addition to an existing geothermal energy production system to capture additional energy from spent geothermal fluids. This is a truly innovative approach.

PI Response:

Reviewer 23463

Comment: The main strength is the novelty. This has not been done before, it can be potentially very useful, therefore it is worth doing even though the likelihood of success may be low.

PI Response:

Reviewer 23466

Comment: The strength of this research is that is could if economically successful provide a means of harnessing many low temperature energy resources, including geothermal. Its very novel and is a different approach than most traditional approaches. It also is attempting to build on experience gained in the water purification industry. The assumption is that the osmotic engine will be cheap enough that the low efficiency is not an issue.

PI Response:

Reviewer 23465

Comment: The project meets the DOEGP's mission and goals.

The project has successfully met the stated technical goals and objectives for the first two phases.

If successful, this innovative application could be significant game changer.

Project team has a strong background in their area of expertise, and are employing that expertise in a new area. The project was deployed in a responsible manner by experienced and competent technical staff and contractors.

The project is well conceived and has employed a reasonable, logical deployment plan.

PI Response:

WEAKNESSES

Reviewer 23443

Comment: It has yet to be demonstrated that the system is viable or economic.

PI Response:

Reviewer 23463

Comment: The weakness is similar to any project that is cutting new ground. There are only one's own mistakes to learn from and therefore it will not be easy progress.

PI Response:

Reviewer 23466

Comment: This project has some very large hurdles. We know the engine will be a very low efficiency and this requires that the engine itself be very inexpensive. While it appears that the membranes will be relatively inexpensive the other parts of the engine will necessarily be large and may require expensive materials and fabrication. Although the concept is valid it may not be economically possible.

PI Response:

Reviewer 23465

Comment: The PI did not discuss where this project would be deployed in an EGS setting. The PI did not provide any information on project life, O and M costs, corrosion, erosion or scaling problems.

The PI did not discuss location and permitting barriers. The PI did not discuss parasitic losses. The PI did not discuss cost of electricity on a kWh basis or a projected levelized cost.

PI Response:

IMPROVEMENTS

Reviewer 23443

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23463

Comment: It was not clear how vigorously other applications (non-geothermal applications) are being sought by the PI and Oasys. This project has applications across a broad range. The team is advised and encouraged to actively seek interest from other industries.

PI Response:

Reviewer 23466

Comment: I recommend that economic projections be added to the phase one or two component. This engine is unique and a small working model should likely be built, however I think it prudent to limit the demonstration size to limit the potential downside, if the economics are not encouraging.

PI Response:

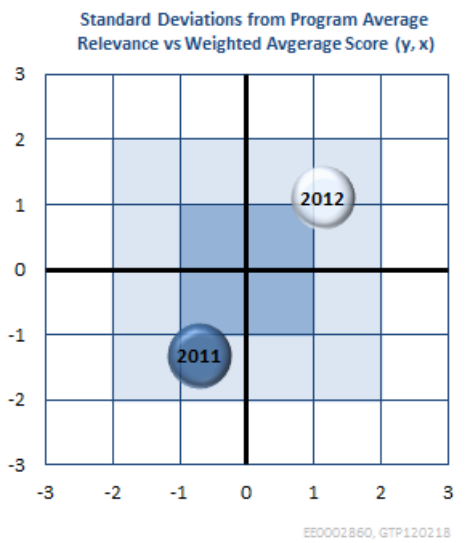
Reviewer 23465

Comment: Why not test this technology at the Geysers? At the Geysers, there are numerous large water storage tanks within the geothermal field.

The PI should be required to provide cost of electricity on a kWh basis, levelized cost, and information on on project life, O and M costs, corrosion or scaling problems. The PI should be asked to elaborate on parasitic losses.

The PI should a market analysis for this type of technology. Provide a market projection of how many do they expect to sell, to who and by when.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002860
Project: Dixie Valley Bottoming Binary Project
Principal Investigator: McDonald, Dale
Organization: Terra-Gen
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23443

Score: 4.0

Comment: The successful completion of this project will expand the amount of electricity that can be gleaned from a given geothermal fluid by lowering the temperature of the spent fluids. This fits very well with the Geothermal Technologies Office's goal of maximizing the energy produced by a given geothermal resource. The project has made notable progress.

PI Response:

No response entered.

Reviewer 23463

Score: 4.0

Comment: This project is similar to the Beowave project and it is being conducted in a similar fashion. The same commentary on relevance apply here as well.

There are more Low Temperature reservoirs and they are easier to access. This is true in many other regions around US and around the world. The hard data that the project will supply on the levelized cost of electricity and the experience to be gained on long-term questions such as the fouling of the heat exchangers and the aquifer temperature drop should be of relevance to projects in those regions. The lessons learned in the area of power conversion are also applicable in areas outside geothermal energy sector but in areas such as waste heat utilization etc.

It will be interesting when enough data are collected over a couple of years to observe the variation of power generation with extraneous factors such as the ambient temperature, the wet bulb temperature, the time between heat exchanger maintenance, etc.

PI Response:

No response entered.

Reviewer 23466

Score: 4.0

Comment: This demonstration project demonstrates more power can be produced using existing resources. It also demonstrates that this can be done with equipment currently available from the market at a price that is competitive (actually better than) developing new resources. The project also provides data for scale issues when the resource temperature is lowered. The operation of the bottoming cycle will provide data regarding plant integration, and impact on the resource. Although not mentioned in the presentation I think it important to capture the relative maintenance effort of the binary cycle as compared to the flash plant at Dixie Valley.

PI Response:

We plan to track the O&M costs of this binary facility separately from the main steam flash plant.

Reviewer 23465

Score: 4.0

Comment: This project fits well with the DOEGP's mission and goals. Like the Beowawe Bottoming Binary Project the real benefit of this project was improvement of power plant efficiency by the addition of 1.8MW without drilling an additional production well. The cost of generating an additional 4.4 MW net with $2 million from DOEGP plus $13.5 million in match equates to $3.5 million/MW. Assuming a 20 year life, and not factoring in O and M costs, this roughly amortizes to $175 MW. The project was well thought out and seems to have anticipated adjustments in plant operations to accommodate the bottoming cycle. This project addresses a market barrier for incorporating bottoming cycles to achieve efficiency gains. When this review took place the project was 95% completed and no information on the cost of electricity and levelized costs were provided to the reviewers.

PI Response:

The actual guaranteed net output of the binary plant is approx 4.9 Mw. We expect to commence reporting O&M data soon for the required period of 2 years.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23443

Score: 4.0

Comment: The technical approach is well thought-out and seems to be effective in demonstrating the efficacy of the pilot plant. Experience from the Beowawe project led to the incorporation of a refrigerant surge tank to store the refrigerant during upset conditions. In addition, the brine scaling potential was evaluated as a function of heat removal during bench scale experiments.

PI Response:

No response entered.

Reviewer 23463

Score: 3.0

Comment: It is expected to generate approximately 5.0MW net from 8500 gpm 225F brine. This is a feasible target. Different from Beowave, this project is aiming to use air-cooled condensers (ACC). TAS Energy is the equipment supplier (the same as in Beowave). A Barber-Nichols expander is used and R134a is the cycle fluid. The critical temperature for R134a is 214oF, this implies that the fluid is expected to be heated to above the critical point. No data were provided on turbine inlet pressure.

The choice of ACC is good because this means a plant different from Beowave and adds to the experience value.

In general, the choice of the equipment supplier does seem reasonable. A Kalina cycle could also have been contemplated since it is, on pure thermodynamic terms, better suited to low temperatures, although Dixie enjoys brine temperatures higher than Beowave.

PI Response:

The choice of dry cooling for this facility was due to 1) the lack of additional water rights for makeup water, and 2) the ease of permitting. The choice of power cycle was a commercial one based on the technical approach chosen by each of three bidders.

Reviewer 23466

Score: 4.0

Comment: The data collected during this project will be valuable to encourage other operators to add additional generation equipment to harness the lower temperature thermal energy. Researcher is developing data on brine scaling, water versus air cooling, permit impacts, economics, and space requirements that are immediately appropriate to other geothermal sites. Researcher is developing project under an Engineer, Procure, and Construct contract. Many operators do not have the expertise nor time to pursue adding additional generation. The use of this contracting vehicle will be useful to the industry.

PI Response:

The size of this project and requirements set forth by lenders dictated the project be developed utilizing an EPC contracting approach.

Reviewer 23465

Score: 4.0

Comment: The project was successful as far as the technical aspects are concerned. All project tasks were completed and technical targets/goals were met on time. The project is 98% completed and operating with only minor reporting and fine tuning remaining.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23443

Score: 3.0

Comment: The plant components have been been designed, fabricated, and are being installed. This represents good progress toward the goal of demonstrating the efficacy of the binary plant. The quality of the effort to date has been good and the successful operation of the pilot plant will be significant.

PI Response:

No response entered.

Reviewer 23463

Score: 4.0

Comment: We do not have access to the original schedule but it looks like the project is on track. Lessons learned in Beowave were applied, e.g. adding a refrigerant surge tank to increase storage capacity in order to ensure against loss of refrigerant during process upset conditions.

Since this is not an island grid, the plant is operating in a baseload generation mode. It would have been nice to have at least one load-tracking project to provide data on the dynamics and dispatchability of such geothermal plants.

The collected data will probably be similar to Beowave, which did not include the weather conditions. This should be available from other sources. It would be good to co-locate the local weather conditions along with the plant performance in a future database. This would make it easier to identify the variations of plant performance with the change in weather conditions, especially the temperature. The wet bulb temperature needs also be reported if hybrid cooling is to be used as being contemplated. Compared to Beowave, the weather conditions are more important because Dixie is a plant with air-cooled condensers.

PI Response:

Operating data, including ambient temperature, will be provided for the required period of 2 years following initial commercial operation of the facility.

Reviewer 23466

Score: 4.0

Comment: This project appears to be on schedule and will be in operation soon. Permitting, engineering, procurement, and construction have all be coordinated through the EPC contractor. The addition of 5 MWs of additional power is significant.

PI Response:

No response entered.

Reviewer 23465

Score: 4.0

Comment: The project was successful as far as the technical aspects are concerned. All project tasks were completed and technical targets/goals were met on time. The project is 95% completed and operating with only minor reporting and fine tuning remaining.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23443

Score: 2.0

Comment: The project management has been effective and has been able to obtain the pilot plant components in a timely manner. The project is somewhat behind schedule but the pilot plant is ready to start, or may be in operation. As is appropriate, the majority of the budget has been consumed.

PI Response:

No response entered.

Reviewer 23463

Score: 4.0

Comment: It is good that the lessons learner in the previous project are being applied here. The project seems to have been conducted in accordance with the original timeline. It has achieved its initial objective of providing data to help assessment of the technical and economic feasibility of a power generation expansion at the existing Dixie Geothermal Power Plant using the Low Temperature (225oF) brine, which was injected into the reservoir prior to the project.

PI Response:

No response entered.

Reviewer 23466

Score: 4.0

Comment: The use of an EPC contractor appears to have worked very well. Coordination between the site personnel and existing production facility has been effective. Reporting of performance data will convince other operators that this is a good investment.

PI Response:

No response entered.

Reviewer 23465

Score: 4.0

Comment: The PI and project team are well qualified to conduct the indicted work. The project adheres well to DOE policy and objectives. The project was completed on schedule. The PI had the appropriate staff on board and contracted out with experienced subcontractors. The spending plan is acceptable in relation to project schedule. The PI included appropriate decision points for future deployment of work. The project was deployed in coordination with partners, and permitting agencies.

PI Response:

No response entered.

STRENGTHS

Reviewer 23443

Comment: The major potential strength of this project is to generate additional electricity from ostensibly spent geothermal fluids. Additionally, this project carries through two years of pilot plant operation. The demonstration data will allow the evaluation of the economics of whether the additional electricity can cover the capital investment and debt service costs.

PI Response:

Our economic analysis of the project indicated a positive rate of return.

Reviewer 23463

Comment: A principal strength of the project is the commitment of the recipient to the project and the honesty with which the results are reported. This will make the results of value to others interested in similar applications.

PI Response:

No response entered.

Reviewer 23466

Comment: The strength of this project is that it is simple and has a clear path towards success. Adding more capacity with existing resource makes economic sense and the demonstration that the project works will convince other operators to add bottoming cycles.

PI Response:

No response entered.

Reviewer 23465

Comment: The project met the DOEGP's mission and goals. The project met the stated technical goals and objectives. Project management team was strong and capably administered DOE and match share funds in a prudent and acceptable manner. The project was deployed in a responsible manner by experienced and competent technical staff and contractors. The project was completed on schedule. The PI employed a well conceived project deployment plan.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23443

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23463

Comment: No weakness could be identified. Possible improvements are mentioned under the heading of "Improvements".

PI Response:

No response entered.

Reviewer 23466

Comment: None noted.

PI Response:

No response entered.

Reviewer 23465

Comment: The cost of electricity on a kwh basis was not provided. The project levelized cost was also not provided. No O and M costs wer provided. These costs should have been prepared for the PEER review. The cost of adding a 4.4MW net bottoming cycle at $15.5 million/MW was another expensive lesson.

PI Response:

The actual guaranteed net output of the facility is 4.9 Mw, or approx $3200/kW, which is the same installed capital cost as our Beowawe bottoming binary facility on a per-kW basis. O&M costs for the binary facility going forward will be tracked separately from the main facility and will be reported. The value of energy revenue is proprietary.

IMPROVEMENTS

Reviewer 23443

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23463

Comment: In terms of the thermodynamic cycle, a Kalina cycle could also have been contemplated since it is, on pure thermodynamic terms, better suited to really low temperatures such as this one. In fact, it is curious that across all of the Low Temperature projects only one of them has chosen to use a version of the Kalina cycle. I must emphasize that this is a point to be made on the entire program rather than this particular project only.

A possible improvement could be to do some dispatchability tests pretending to run the plant in load-tracking mode during the reporting period. Admittedly, this would be of no benefit to the plant owner but would provide very valuable data for future employability of such plants in island grid applications.

PI Response:

The selection of heat exchanger type was a commercial decision by the bidding Suppliers for this application. We do not anticipate the ability to operate in a dispatchable mode, since the facility is a "must take" plant.

Reviewer 23466

Comment: I recommend that the data collected be used to show how the site production and economics are impacted before and after this project.

PI Response:

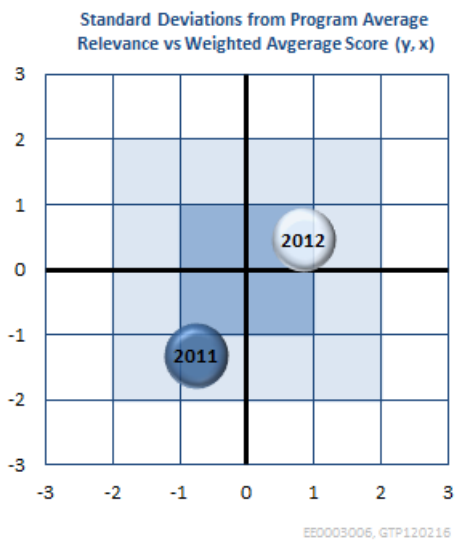
Net generation will be reported on a monthly basis for a period of 2 years. The value of energy revenue is proprietary.

Reviewer 23465

Comment: The use of wet cooling could improve power plant efficiency. There are plenty of studies and demonstrations that the PI could have accessed to explore this subject. A water misting and distribution system located at the base of the air condensers should be considered, however, this is predicated on the availability and cost of cooling water. This too could be minimized if only a fraction of the downstream geothermal fluid could be tapped for this purpose. Critical to this is the TDS and scaling characteristics of the geothermal fluid.

PI Response:

Air cooling was selected due to 1) the lack of water rights for additional consumptive use at this facility, and 2) permitting challenges.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0003006
Project: Rural Cooperative Geothermal Development- Electric and Agriculture
Principal Investigator: Silveria, Daniel
Organization: Surprise Valley Electrification Corp.
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23397

Score: 3.0

Comment: The relevance of the current state of the project to the GTO's mission and goals is not clear. The impact seems that it has limited scope to the specific project; however, the broader impact beyond the scope of this project. The first two stated project objectives do not seem relevant to the GTO mission. The third objective is relevant to the GTO goals; however, this objective was much less developed in the materials provided for the peer review. It is not clear what is novel and therefore what is being developed in this project that is of value to other Rural Electric Cooperatives. This may just be a function of the material that was supplied for the purposes of the review, but a clear delineation of the impacts beyond Surprise Valley is necessary.

PI Response:

Reviewer 23443

Score: 3.0

Comment: This is a standard Low Temperature geothermal resource development project. The project started with little information on the geology and geothermal regime in the area other than the presence of hot springs and the elevated temperature of an agricultural well (1200 gpm @ 235 F). The overall effect on the local community can be significant.

PI Response:

Reviewer 23457

Score: 4.0

Comment: The goal of this project is to develop up to 4 MW of base load power and promote cascaded uses for a Rural Electric Co-operative. Successful implementation of this project will encourage other rural co-operatives to produce electric power (and direct uses) from small Low Temperature geothermal sources.

PI Response:

Reviewer 23465

Score: 4.0

Comment: This is the kind of project that the DOEGP should continue to fund. This project qualifies under the defined DOEGP's mission and goals.
The project objectives are to develop geothermal power production and promote the creation of cascaded businesses to benefits within the community. The project will bring approximately 4MW of renewable, base load power. The PI and partners are working in earnest to meet the stated objectives.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23397

Score: 3.0

Comment: The technical approach to this project is valid and good and this can be seen in the successes that have been seen thus far. Additionally, the performers have reached out to Roy Mink and the University of Nevada, Reno to provide assistance in the characterization of the system. One area for improvement would be a detailed assessment of the economics of the system. An additional area for improvement would be a detailed approach to how this project can have an impact beyond Surprise Valley.

PI Response:

Reviewer 23443

Score: 3.0

Comment: The technical approach used established methods for determining the geologic and geothermal regimes. A conceptual model has been developed for the geothermal regime in the area. The approach has been successful in that two geothermal production wells have been drilled and developed.

PI Response:

Reviewer 23457

Score: 3.0

Comment: Scientific and technical approach consists of a number of logical steps:
1. Gather geological and geophysical data, and develop a conceptual model.
2. Site and drill 2 production and 1 injection well.
3. Design and construct a 2-4 MW power plant.

Plans for well testing (necessary to ascertain the project size) and for constructing a reservoir model have yet to be formulated.

PI Response:

Reviewer 23465

Score: 4.0

Comment: The technical approach taken by the PI is rational, logical and appears on its way to be being a very successful operation. The PI should and project team should be applauded for their efforts in overcoming technology and geology knowledge gaps, and for effectively communicating to partners, contractors and cooperative customers their vision for this project. It appears as if the PI employed the right procedures, methods and equipment.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23397

Score: 4.0

Comment: The project has seen many successes and accomplishments. It is commendable that this project has been largely self-sustainable and has been able to accomplish so much with limited GTO funding.

PI Response:

Reviewer 23443

Score: 3.0

Comment: Two successful geothermal wells have been drilled and developed and a pilot power plant is being designed. The geothermal regime model that was developed has proven its worth with the two installation of the two production wells. The objective of this project is more to demonstrate that a small rural electrical cooperative can be successful in

developing a low temperature geothermal system than in demonstrating a new technology. The installation of the pilot plant will show that these entities are capable of this task.

PI Response:

Reviewer 23457

Score: 4.0

Comment: Project appears to be progressing according to plan.
1. Gathered geological/geophysical data, and developed a conceptual model.
2. Used the conceptual model to drill two successful production wells. The injection well will be drilled this summer.

PI Response:

Reviewer 23465

Score: 4.0

Comment: The project is on its way to achieving their stated technical objectives. The projects targets achieved include the successful drilling of two geothermal wells in two attempts. Both production wells resulted in good temperature and flows. Progress is being made to achieve successful drilling of an injection well by mid 2012, and the design and construction of a building piping system and electrical transmission system also by 2012, and engineering and siting a 4.0 MW power plant in 2013. Another positive aspect of this project is the risk the Recipient took in drilling two wells and using their match share with no DOEGP money. The project has made significant progress in 2.5 years.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23397

Score: 4.0

Comment: The management of the project thus far has been very good. It is clearly better to delay the project by contracting a driller that is highly capable rather than wasting funds to keep the project on its original timeline. That decision is to be commended. The project has recruited the assistance of a strong team of collaborators that will result in a higher likelihood of success. Additionally, the management of the budget is also very good. The performers have been able to leverage a small amount of DOE funding into what is turning out to be a highly-successful project.

PI Response:

Reviewer 23443

Score: 3.0

Comment: The management of this project has been effective in spite of major changes to the scope during its progression - i.e., the decision to drill a new geothermal production well rather than rework an existing agricultural well. In addition, the PM found that geothermal well drilling is a specialized field and had to replace the initial driller. In spite of a lack of experience with this type of activity, the project has progressed well.

PI Response:

Reviewer 23457

Score: 4.0

Comment: The project appears to be proceeding according to plan. The size of the power plant will be decided after the drilling and testing of the injection well.

PI Response:

Reviewer 23465

Score: 4.0

Comment: This is a very well managed and coordinated project. The Recipient has used a considerable amount of their match share to drill the two wells and has only received $60,000 in DOE funds. The PI and project team are well qualified to complete the indicted work and has planned for future expansion. The project adheres to DOE policy and objectives. The spending plan was discussed in relation to project schedule. The PI included appropriate decision points for future deployment of work. The project is being deployed in coordination with multiple partners. The PI has been in constant discussions with state permitting agencies and project collaborators.

PI Response:

STRENGTHS

Reviewer 23397

Comment: One key strength to this project is the progress with limited use of DOE funding. Additionally, the project is well-managed and is leveraging scientific resources outside of the prime performer. The team has reached out to obtain input on developing a geologic model of the system.

PI Response:

Reviewer 23443

Comment: The Surprise Valley Electrification Corp. has demonstrated that it is capable of finding the technical expertise necessary for the successful completion of the project. The technical approach uses standard hydrologic and geologic approaches.

PI Response:

Reviewer 23457

Comment: A well thought out project plan.

Two successful production wells. Drilling of the single injection well will start this summer.

Flexibility in the size of the power plant.

PI Response:

Reviewer 23465

Comment: The project meets the DOEGP's mission and goals. The project has successfully met the stated technical goals and objectives for Phase 1. Project team has a strong background. The project partners contracted to perform diverse tasks are highly experienced and capable. The project was deployed in a responsible manner. The project is well conceived and has employed a reasonable, logical deployment plan.

PI Response:

WEAKNESSES

Reviewer 23397

Comment: The key weakness of this project is the lack of a specific plan for dissemination of the lessons learned and best practices for other RECs to follow.

PI Response:

Reviewer 23443

Comment: It is unlikely that a small rural electrical cooperative would be successful in this sort of endeavor without major Federal and State subsidies.

PI Response:

Reviewer 23457

Comment: No cascaded uses are described. It is not clear as to what uses are feasible in the area. Well testing and reservoir modeling does not appear to be a part of the plan. Because of the low temperature of the resource, it is unlikely that the power project will be cost competitive with other sources of power.

PI Response:

Reviewer 23465

Comment: Hard to find any.

PI Response:

IMPROVEMENTS

Reviewer 23397

Comment: What needs to be strengthened is an approach to how this project can have an impact beyond Surprise Valley. This is needed to help the project better meet the needs of the Geothermal Technologies Office and add to the broader impacts and relevance of the project to the GTO goals. One idea for a way to disseminate the information is for the performers to organize a conference or workshop for other RECs, so that they might start building the connections and learn from the lessons at Surprise Valley.

PI Response:

Reviewer 23443

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23457

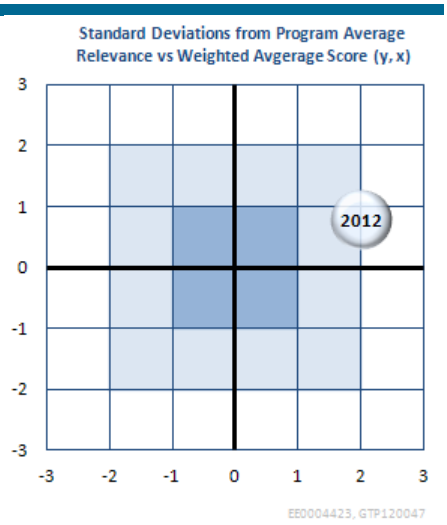
Comment: Well testing and reservoir modeling should be accorded high priority in order to ensure the longevity of the geothermal resource.

PI Response:

Reviewer 23465

Comment: No comment for improvements.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0004423
Project: Scale Resistant Heat Exchangers for Low Temperature Geothermal Binary Cycle Power Plant
Principal Investigator: Welch, Phillip
Organization: Energent Corporation
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23450

Score: 3.0

Comment: The project acknowledged competing technologies to address scale formation. The primary focus is amorphous silica, but other scales can be addressed using mechanical or electromagnetic methods. I believe there is something to the EM methods, though a review shows some confusion as to the actual mechanisms involved. More effort should be made in this area before discounting.

Scale formation is ubiquitous in geothermal production systems and utilizing lower temperature resources or bottom cycle heat recovery will result in more and different kind of scale issues.

PI Response:

Reviewer 23466

Score: 4.0

Comment: This project hits one of the key parameters limiting low temperature resources, that is the limit on injection temperature. Lowering the injection temperature makes more thermal energy available to the power cycle, reduces parasitic loads and improves the overall economic performance of low temperature resources. This is important research.

PI Response:

Reviewer 23457

Score: 4.0

Comment: Reduction of scale deposition in heat exchangers and development of a variable phase turbine will accelerate the use of low temperature geothermal sources by making it possible to lower the "rejection temperature" from ~ 175 F to ~120 F. Testing has yet to commence on different techniques for reducing scale deposition. Assuming that the project is successfully completed, the variable phase turbine will provide an alternative to conventional binary power plants for electric generation using low temperature sources.

PI Response:

Reviewer 23443

Score: 4.0

Comment: This project, if successful, has the potential to notably impact the Geothermal Technologies Office's mission. Scaling of heat exchange surfaces has been a major problem for the Geothermal industry since its inception. The development of a scale resistant heat exchanger and a variable phase turbine-generator should allow additional electricity to be generated from either low temperature resources or the spent geothermal fluids from operating plants.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23450

Score: 3.4

Comment: The hermetic sealed turbine is interesting, but raises the question what is the potential to lower cost of power and how much? This projects addresses by innovative use of equipment components and assemble. The use of the proven variable phase turbine shows technology maturity, but still potential for incremental gains such as looking at alternative bearing materials for direct drive of generator. The gain in efficiency is small but can go as low as 110F for very low temperature resources with clean or fresh water.

PI Response:

Reviewer 23466

Score: 3.0

Comment: Research approach is to evaluate known methods of scale reduction and select the one with the best performance price ratio. Researcher considered abrasion, chemical, and complete removal of TDS to abate scale issues. Researcher is building on water treatment technologies developed by the power and cooling tower industry, which gives them a significant head start and conserves research funding.

PI Response:

Reviewer 23457

Score: 3.0

Comment: Four (4) different techniques for scale reduction will be tested in parallel. Exploration of several different techniques mitigates risk of failure. The best technique will be incorporated and tested in the variable phase turbine generator. The "scale reduction method" may need to be optimized on a case by case basis. Project is co-located with DOE 1-MW VPT project at Coso; the optimum scale reduction method will be tested with this powerplant.

PI Response:

Reviewer 23443

Score: 3.0

Comment: The technical approach explores both physical and chemical scale removal from the heat exchange surfaces as well as an attempt to magnetically retard scale formation. There is a significant probability of failure using these approaches, but even that failure will provide important information. The development of the dual phase hermetic turbine-generator will be a significant advancement that could have broad application.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23450

Score: 3.0

Comment: Project has developed a compact binary power cycle that can use fluids as low as 110°F. Bench testing followed by field tests are need to confirm technical and commercial potential.

PI Response:

Reviewer 23466

Score: 3.0

Comment: Researcher slightly behind schedule, but progressing along a defined path and hope to complete within the original time frame.

PI Response:

Reviewer 23457

Score: 3.0

Comment: The project is behind schedule by about 9 months. Design of both heat exchangers and variable phase turbine is complete. Heat exchangers are under construction, and testing is expected to start soon.

PI Response:

Reviewer 23443

Score: 3.0

Comment: The accomplishments to date are limited to those of design and numerical simulation of components. These are significant in relation to the resources expended to date. The design activities were completed approximately 9 months behind schedule.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23450

Score: 2.5

Comment: Looks a little weak - reprogrammed some activities?

PI Response:

Reviewer 23466

Score: 4.0

Comment: Good discussion of trying different technologies and how they can be integrated into geothermal sites. Good coordination to demonstrate technology at COSO and relations with site owner appear good.

PI Response:

Reviewer 23457

Score: 3.0

Comment: Approximately 50% of the project funds have been spent which is more or less in line with the work performed to-date. Future plans call for the testing of heat exchangers and variable phase turbine. Assuming that these activities are successfully completed, it should be possible to attain the goals of this work.

PI Response:

Reviewer 23443

Score: 2.0

Comment: The previously mentioned schedule delay in generation of the design has been ameliorated by the anticipated shortening of the construction and installation phase (II) of the project. There is no indication of the potential remedies if these activities cannot be streamlined. There is also no indication of a go/no go decision that is dependent upon the initial testing of the scale resistant heat exchangers.

PI Response:

STRENGTHS

Reviewer 23450

Comment: Willingness to try different materials, cycles, technical understanding of power cycles are strong attributes.

PI Response:

Reviewer 23466

Comment: This research is attempting to research the market and to adapt and apply the best scale inhibition technologies developed in other industries. This seems like a very reasonable approach that will yield reasonable results and give a good return on research investment. The effort to research the cooling tower industry and see what methods (chemical, electro-magnetic, filter, abrasive, etc) have the highest probability of success is a very prudent approach.

PI Response:

Reviewer 23457

Comment: Use of multiple techniques for reducing scale should mitigate the risk of failure and not being able to attain the project objectives.

PI Response:

Reviewer 23443

Comment: This project has the potential to be able to add significantly to the amount of electricity that can be gleaned from low temperature geothermal resources or from spent fluids from operating geothermal plants.

PI Response:

WEAKNESSES

Reviewer 23450

Comment: Project schedule and competing projects have stretched company resources resulting in delays.

PI Response:

Reviewer 23466

Comment: Scale buildup is generally a long term problem and it may take longer to document the limitations than a three year project. While this project helps start this process a longer term approach is needed. This research is not so much about new innovations as a project to determine the best developments in other industries that might be applied to the geothermal scale issues.

PI Response:

Reviewer 23457

Comment: Scale-up and in service issues have yet to be identified.

PI Response:

Reviewer 23443

Comment: There is a significant risk of failure associated with the development of scale resistant heat exchangers as well as with the development and operation of the hermetic turbine-generator.

PI Response:

IMPROVEMENTS

Reviewer 23450

Comment: Better project planning and management, additional staff resources may be required.

PI Response:

Reviewer 23466

Comment: Scale will happen as the injection temperature is reduced. Research aimed at capturing scale constituents, finding a market for the constituents of scale could help transform an issue into an asset. This area is a very difficult area to create break though solutions. Perhaps some use of moveable heat transfer surfaces (allows cleaning perhaps from pressure waves), using thin membranes for heat transfer? We need some new ideas in this arena.

PI Response:

Reviewer 23457

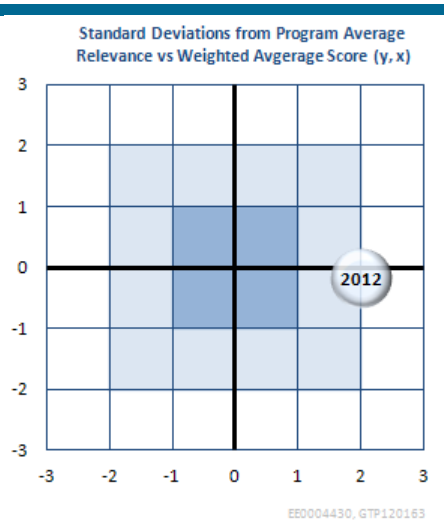
Comment: Commercialization plan is sketchy and needs to be more fully developed.

PI Response:

Reviewer 23443

Comment: Reviewer did not provide comments for this criterion.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0004430
Project: Kalex Advanced Low Temperature Geothermal Power Cycle (The Bald Mountain Project)
Principal Investigator: Bandt, Larry
Organization: Oski Energy, LLC
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23450

Score: 2.6

Comment: It is unclear why there is still a thermodynamic controversy on ammonia-water working fluids for binary power cycles. The potential of ammonia-water power cycles is great due to a number of reasons (fire safety), lower operating costs, safety, lower temperature resources, etc. The project seems to be getting started on a number of elements.

PI Response:

Reviewer 23457

Score: 3.0

Comment: Project goal is to demonstrate theoretical and actual performance/cost advantages of ammonia/water cycle (Kalex cycle) over ORC plants currently being used for power generation from low temperature (< 300 F) geothermal sources. Improved performance and lower cost should help in promoting the use of low temperature geothermal sources for power generation.

PI Response:

Reviewer 23466

Score: 3.0

Comment: Project objectives include validating theoretical and actual performance and economic advantages of the ammonia/water fluid power cycle as compared to the Organic Rankine Cycle (which is the standard for low temperature). Researcher wants to demonstrate a 15 -20% improvement of the Kalina cycle over current technology while lowering the installed cost/kW. Research to show that the Kalina Cycle will reduce the number of wells required as well as reduce the temperature of the geothermal brine. Research can be boiled down to reducing installed cost/kW, and improving efficiency. Researcher is depending on modifying the Kalina cycle to achieve the desired endstate. Researcher references reduced drilling costs, however there is no research into drilling methods, the claim is that higher efficiency will reduce

the required number of wells. A significant reduction in the cost/kW and efficiency improvement does support DOE goals.
PI Response:

Reviewer 23443

Score: 3.0

Comment: The success of this project may allow the development of lower temperature geothermal resources. The ability to vary the NH3/H2O ratios during the operation of the plant in response to the input temperature variations can be a major advancement of technology. One of the partners in the effort has experience with the NH3/H2O heat extraction system. This may provide notable progress toward the Geothermal Technologies Office's goal of providing an addition 3 GW of electrical production from geothermal resources by 2020.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23450

Score: 3.5

Comment: The project collaborators were selected to provide wide experience base to demonstrate the Kalina and derivative power cycle technologies. The project objective is broad - to validate the theoretical and actual performance of ammonia -water vs ORC power cycle. This validation is accomplished by detailed thermodynamic modeling using industry software to evaluate the relative merits of ammonia -water vs ORC power cycles. If theoretical modeling suggests a potentially benefit, a 250°F resource temperature will be tested. The Kalex power cycle offers potential for easier operation with the dynamically adjustable water-ammonia mixture to compensate for ambient and resource temperature changes.

The problem with low temp resources are that large production volumes are required, in turn requiring more wells, requires more drilling (which translate to more drilling risk exposure) this potentially may require fewer wells. Economic data to support this contention was not represented.

Like the cross check with economics from phase 1 to 2.

PI Response:

Reviewer 23457

Score: 3.0

Comment: Scientific/technical approach consists of a number of logical steps:
1. Theoretical modeling of Kalex and ORC cycles (Phase 1).
2. Engineering design and cost estimates (Phase1).
3. Construction of the power plant (Phase 2).
4. Obtain performance data. (Phase 2).

PI Response:

Reviewer 23466

Score: 2.0

Comment: The first phase of activities includes numeric modeling of the proposed cycle and state of the art organic rankine cycles. Cost estimates are also developed for each cycle. This is a reasonable approach. No results of data were presented during the presentation although researcher did present statements that the efficiency of the proposed cycle is higher, the costs for the proposed cycle are higher than ORC technology and he expects the net effect will be that the improved efficiency will offset the higher costs.

While the approach is reasonable as an evaluator I'd like to see the data, cost/kW, projected cost/kW, and efficiency. The way the data was presented causes me to doubt the data is as positive as researcher wants to portray.

The Kalina cycle requires more hardware and controls than the ORC cycle and researcher is claiming that his adaptations to the Kalina cycle are automating the cycle. It would be nice to see a description of how that automation is working, what it is controlling, etc.

PI Response:

Reviewer 23443

Score: 3.0

Comment: The technical approach is straight forward and should be effective in attaining the goal of evaluating the efficacy of the NH3/H2O system for geothermal heat extraction for the generation of electricity. The effort to date has consisted of numerical simulations of both the Advanced Cycle System and the potential economics of the construction and operation of the system.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23450

Score: 3.0

Comment: Project is hampered by lack of suitable site to test power cycle. Modeling and evaluation is still in progress.

PI Response:

Reviewer 23457

Score: 3.0

Comment: 1. Completed theoretical model and simulation studies. Results indicate that Kalex cycle offers superior performance (about 20 %) compared to ORC.
2. Engineering design completed, and cost data generated.

Except for site selection, work is proceeding according to plan. Non-availability of a suitable site and high cost of the Kalex powerplant may prove insurmountable obstacles.

PI Response:

Reviewer 23466

Score: 2.0

Comment: Very minimal data was presented. Researcher also does not have an agreement for a demonstration site. His requirement to build a site in increments of 20 MWs also severely limits possible host sites. It was unclear from where the matching amount would come. Presenter indicated they were in search of an investor. Since this project depends on a large match amount it appears its completion may be in serious doubt and it may not go beyond the numeric modeling phase.

The Kalina cycle may also require special metal components due to the mixture being used in the cycle. Normally these metals are more expensive. This makes the claim of cost reductions less believable especially since no cost data was presented.

PI Response:

Reviewer 23443

Score: 3.0

Comment: The accomplishments to date are limited to the estimates from numerical simulations. In addition, a site for a potential demonstration plant has not been selected, so the actual geochemical compositions of the potential geothermal fluids have not been incorporated into the numerical simulations. The progress to date is adequate for the resources applied.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23450

Score: 3.0

Comment: Need to explain the business model - how this would be cost competitive with cheaper, but less efficient technologies. Project greatly hampered by field testing.

PI Response:

Reviewer 23457

Score: 3.0

Comment: Technical, schedule, and spending appear to be according to plan. Because of site selection issues, Phase 2 will be delayed by an unknown amount of time.

PI Response:

Reviewer 23466

Score: 2.0

Comment: No agreement has been competed for a host site. Since researcher needs a 20 MW site this is a significant issue. To date it appears research has focused on modeling with very little actual construction or fabrication or coordination to get a site. At this point I would expect at least to see a list of potential sites and what is being done to coordinate the demonstration.

PI Response:

Reviewer 23443

Score: 2.0

Comment: The project management has been adequate for the modeling efforts conducted to date. There is no indication that there are go/no go decision points either at the end of phase I or during phase II activities.

PI Response:

STRENGTHS

Reviewer 23450

Comment: Project personnel experience with geothermal power cycles, real world economics, geothermal operating environment, and general technical level.

PI Response:

Reviewer 23457

Comment: A well thought out plan to document the performance/cost advantages of ammonia/water cycle compared to ORC power plants.

PI Response:

Reviewer 23466

Comment: The strength of this project is in the science and the fact that the Kalina Cycle can deliver a higher efficiency than the ORC cycle.

PI Response:

Reviewer 23443

Comment: 1) This project has the potential to increase the range of geothermal resources capable of generating electricity which will help the Geothermal Technologies Office's goal of adding 3 GW of electrical production by 2020.

2) The researchers have allied themselves with the only organization with experience with an operating NH3/H2O system.

PI Response:

WEAKNESSES

Reviewer 23450

Comment: No project test site or backup.

PI Response:

Reviewer 23457

Comment: Delay in finding a site for locating the demonstration power plant. Theoretically predicted advantage of Kalex plant versus ORC may be negated by the high cost of the Kalex powerplant.

PI Response:

Reviewer 23466

Comment: There appears to be a lack of a clear path to finish this project. There is no site location for the demonstration and since the researcher wants to build a 20MW facility this is a very significant issue. A 20 MW site is a significant resource and most investors will not want their site to be a research site. To date most of the research has been modeling and involved little construction or fabrication. There is a significant amount of work still to be done.

PI Response:

Reviewer 23443

Comment: 1) There is not a site selected for a potential demonstration plant, thus the detailed geochemistry of the potential working fluids is unknown and their effect on the NH3/H2O system cannot be simulated.

2) Previous experience with the NH3/H2O system has shown that there are significant materials problems with the system components. There is no indication that these problems have been analyzed and that materials that will with stand the rigors of this system exist or are readily available.

PI Response:

IMPROVEMENTS

Reviewer 23450

Comment: Alternative site selection.

PI Response:

Reviewer 23457

Comment: Recommend working with various US power developers to find an appropriate site for the demonstration plant.

PI Response:

Reviewer 23466

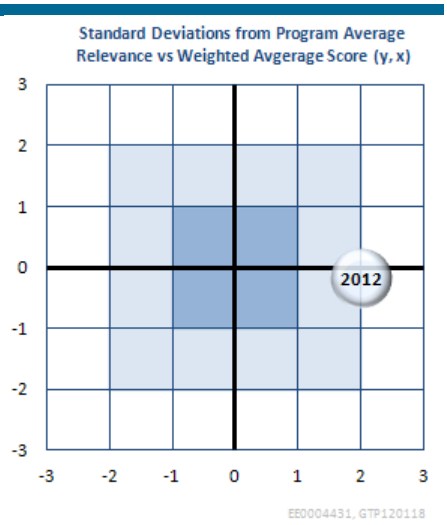
Comment: I suggest there be a road map developed. An endstate identified and then a path to get there. The 20 MW criteria is especially concerning. This project needs to be demonstrated, the first one might need to be smaller than 20 MWs.

PI Response:

Reviewer 23443

Comment: Reviewer did not provide comments for this criterion.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0004431
Project: The Canby Cascaded Geothermal Development Project
Principal Investigator: Merrick, Dale
Organization: Modoc Contracting Company
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23457

Score: 3.0

Comment: Project goal is to develop a net-zero energy community through cascaded uses (power, district heating, aquiculture) of a Low Temperature (~205 F)
geothermal resource. If the project proves to be economically viable, it will help promote the use of low temperature resources.

PI Response:

The project currently has two wells, ISO-1 and ISO-2. Max temperature of the ISO-1 well was 223 F while the max temp of ISO-2 is 205 F. The data indicates that temperature increases the closer we get to a fault to the south, therefore the proposed ISO-3 geothermal wellwould be sited appropriately.

We believe this is a true statement as other towns in Modoc County and beyond are waiting to see if the Canby Project will be sucessful. We intend to demonstrate that the economical viability will be captured by numerous downstream direct-use applications after the power cycle.

Reviewer 23466

Score: 3.0

Comment: Demo project objective is to demonstrate that a holistic approach to geothermal development nets the most value to a community. If successful this could promote development of small low temperature geothermal resources throughout the West. Researcher intends to develop cascaded agriculture and district heating applications around a small electric development. Researcher has plans for electric production, agriculture uses (aquatic and greenhouse), and district heating. This does support the goal of developing more small low temperature resources.

PI Response:

Agreed.

Reviewer 23443

Score: 3.0

Comment: This project is aimed at demonstrating that a local community can use a low temperature geothermal resource for a series of uses from initial electrical generation to space heating to aquiculture. Without a significant federal government subsidy, this sort of project would not be economically viable.

PI Response:

The term "economically viable" should be put into perspective.

The CEC staff in 1998 was not in agreement to fund our first project, the I'SOT Geothermal District Heating Demonstration Project. Staff said the "low cost of natural gas makes the project not economically viable", but one of the Commisioners (David Rohy) took exception and instructed Staff to help fund the project (those activist Commissioners!). The entire area has no access to natural gas, only propane and electricity, which is like many communities in the American West. As of 2010, the energy savings from the I'SOT Project was approaching $87,000 per year pumping an annual average of 16.7 gpm of geothermal water. This is significant, not only in terms of what you can do with a small resource but economical viabilty. Propane also follows petroleum prices, not natual gas prices. So, after about 15 years, the project cost of $1.2 million will be fully paid off (if we had taken out a loan for the entire amount), after that time, for generations, the project savings speak for themselves. The problem has always been getting funding from risk adverse banks, which brings us back to why we approached funding agencies to reduce that risk in the first place.

The project vision is to create a net-zero energy community on a geothermal resource that will not only provide space heat for a residential area, but provide energy and power for businesses that create jobs and income. With the experience of what has been possible with only 16.7 gpm, why would we not go further?

There is a fish farm two miles away from Canby at Kelley Hot Springs (KHS). They sell tilapia to "live market" in China Town in San Fransisco every week. They are one of the largest live tilapia fish farmers in California. Their profit is between $400-$500 K annually. Our geothermal project in Canby plans to use our friends at KHS as consultants and a model going forward. Our engineer believes it is possible to approach the size of the KHS fish farm in our cascaded geothermal model by using our fish farm to cool the power plant (via heat exchager), leaving the "waste heat" from the power cycle to heat the district heating system and future greenhouses.

It is also the project view to, at the end of the day, use whatever resource is available from the project wells, capturing any value the well has and over time justifying the cost of drilling. For example, the first project geothermal well, ISO-1, delivers 37 gpm with a drawdown of 250 ft. Not great by any stretch. It also had problems with arsenic and mercury that had to be mitigated before final discharge to a local river. It would have been the conventional wisdom at the time to abandon the well and the project because it wouldn't have seemed "economically viable" to continue. As previously discussed, the cost of drilling this well will be captured.

Again, the ISO-2 geothermal's potential remains to be known until fully developed, the intention still to maximize the potential of that well and develop further. Incidentally, both wells were drilled with mud rotary rigs that limited production of the identified geothermal aquifer, which will be addressed drilling the proposed ISO-3 well with air at the targeted production zone. Further, the fault identified by the recent MT survey about 300 ft to the east of ISO-2 could be intersected to increase the injectivity of the well.

By contrast, there have been thousands of "unsucessful" wells drilled for power production over the last 50 years where the developer walked away and abandoned the wells because they didn't satisfy a pre-determined economic break-off point.

As has is being shown with the first I'SOT Project, economical viability will be demonstrated with the Canby Cascaded Project because the value is captured by multiple activities, when all taken together, make absolute economic sense for generations.

Reviewer 23397

Score: 3.0

Comment: This project is highly relevant to the goals of the Geothermal Technologies Office, particularly as the project objectives are stated on Slide 6 of the review presentation. The overall goal of the project is to develop a net-zero community using Low Temperature geothermal energy to produce electricity and use the lower-enthalpy stream in direct-use applications. Just as electricity co-generation projects are able to leverage the waste stream into useful applications, this project will leverage the direct-use applications to lower to net cost of the electricity production (or increase the net present value of the overall project). The impact of the project would be much greater if a clear data dissemination plan were put in place. To result in a broader impact, the objective of the project (supported by a technical plan) needs to be more than just to demonstrate.

PI Response:

A technology transfer plan will be put into place by the Go/No Go decision point.

It would be our preference to make the project data available to the National Geothermal Data System AND by developing a website that a user could enter and view system data in real-time, from power generation though the cascaded system. Our vision is to be a place where engineering and geology students along with community leaders, can come and learn from our experience developing a geothermal project. A website would be a great way to enable this process.

The district heating system currently has a data acquisition system (DAS) that would be upgraded and expanded to include the entire system.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23457

Score: 3.0

Comment: Review of available data from DWR records, shallow aquifer chemistry (including isotopes), and a MT survey will be used to site a third well (ISO-3). Additional development (stimulation?) of ISO-2 for injection is planned. Work will also be undertaken to optimize the direct uses of geothermal fluids. A well testing plan has yet to be formulated.

PI Response:

The ISO-2 well will be developed with air to about 1500 feet. Friends of the project Susan Petty and Bill Livesay believe there is a good likehood that there is more than meets the eye with respect to permeability with this well after development. The fact that the well is isothermal 1000 suggests enough permeability to allow sufficient thermal convection within the geothermal aquifer. A well testing plan will be forlumated by project consultant Burhard Bohm to obtain pertinent well information to proceed to the next stage of well development.

Reviewer 23466

Score: 3.0

Comment: The approach is to apply known techniques assembling them in a way that maximizes use of the resource and encourages the community to develop the resource so that less outside support is necessary for the community. Researcher is using magnetotelluric and isotope analysis. Some other less expensive techniques might be added to create multiple overlays (2 meter survey, overhead data, gravity survey, etc) and hopefully create information that improves drilling confidence. Although researcher seemed confident about techniques, the drilling did not identify a permeable reservoir although useful information was compiled. Drilling technique of reverse circulation used which apparently increased the rate of penetration through the largely clay type material. Allegation is that this reduce the cost, however there was not objective cost data presented to validate claim. Community involvement appears high and actually aligning the success of the project with the success of the community is a great way to make the project enduring.
Since a large part of this project involves the secondary uses I would expect to see more attention paid to the secondary use development. Most of the presentation was about drilling.

PI Response:

In all of the data to date, we have identified the target geothermal aquifer for the proposed ISO-3 geothermal well, which is seen in the MT survey at station 2-6 that extends for approximately 300 feet. If drilled with air through this section, production from the formation should be maximized. According to preliminary talks with project partner Hydro Resources, costs to drill with reverse circulation to a depth of 2400 feet should be between $500,000 to $750,000 depending upon well design, particulary if the depth of the surface casing was reduced from 1500 feet to a shallower depth..

With respect to attention to secondary use development, the project engineer Brian brown has not completed the ascaded design. These details will be made available for review for the Go?No Go decision point.

Reviewer 23443

Score: 3.0

Comment: The project is using standard geothermal exploration techniques which lowers the potential risk of failure. Considering the lack of geothermal experience by the Surprise Valley Electrical Coop., the progress has been commendable and the setbacks have been handled well. The geophysical survey has provided important additional information and the addition of an experienced driller for the smectite-rich sediments was essential.

PI Response:

Thank you. A development is a series of events managed in such a way that, hopefully, will yield maximum benefits from the effort undertaken.

Reviewer 23397

Score: 2.0

Comment: Perhaps it was a function of limited information being presented at the Merit Review, but with the information presented it seems that the technical approach is inadequate. Stating that “[w]e used the best available geotechnical experts to explore and plan well drilling activities” is not sufficient for a technical review. There was no information

presented about the resource characterization and the development of a conceptual geologic model. This is should be the next step prior to locating and drilling ISO 3. The review presentation states that the drill site has been selected based on a number of techniques, but the details provided were scarce and make it difficult to provide an informed scientific assessment. There were no details of the expected reservoir characteristics that would lead one to believe that adequate temperatures will be found in ISO 3. Additionally, one of the stated objectives of the project is to demonstrate financial viability. The PI said that they have done some financial analysis; however, without the details of this analysis or even the results of the analysis it is unclear whether or not the project will meet this objective.

PI Response:

Honestly, at the point of the Peer Review, we did the best we could with the available information we had at the time, so I used "best available" scenarios; what's a project manager to do?!

Since the Peer Review, an MT survey has been completed, dovetailing with an isotope study, not just at the project site, but in Canby in general, and further tying in a local hot spring two miles away, that gives us a better picture of how the geothermal system works in the area, along with future promising targets for drilling and developing the resource after this project is completed. It is now also understood that resource temperatures increase as you go south toward the Pit River Fault (ISO-1 temp at 2100 ft is 223F; ISO-2 temp at 2100 feet is 200F). We're getting' there…

The financial analysis will be completed by the Go/No Go decision point since it was incomplete at the time of the Peer Review. The first financial analysis was based on a 1 MW scenario; the second analysis will be based on 100 kW increments.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23457

Score: 2.0

Comment: Project started in February 2011. Work has yet to be completed on the Environmental Review and location of the third well (ISO-3). A Go/No Go decision will be taken at the end of Phase 1 (September 2012?). Both the existing wells (ISO-1 and ISO-2) have low productivity, and are unlikely to provide any significant production or injection capacity for an electrical powerplant.

PI Response:

According to our environmental consultants, our environmental review is likely to have a Finding of No Significant Impact or Negetive Declaration. The review is on schedule to be completed in September 2012.

The ISO-1 geothermal well will be used as a back-up well for the district heating system and to supplement during times of peak use. The final utility of the ISO-2 well is still unknown until it is fully developed.

Reviewer 23466

Score: 2.0

Comment: The lack of permeability of the drilled well limits what can be done. Its likely that another well will be required. Researcher states that the new well is isothermal for a large region which would indicate some permeability and this is in conflict with the flow test, which indicates little permeability. Perhaps there is some misunderstanding of the

data, in any case this requires explanation. Its unlikely that the reservoir is isothermal and not permeable. No results for the magnetic survey or isotope were shown, only mention that the tests confirmed the drill site location. Since the well was not successful this casts doubt on the usefulness of the two surveys (magnetic and isotope) conducted. Both the science and the application of these tests need further explanation.

PI Response:

The ISO-2 well is isothermal from 2300-3300 ft at 205F, indicating enough permeability to allow hydrothermal convection. At 205F, friend of the project Susan Petty believes we have more of a well than it appears since the temperature is low enough not to cause the drilling mud to harden and permanently damage the well. Quickly emptying the pump chamber should clean out the drilling mud from the well, giving us a better idea of productivity/injectivity. In any case, the ISO-2 well is now the target well for injection since the temperature is 205F, cooler than 223F at the ISO-2 well temp at 2100 ft.

An MT (magnetotellurics) survey final report was completed after the Peer Review in May 2012. The survey tied in a local hot spring which enabled the geophysical team to further understand the local geothermal resource and what they were looking for. These surveys have been provided to the Low-Temp team for further analysis.

A third well will be needed (ISO-3) which has always been a part of the proposed plan. Our Phase 1 task has been to find the permeability needed in order to secure funding for Phase 2 implementation.

Reviewer 23443

Score: 3.0

Comment: The accomplishments and goals of the project are modest. Geophysical and geochemical methods have been used to successfully locate production wells. An analysis has been conducted that indicates the potential for multiple uses of the geothermal fluids after electrical production.

PI Response:

Agreed.

Reviewer 23397

Score: 3.0

Comment: The major accomplishments to date are the completion of the ISO-2 well and the finding that financial projections suggest financial viability; however, no details of the financial assessment were provided. These accomplishments thus far are adequate, but much more detail needs to be provided so that these results can be assessed. Additionally, it seems that the understanding of the geology of the system is rudimentary at this point in the project. One would expect the understanding of the subsurface to be much more mature prior to siting and drilling of ISO-3.

PI Response:

Agreed. As discussed above, a completed MT survey and isotope data have been helpful in plans to site ISO-3.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23457

Score: 2.0

Comment: The existing wells have inadequate production/injection capacity. Even if successful, the third well is unlikely by itself to remedy this situation. A fourth well will most likely be required. Key Go/No Go decision will be taken in the next few months.

PI Response:

As discussed in the previous sections, the ISO-1 well is a backup for the district heating system or as a well to use during peak load.

The ISO-2 well will be developed soon to realize the actual utility of that well. The ISO-2 will be used for injection purposes because of a lower temperature at depth. If well development continues to show inadequate permeability, it may be feasible to directionally drill into a fault 250 feet east of the ISO-2 well (shown by recent MT survey) from 1500 feet after pulling the installed casing set to 3300 feet.

The proposed ISO-3 well siting and drilling program will take advantage of new MT and isotope information and leasons learned with respect to drilling with air as to not damage producing formation(s).

We're not sure at this time if a fourth well will be needed for the task at hand, however, it is the intention to continue development of other promising areas for exploration discovered the the MT survey and isotope study. Preliminary, informal talks have been held with the local utility, Surprise Valley Electric, to partner in developing these sites.

Reviewer 23466

Score: 4.0

Comment: Researcher appears to have a firm grasp on his objective and the full support of the community and researchers that provide needed expertise for drilling and development.

PI Response:

Thanks.

Reviewer 23443

Score: 3.0

Comment: The project management has been adequate for the tasks that have been accomplished and for the project goals. Recognition that the lack of geothermal experienced by the organization was more that compensated by the addition of experienced members to the team.

PI Response:

No Response

Reviewer 23397

Score: 3.0

Comment: Management of the drilling of ISO-2 was good; however, the PIs should direct the development of a geologic model for the system to explain the 1,000-ft isothermal zone seen in ISO-2. A clear understanding of the geologic system is necessary to increase the probability of success when drilling ISO-3. The project seems to be proceeding according to schedule, but it should only proceed to the next step if the probability of success is high.

PI Response:

A geologic model is more clear today than at the Peer Review. The MT survey was wonderful in the sense that it cover such a large area surrounding the project, tying into a local hot springs two miles away. This survey has given us much more confidence on what we are looking for. Hydro Resources has also agreed to submit a paper to the GRC about the MT-4ED survey and results of subsequent drilling if the project goes on the Phase 2 implementation.

Our confidence is high that the cascaded project will be developed with whatever resource is available, from power production to multiple direct-use applications. We are excited because of what we have been able to accomplish with only 16.7 gpm annual average on the district heating project.

The ISO-2 well today could produce about 180 gpm of 205F geothermal water (before it is developed) according to Paul Atkinson, reservoir engineer consultant on the CEC drilling project. We believe that if much can be accomplished with a modest resource, it would help further Low Temperature geothermal projects overall.

We are not convinced that a large resource is needed to be economically viable. The reality is that if we set the bar so high that most community based projects need prolific flow to exist, we have not encouraged development of the technology. We believe that the most important thing is to use the resource you have to the fullest extent and as the resource is understood, develop slowly and deliberately with set goals.

STRENGTHS

Reviewer 23457

Comment: Demonstration of the economic viability of the cascaded uses of a Low Temperature geothermal resource is a worthwhile goal. Success of this project will help in promoting the wide-spread use of low temperature resources.

PI Response:

No Response

Reviewer 23466

Comment: No doubt that this Researchers enthusiasm and ability to get the community to support the project are key strengths. Communities value independence and this project could make the community a net exporter of energy and food. I give the project very high marks in terms of goals, dedication and a desire to set an example that can be emulated by others.

PI Response:

Thank you.

Reviewer 23443

Comment: This is a straight demonstration project that has used proven technologies to accomplish their goals.

PI Response:

Agreed.

Reviewer 23397

Comment: A key strength of this project lies in its innovative use of a cascaded system from electricity production through various direct uses. One would expect that this cascading system would result in an increased net present value of the overall project. The performers have identified a productive system of interest and successfully drilled a well to 3,852 ft through a managed drilling program.

PI Response:

Thank you.

WEAKNESSES

Reviewer 23457

Comment: It appears that ISO-2 (injection well) may not have adequate injection capacity. If ISO-3 also encounters inadequate permeability, then the project costs may go up. Low temperature projects like the present one that require significant drilling expense are unlikely to be cost competitive with other sources of power.

PI Response:

Until we develop the ISO-2 well, we do not know the final injectivity of the well. There are plans, as mentioned in previous sections to increase injectivity if required.

The cost of the ISO-3 well will be kept to a minimum by considering well design and targeting the resource above 2300 feet, drilling with reverse-circulation drilling equipment and with air when in the geothermal aquifer. We are working to keep the cost down between $500-750 k. and the overall budget within budget.

Reviewer 23466

Comment: This project has some very high hurdles to overcome. The well drilled is not permeable and this is a serious setback. A thorough analysis of what was expected before the drilling and what was found needs to be done. A negative aspect of having someone so positive about a project is that they focus on being successful and fail to recognize what the data is telling them. I am convinced that this project leader has the best intentions and will do whatever reasonable to make the project a success. Some oversight might help identify the best options and avoid costly mistakes that would set back both the community and fail to positively contribute to the Geothermal Technologies program.

PI Response:

The reviewer has made some assumptions, maybe because I have not communicated clearly enough, so I will take them in the order that they were given.

-- "The well drilled is not permeable"--This is not a true statement because we see in the data that the ISO-2 well is isothermal for 1000 feet, between 2300-3300 feet. There has to be enough permeabilty for this to occur. Until the well is developed, we will not be able to make any absolute statements.

--"a thorough analysis needs to be done".-- This part of the Phase 1 feasibilty study that is in progress.

--"failure to recognize what the data is telling them"-- The beauty of the Geothermal Technologies Office is that it has allowed this project to hire competant consultants that will analyze the data and also allow input from the Low-Temp team. We believe in the collaborative approach to keep us safe and make the best decisions.
--This reviewer seems to believe that the PI is a rouge cheerleader who acts alone without input or competant consultants. The PI admits to being excited about the project and has for 15 years since the start of the first district heating project. Consider:
**The project confronted and overcame drilling and developing ISO-1,
**Currently discharges geothermal water to the Pit River by working with the Regional Water Board despite arsenic and mercury obstacles (in California!),
**Worked with a nervous funding agency that wanted to pull funding because of the fear of failure,
**Sucessfully negotiated with the US Fish and Wildlife Service after the agency began to contest an NPDES discharge permit to the river,
**Effectively worked with the local Tribes to successfully get their blessing to complete the project.

All the "data" said to stop, yet we had a project at the end of the day because we collaborated with all parties involved to a sucessful end. This is the type of project you look to fund because of the commitment of an entire community.

Reviewer 23443

Comment: This project will have a significant impact on the local community and can, perhaps, demonstrate to other communities in similar settings that there are exploitable resources. The major weakness is the lack of economic viability. This program would not be possible without major Federal and State subsidies.

PI Response:

Agreed. I've discussed economic viability on Page A-2. It's true that State and Federal help has been necessary because banks have been risk adverse and a ressession just makes it worse!

But this PI also believes that if we can bring down the cost of development, other towns in the area will explore known resources to their benefit. We are also willing to take some risks and get through the learning curve so that we can further understand our local resource for development. Where we are, no development means no growth, no hope for much of a future.

Further, our local utility is interested in partnering with our project and local landowners to meet the co-ops electrical load in the next 10-20 years by developing local geothermal resources. What makes these projects more attractive to the landowners is if they are able to not only receive revenue from geothermal leases from power generation but support other endevours like the Canby Project.

Reviewer 23397

Comment: One of the weaknesses of the project is the apparent lack of geologic knowledge of the system. It is not clear that the probability of success of drilling a successful ISO-3 well is increased by the current knowledge of the system. Additionally, the review materials did not provide any detailed information on the financial analysis that was said to have been completed. A thorough financial analysis is absolutely necessary to assess the success of the cascaded project.

PI Response:

Agreed. At the time of the Peer Review, we did not have the information we have today with regard to the project isotope study and MT survey. This study will be reviewed by the Low-Temp team. Also a final and though financial analysis will also be completed as well before the Go/No Go decision point.

IMPROVEMENTS

Reviewer 23457

Comment: Testing of existing wells (ISO-1 and ISO-2) and the planned well ISO-3 for permeability and reservoir continuity should be given high priority.

PI Response:

Agreed.

Reviewer 23466

Comment: I recommend a thorough review of the next steps to help the researcher identify the next best step. Requiring the researcher to develop an interim briefing will force thought about the best options and hopefully identify the best next step.

PI Response:

Agreed. Our project has been proactive in briefings with the DOE Low-Temp team to access their thoughts on next best steps and other options. That process has been very helpful.

Reviewer 23443

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Thank you.

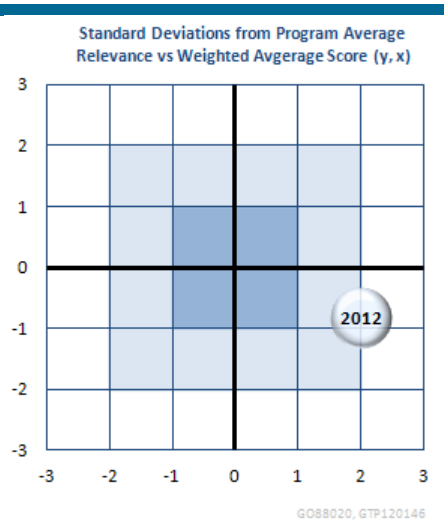
Reviewer 23397

Comment: The performers should do a complete conceptual geologic model of the system as well as perform a thorough financial and economic analysis of the cascaded system. The financial assumptions should be clearly delineated and the

most likely metric for analysis would be the net present value of the project. They should compare the NPV of the cascaded project to various perturbations of potential projects using the same resource such as electricity only, and direct-use only.

PI Response:

Agreed, thank you.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0004435
Project: Small Scale Electrical Power Generation from Heat Co-Produced in Geothermal Fluids: Mining Operation
Principal Investigator: Clark, Tom
Organization: ElectraTherm, Inc.
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23414

Score: 4.0

Comment: Doing the Denbury demonstration project in Mississippi and preparing for the Florida Canyon Mine demonstration are strong indications of relevance.

PI Response:

Reviewer 23441

Score: 4.0

Comment: The project's objectives are to develop and demonstrate an Integrated ORC Power Module assembly working off 240 F with a maintainable Sondex evaporator for co-produced fluid applications. A new ORC control algorithm is a part of the innovation. The project design has already considered details of the operation including extending 90% into the vapor dome with an isentropic expander. Clark has an extensive background in rotating equipment that is being employed for this project and he was very comfortable answering the questions from the reviewers. The project is both relevant and on target with regards to the Geothermal program goals. Having said that, there is a fine line at times between reporting and presenting an infomercial and ElectraTherm needs to be cautious that they do not cross that line. A comprehensive project economic design evaluation has been developed as part of this project. While certain adjustments on the sheet would be preferred, for example – first presenting LCOE and then including the impact of Federal incentives, asking whether 90% availability is realistic, which may prove challenging for reasons not directly related to performance of the system at the site, etc.
In sum, the project has made substantial progress and impact on the DOE's Geothermal Technologies Office missions and goals and has addressed knowledge gaps and barriers on co-produced fluids. As the demonstration moves forward, it will be interesting to see whether the encouraging design expectations are met. Reassessments seem likely.

PI Response:

Reviewer 23466

Score: 3.0
Comment: The objective of the project to demonstrate the technical and economic feasibility of small scale power generation from low temperature co produced fluids contributes to DOE goals. A single robust and economic package would enable the harnessing of many small resources. Researchers goals align with those of the geothermal technologies program, for example remote operations, low maintenance, material flexibility, and minimizing installation cost.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23414

Score: 3.0

Comment: This was all pretty straightforward engineering optimization.

PI Response:

Reviewer 23441

Score: 3.5

Comment: The ElectraTherm is using the City University of London for Thermodynamic modeling and these were developed using the ?-NTU method in which a heat exchanger is subdivided into three zones, each of them being characterized by both the exhaust gases and water side pressure drop as well as heat transfer coefficient. The evaluation of the two-phase zone pressure drop and heat transfer with respect to the vapor quality was carried out. The model of rotary piston expander describes the evolution of the fluid through the device and was split into three global steps: pressure drop across the supply port, isentropic and expansion at constant volume, internal and external heat transfers. Some specific reference to work would have enhanced the presentation and the lack of this discussion is a technical weakness that needs to be addressed.

PI Response:

Reviewer 23466

Score: 2.0

Comment: The basic innovation is to use a screw expander that allows remote, robust harnessing of the small resources. Researcher claims to have an innovative lubrication of bearings that allows an expansion into the wet region. Previous screw designs have failed because the moving seal necessary for screw compression/expansion have not been durable and over time these seals fail. There was no mention of how this problem is made better by the researchers device, the lubricated bearing seems to be necessary for sealing but it is not a part of the moving seal at the perimeter of the screw.

Researcher admits that adiabatic efficiency of his device is 68-71% which is considerably lower than other expanders already on the market. Given that this device (the screw) requires complex machining its difficult to see how continued development along the same path will net better results in terms of economics and long term service. Researcher uses "value engineering" in his presentation but fails to quantify results. For example the heat exchanger analysis seems more to be a sizing exercise rather than an innovation in heat exchangers.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23414

Score: 3.0

Comment: These folks are on schedule to achieve all that they promised to do.

PI Response:

Reviewer 23441

Score: 3.5

Comment: There has been excellent progress on developing innovative positive displacement screw expanders and compact plate type heat exchangers to optimize performance of the Organic Rankine Cycle. At the same time, the project has also focused on innovations in the control scheme that should prove beneficial.
1. Quality – the quality of the effort as reported thus far appears to be excellent. A test site with a one year evaluation of the water quality and issues for corrosion and scaling employing material coupons is already providing valuable feedback for the design.
2. Productivity – the level of productivity in work (~$550K) has been commendable, the project has worked at optimizing the evaporator solution to be able to handle variable geothermal water chemistry levels and still meet design performance over time. The use of a plate and frame Sondex heat exchanger which is cleanable and integrates the pre-heater and the evaporator duty into one assembly may prove to be an important approach to the design of geothermal ORC. The design also has the flexibility to utilize various plate material selections to meet the need of specific well chemistry. If Titanium is used as was suggested in the oral presentation, there would be a need to revisit the project economics.

PI Response:

Reviewer 23466

Score: 2.0

Comment: Researcher presented very little data about the output and cost of his device. When asked, he did provide data that indicates a cost of $2,000/kW and an adiabatic efficiency of 68 - 71%. While the $2,000/kW seems very encouraging there is not adequate data to determine what this number represents. For example, is this just the screw expander or does it include the generator, the heat exchangers, gear reduction, controls, etc. The researcher spent time discussing the Presidential visit, a political event, whereas this is a technical review, and his time might have been better used promoting the positive aspects of the research.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23414

Score: 4.0

Comment: In addition to bringing the project in on budget and on schedule these folks had to scramble to host a visit from President Obama. 'No shortage of opportunities to fail, but they didn't.

PI Response:

Reviewer 23441

Score: 4.0

Comment: The project appears to be well managed and is delivering in a timely manner. Having said this, the most challenging portion of the project effort is still to come. However, full credit will be given for this criterion.

PI Response:

Reviewer 23466

Score: 3.0

Comment: This project appears to be on schedule. Data sharing also appears to be good.

PI Response:

STRENGTHS

Reviewer 23414

Comment: Demonstration projects.

PI Response:

Reviewer 23441

Comment: ElectraTherm's modest demonstration of ORC for Low Temperature geothermal applications is on track and making very good progress. The scientific and engineering teams are staffed with capable researchers and applied engineers. The goals of using basic thermodynamics and information about the site specific reservoir fluids are being integrated into a practical, yet innovative ORC design that will be deployed and demonstrated in a field application. The lead organization already is developing an evaluation tool that may be employed at other sites for assessing the economics of constructing such a system at their own site.

PI Response:

Reviewer 23466

Comment: Researcher has a working screw expansion machine that can be tested and applied widespread if the performance criteria merits. Researcher is attempting to improve the basic machine with enhancements to heat exchange, controls, lubrication, and integration into existing infrastructure (grid, wells, site).

PI Response:

WEAKNESSES

Reviewer 23414

Comment: 'Not a lot of breaking edge science. I personally don't see that as a problem with a project like this. Oftentimes the "and do good science too" demand is a distraction from solving the problem at hand. But it's part of the criteria we were given to work with.

PI Response:

Reviewer 23441

Comment: The project presents a nice screening tool for project economics. Further developments would permit a better assessment of where the initial predictions are subject to project specific adjustments. It is not clear as to how much background in depth engineering is behind the economic screening tool.

PI Response:

Reviewer 23466

Comment: I saw very little data about the performance of this machine. More hard data on machine performance results will help determine whether or not this business venture is successful. It appears that this machine will not be as efficient as a standard ORC turbine (such as the ones in development by Pratt and Whitney, Turbine Air Systems and others) however efficiency is only one measure that contributes to success. The ultimate efficiency is economic efficiency. The cost of manufacturer and long term performance contracts both contribute to economic efficiency. The market needs competition and hard data will be more persuasive in the market than the use of terms like "value engineering." I strongly recommend that more hard data be collected and reported.

PI Response:

IMPROVEMENTS

Reviewer 23414

Comment: None. Excellent job.

PI Response:

Reviewer 23441

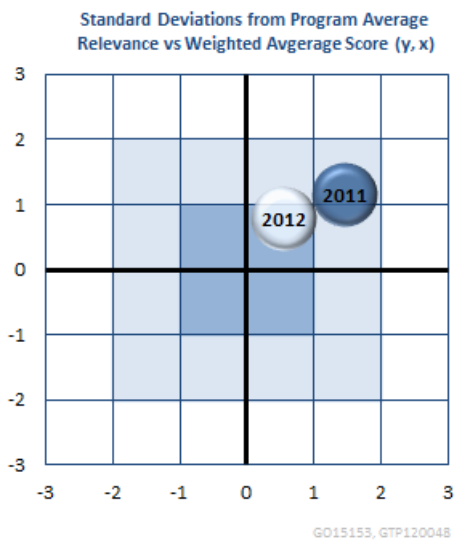
Comment: lt would be hoped that in the future the company will work towards that they have a full engineering design with costs that is being used as the basis for their screening evaluation.

PI Response:

Reviewer 23466

Comment: This project needs to focus on reporting machine performance and cost.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO15153
Project: Demonstration of a Variable Phase Turbine Power System for Low Temperature Geothermal Resources
Principal Investigator: Hays, Lance
Organization: Energent Corporation
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23450

Score: 3.3

Comment: Variable phase turbine will use lower temperature waste heat or resources. The variable phase cycle eliminates several components - no gearbox, with a simpler. turbine and generator set run at the same speed. This should incrementally reduce parasitic load and potentially lead to lower cost per MW.

The use of off the shelf components allows creative design for a simpler, more efficient binary power plant.

PI Response:

Reviewer 23457

Score: 4.0

Comment: The project is to construct and demonstrate a 1-MW variable phase turbine (VPT). Based on a pilot plant, the VPT is predicted to be up to 30% more efficient than the comparable binary plants for electric generation from Low Temperature (220-340 F) geothermal resources. Depending on the success of the 2-year planned operation of the power plant, VPT may represent an attractive alternative to binary plants and lead to greater usage of low temperature resources.

PI Response:

Reviewer 23466

Score: 4.0

Comment: The objective of this project, to demonstrate a variable phase turbine, aligns perfectly with the goal of producing more power from low temperature resources. Since the device is simple it also promises to achieve another goal of reducing cost/kW. This machine will produce a new market and create downward price competition for other ORC binary cycles. The researchers are building on research and experience they have in the vapor compression chiller market, which is directly transferable to the ORC cycles. The DOE Geothermal Technologies Office is getting a good return on its investment in this research.

I also point out that since the researchers are implementing the trilateral cycle they are getting more of the geothermal energy into the power cycle which will improve the net output of the turbine. This focus on getting more energy into the power cycle (especially for low temperature) means the net output could improve by more than the 30% objective in the research.

PI Response:

Reviewer 23443

Score: 4.0

Comment: The success of this project will allow substantial advancement toward Geothermal Technologies Office's goal of adding 3 GW of electrical generating capacity by 2020. This system can be used as an add-on to existing geothermal power plants to exploit the spent geothermal fluids.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23450

Score: 3.3

Comment: The technical approach looked at ways to simplify the process elements in a binary power cycle. The test design examined heat exchanger performance and verified turbine efficiency calculations.

PI Response:

Reviewer 23457

Score: 4.0

Comment: The VPT turbine was demonstrated in a pilot plant. Based on a test of two designs for the liquid heat exchanger, a shell and tube type heat exchanger was chosen. A parallel research project is evaluating various schemes for reducing scaling in liquid heat exchangers; one of these schemes will probably be implemented in a future design of VPT. The 1-MW turbine will be operated for two years to demonstrate its long-term viability. Because of the unavailability of suitable scale reduction technology at present, the 1-MW will be initially operated with a rejection temperature of about 175 F. The turbine will provide a test bed for testing one or more scale reduction methods being developed in a parallel project.

PI Response:

Reviewer 23466

Score: 4.0

Comment: Research is built around a market and a machine with which the researchers have a decade of experience and they are approaching the modifications in a pragmatic and thorough manner. The demonstration they are implementing respects the geothermal site operator and will develop a platform for business extension when they finish the demonstration. The liquid to liquid heat exchanger avoids the pinch point and allows more energy into the power cycle. This is a huge improvement. The use of a nozzle and turbine combination is proven technology lifted directly from the researchers experience in the vapor compression chiller market. This is a crossroad of knowledge that DOE can use to leap forward and a wise investment. The reduced shaft speed eliminates gears (which in turn eliminates friction loss and maintenance) and simplifies the device. Hermetically sealing the turbine and generator has a huge upside for reducing maintenance and improving the reliability of the turbine generator set. The most common device with a hermetic seal is a refrigerator compressor which have been known to operate for 15 -20 years without failure. Since the researcher works in the refrigeration market this is another example of adapting and applying technology developed in another field for geothermal applications which costs only a fraction of original research.

PI Response:

Reviewer 23443

Score: 3.0

Comment: The technical approach is sound and has demonstrated that the estimates from the numerical simulations are conservative. The pilot plant operations data were about 10% greater than the estimates. The demonstration plant is currently being installed and will be operated for 2 years. This system is also being tested for application to waste heat streams in Japan (Incinerator) and on a ship.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23450

Score: 3.0

Comment: Currently testing and commissioning VPT at Coso. Test results yet to be collected, analyzed, and disseminated.

PI Response:

Reviewer 23457

Score: 3.0

Comment: The 1-MW VPT turbine was designed, built , and installed at Coso. The planned 2-year operation is slated to start in May 2012.
To avod scaling in the heat exchanger, rejection temperature will be at least initially limited to 175 F; this may negate the advantage of VPT over ORC.

PI Response:

Reviewer 23466

Score: 4.0

Comment: The project is on schedule and progressing. The researcher has a detailed milestone schedule. Published results indicate the research is achieving not only the schedule but exceeding the performance expectations predicted. Particularly important are the demonstration at COSO and the reductions in cost/kW predicted. Researcher is reporting concrete cost and performance results.

PI Response:

Reviewer 23443

Score: 3.0

Comment: The accomplishments have included operating a pilot plant that confirmed the performance estimates from the numerical simulations. In addition, a liquid-liquid heat exchanger was selected for energy transfer. The quality of the collected data seem to be high. The target of 1 MW of electrical power added to the Coso plant should be accomplished in the next couple of months.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23450

Score: 2.5

Comment: Project could benefit from additional staff resources and better project integration with other ongoing projects.

PI Response:

Reviewer 23457

Score: 3.0

Comment: The PI reviews the project progress and costs on a weekly basis. Because of an escalation in various costs and DOE's inability to provide additional funds, the company will need to bear the extra costs to complete the test.

PI Response:

Reviewer 23466

Score: 4.0

Comment: Researcher is working with COSO personnel in an effective and productive manner. Particular attention is being devoted to protecting the geothermal resource and infrastructure (not clogging up the well with too low an injection temperature) while at the same time getting the lowest injection temperature possible. This research is being very closely integrated with scale abatement research. Cost plan overruns are being picked up by the researcher, which protects DOE from overruns and keeps the research going forward.

PI Response:

Reviewer 23443

Score: 2.0

Comment: The project has suffered from cost over-runs. Some of this was due to the fact that this has been a one-of-a-kind facility and the fabrication and installation of components was more expensive than anticipated. The original schedule time-line was not provided, so one cannot evaluate schedule performance.

PI Response:

STRENGTHS

Reviewer 23450

Comment: Knowledge of project personnel.

PI Response:

Reviewer 23457

Comment: 1-MW VPT is ready to be put into long-term operation. Provided suitable scale reduction technology becomes available, VPT should be more efficient than ORC.

PI Response:

Reviewer 23466

Comment: I give this research very high marks, because is builds on the researcher's experience in the vapor compression refrigeration market. Secondly if successful it will increase the output of lower temperature power plants by much more than the 30% predicted. The trilateral cycle is key to getting more thermal energy into the power cycle. This research has reasonable goals and is progressing along a path that allows time for both innovation and resolving issues that are bound to arise. Researchers also appear to have a very firm grasp of the issues they are addressing.

PI Response:

Reviewer 23443

Comment: The success of this project will allow the generation of additional electrical energy from geothermal systems. This can be an add-on to exploit seemingly spent geothermal fluids. The fact that two systems to exploit waste heat resources have been sold indicates that there is faith in the ultimate viability of this approach.

PI Response:

WEAKNESSES

Reviewer 23450

Comment: Project planning.

PI Response:

Reviewer 23457

Comment: Inability to prevent scaling in the liquid heat exchanger may negate the predicted superior efficiency of VPT.

PI Response:

Reviewer 23466

Comment: I believe this research is a home run. I would like to see DOE reach out to this research and help distribute results oriented data that will help propagate the success.

PI Response:

Reviewer 23443

Comment: The cost over-runs are significant, but may be ameliorated by the commercial production of modules for future facilities.

PI Response:

IMPROVEMENTS

Reviewer 23450

Comment: Better project oversight by GTO.

PI Response:

Reviewer 23457

Comment: Co-ordinate with the parallel research project and incorporate a better design for the liquid heat exchanger.

PI Response:

Reviewer 23466

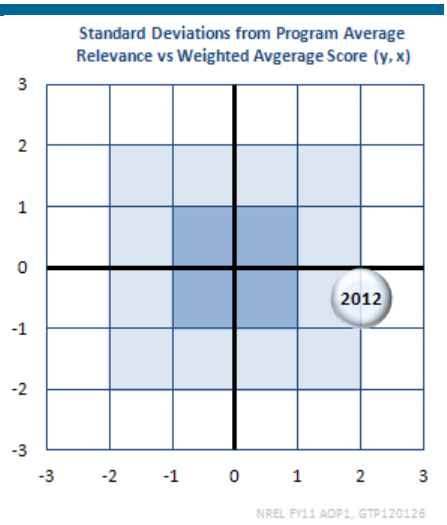
Comment: This research could be exported to any low temperature thermal energy market, such as natural gas compression waste heat, engine waste heat (reciprocating, turbine -- any heat engine).

PI Response:

Reviewer 23443

Comment: Reviewer did not provide comments for this criterion.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: NREL FY11 AOP1
Project: Low Temperature Power Production Field Validation
Principal Investigator: Williams, Tom
Organization: National Renewable Energy Laboratory
Panel: Low Temperature and Co-Production Demonstration

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23443

Score: 3.0

Comment: This project is to develop a predictive numerical simulator that will estimate the Levelized Cost of Electricity from geothermal fluids co-produced from oil and gas operations. The simulator was to be validated with data from the Rocky Mountain Oilfield Testing Center. A simulator has been developed, but field data validation has been severely delayed. Thus, some controlling factors have been evaluated and others have not.

PI Response:

No response entered.

Reviewer 23457

Score: 3.0

Comment: The goals of the project are to (1) validate LCOE of $0.11/kWh through measurements of plant performance at RMOTC, and (2) identify near term low-risk options to reduce LCOE. Reduction in LCOE is essential for promoting the use of Low Temperature sources for power generation.

PI Response:

No response entered.

Reviewer 23466

Score: 3.0

Comment: The objectives of this project are to validate life cycle cost of electric power from geothermal energy from actual plant data, identify near term low risk options to reduce life cycle cost and reduce the uncertainty in projecting or estimating plant electrical production. Goals include identifying options that reduce LCOE from $0.11 to 0.06 per kWH. A major part of the study effort includes sharpening the projected output from design point data to actual operating data over the course of a year. A reliable source of data that includes cost and benefits does help better define geothermal opportunities using economic criteria which is how business investments are made.

PI Response:

No response entered.

Reviewer 23465

Score: 2.0

Comment: This project fits well with the DOEGP's mission and goals. It is critical for this oil and gas coproduction project to validate that it is economically feasible to operate a small (<300kW) geothermal unit at $0.11/kWh, using low temperature (210F) brine, and that the data is available for interested parties to examine the results. The implications of this are important for many locations in oil producing states like Texas, Louisiana, Oklahoma, etc. Success of this project is crucial especially if it is to be taken seriously in highly environmentally regulated states like California. In California, there are abundant low temperature geothermal resources in many producing and marginally producing oil fields.

If this demonstration project is unable to achieve an "acceptable" profitability at RMOTC by bringing the LCOE to a competitive level, to $0.06/kWh now and not 2020, then it is highly unlikely that tapping into this energy source will work anywhere else in the continental U.S. This conclusion is predicated on factors, just to name a few, price of natural gas, brine temperature, ambient temperature, availability of water for cooling, accessible electrical distribution system.

Reducing the uncertainty of estimated plant energy production between simulation tools and actual plant production is by 15-minute monitoring and collection of working fluid temperatures, brine pressure and temperatures, and ambient conditions will result in a more efficient operation.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23443

Score: 2.0

Comment: The technical approach was sound and a numerical simulation model has been developed. The inability to exchange data between the researchers and the field site has severely limited the ability to make serious predictions.

PI Response:

The ability to exchange data was mentioned in the presentation though obviously not clearly enough. We have plans to allow researchers access to all of the data via NGDS. This has not been implemented yet simply because data collection had not begun at the date of the project presentation

Reviewer 23457

Score: 3.0

Comment: (1) Develop a model to characterize the effect of transient deviations (e.g. weather) from the design conditions.

(2) Obtain operational data on the RMOTC plant to validate LCOE.
(3) Identify low-risk options for decreasing LCOE.

Data from a single power-plant (RMOTC) is unlikely to be the final word on LCOE. Plans to gather data from a statistically significant number of power plants are lacking.

PI Response:

With regards to gathering data from multiple plants, this is an excellent point and part of the longer term plan. However that activity was not part of this project and so was not discussed, though it was mentioned briefly in the verbal comments by the presenter.

Reviewer 23466

Score: 3.0

Comment: Researcher has defined a suitable algorithm that captures appropriate inputs and has a model that allows one to perform sensibility analysis. A key part of this research is go beyond simulation and calibrate the model with an actual plant. Although not all data collection inputs were shown, the frequency of collection suggests data collection will allow very detailed calibration and analysis.

A limitation of the research is that it is focused on the RMOTC site and the calibration will be subject to RMOTC conditions. Hopefully the researcher will normalize the model so that with a few inputs it can be adjusted to simulate most locations. It appears that the major calibration will be based on outside air conditions whereas there are many other parasitic loads (well pumps and internal refrigerant pumps) that could have a large impact on net power produced.

On the positive side since the RMOTC site is a very low temperature and the data will help define the lowest temperature where electric production is economically feasible.

PI Response:

The point of calibration the model to RMOTC site was evidently not communicated clearly in the presentation. The RMOTC site provides a calibrated model with inputs that can be adjusted for other sites and designs. The model will have additional validation against other data sets in the future.

Reviewer 23465

Score: 2.0

Comment: The project targets are the following: 1)The collection of operating data to provide a better understanding of the power production in different conditions, 2) Improve simulation models and validate LCOE estimate of $0.11/kWh, 3) Demonstrate a 2% improvement in annual net power plant electricity output over current binary technology in low temperature applications. All three targets are achievable given the technical approach taken by the PI. The approach is rational, logical and deployed in a reasonable sequential manner. The project employed the right procedures, methods and equipment.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23443

Score: 2.0

Comment: A predictive numerical simulation code has been developed, but is unable to be validated due to a lack of data from the field. The communication problems between the researchers and the field site have been devastating.

PI Response:

I won't disagree with the score of 2. on accomplishments here and from other reviewers, but simply note that the root causes (lightning strike, funding at RMOTC) were beyond our control.

Reviewer 23457

Score: 2.0

Comment: (1) Developed a model for the hourly simulation of the power plant.
(2) Project is about a year behind schedule as far as gathering power plant operation data is concerned. Apparently difficulties at RMOTC and data transfer protocol are responsible for the delay.
(3) Identified hybrid cooling as an option for reducing LCOE by about 6%.

PI Response:

No response entered.

Reviewer 23466

Score: 3.0

Comment: Reach is behind schedule because of lack of support from the RMOTC site (funding) and a lightening strike that took out some of the data equipment. Research has produced a model that is within 3% agreement with data collected to date and used an industry standard (GETEM) as a platform. The model also shows that output is generally better (10%) than that predicted by design points (e.g. the cooler weather increases output). Research has demonstrated that hydride cooling has a significant impact on net power produced.

PI Response:

No response entered.

Reviewer 23465

Score: 2.0

Comment: The project appears to be successful as far as the technical aspects are concerned. All project tasks will be completed and technical targets/goals should be met, however, there have been some unanticipated delays in implementation due to a lightning strike and personnel turnover at RMOTC. As a result the project is behind schedule. For FY 2012 the project is now 32% complete. The total DOEGP project cost is $1.4 million. No information was

provided on RMOTC match share. No current LCOE cost data was provided nor was any information provided on the life, and O and M costs. The anticipated project completion date is October 2012.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23443

Score: 2.0

Comment: Project management has been hampered by the loss of the field test facility and the inability to obtain funding to bring the facility back on line. In addition, staff changes at the field test facility hampered recovery efforts.

PI Response:

No response entered.

Reviewer 23457

Score: 2.0

Comment: Although no field data has been gathered to-date, approximately 90% of the project budget has been spent. The project spending should be better aligned with accomplishments. Plans call for power plant data to be gathered starting in the next few months.

PI Response:

No response entered.

Reviewer 23466

Score: 2.0

Comment: The schedule has been delayed because of funding issues at the site. This has delayed the installation of monitoring equipment.

PI Response:

No response entered.

Reviewer 23465

Score: 2.0

Comment: The PI and project team are well qualified to conduct the indicted work. The project adheres well to DOE policy and objectives. The project was completed on schedule. The PI has the appropriate staff on board and is working closely with RMOTC and NREL staff. The spending plan appears to be acceptable in relation to revised project schedule. The PI included has appropriate decision points for future deployment of work. The project does not require coordination with permitting agencies.

PI Response:

No response entered.

STRENGTHS

Reviewer 23443

Comment: The major strength is that the modeling development has used the number crunching engine from a well-accepted code.

PI Response:

No response entered.

Reviewer 23457

Comment: Development a model for the hourly simulation of power plant operation, and validate LCOE using data from RMOTC plant.

PI Response:

No response entered.

Reviewer 23466

Comment: A robust model that can be quickly adapted to any site does reduce the uncertainty of projecting the economic merits of geothermal development. This model contributes to better economic predictions by identifying parameters that have the biggest impact and allowing investors to analyze the sensitivity of each variable. Researchers are well respected in the industry and are developing data that will be validated and tuned to an actual site. This improves the confidence and reliability of predictions.

PI Response:

No response entered.

Reviewer 23465

Comment: The project met the DOEGP's mission and goals. The PI employed a well conceived project deployment plan. There is high probability that the stated technical goals and objectives will be achieved. Project management team was strong and capably administered DOE and match share funds in a prudent and acceptable manner. With less than $140k remaining until October 2012, it is very likely that this project will be completed on time. The project was deployed in a

responsible manner by experienced and competent technical staff. Hybrid cooling was a positive feature to increase power production. Use of the GETEM model.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23443

Comment: The major weakness is the lack of ability to gain field data from the Rocky Mountain Oilfield Technology Center.

PI Response:

As presentation noted this was a delay but not a failure. Data is currently being collected and met the revised schedule presented at the peer review.

Reviewer 23457

Comment: Inability to align project spending with the planned work. Plans to obtain cost data from a statistically significant number of power plants are not a part of the project.

PI Response:

Cost data was never part of the scope of this project and doesn't have a bearing on the project objectives.

Reviewer 23466

Comment: The model has to be adaptable to most geothermal sites, so there needs to be more development that quickly allows the model to adjust. Normalized parameters are required for Outside Weather, Resource Temperature, Pumping Parasitic Loads, etc.

PI Response:

It must not have been clear from the presentation but the model has the ability to adjust for all the parameters noted by the reviewer.

Reviewer 23465

Comment: The cost of electricity on a kwh basis was not provided. The project levelized cost was also not provided. No O and M costs were provided. These costs should have been prepared for the PEER review. The cost of achieving an additional 2-3% power plant improvement from 132kW to 136.5 kW for $1.4 million is a very expensive lesson. It was not made clear if the cost of water for hybrid cooling was going to be factored into the LCOE. No discussion was provided regarding the source of the cooling water. Was the water from a groundwater source or from the geothermal brine? If the water came from the oil producing well, how was it treated? What was the water composition? TDS?

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23443

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23457

Comment: Strengthen management controls. Expand project scope to include a number of power plants.

PI Response:

No response entered.

Reviewer 23466

Comment: I would add normalized factors for outside weather, resource temperature (production/injection), refrigeration pumping, and geothermal resource pumping.

PI Response:

No response entered.

Reviewer 23465

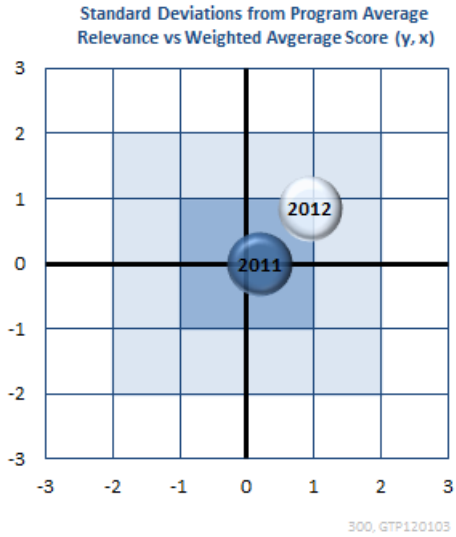
Comment: It is well documented that the use of wet cooling will improve power plant efficiency. Critical to this is the TDS and scaling characteristics of the cooling water. What is the estimated value of the oil and gas produced from the wells?

PI Response:

These are valid points but not really a weakness of the project based upon the established project objectives.

MODELING

Review: 2012 Geothermal Technologies Office Peer Review
ID: 300
Project: Predicting Stimulation-Response Relationships for Engineered Geothermal Reservoirs
Principal Investigator: Carrigan, Charles
Organization: Lawrence Livermore National Laboratory
Panel: Modeling



RELEVANCE/IMPACT OF RESEARCH

Reviewer 23526

Score: 3.5

Comment: This work supports the overall goal of the program to enable EGS as a viable option and path forward for geothermal energy in the US, and as such, is highly relevant. The impact of the work is also high, as the modeling portfolio of the program is beginning to take shape, this work will be an important piece.

PI Response:

We thank the reviewer for the kind remark and appreciate his recognition of the relevance of the project to the goals of the Geothermal Technologies Office.

Reviewer 23397

Score: 3.0

Comment: If successful, this project has the potential to have significant impact on the field. The need for a validated stimulation predictive model is great for the geothermal program, particularly with the focus on EGS. However, the PIs need to take a more active approach in providing their model with realistic inputs from known geological settings. As a reviewer, I would expect to see some basic comparison of the model's predictive results with the results from a field-scale project such as Soultz or Cooper Basin. The real value and impact of this type of model is in its ability to reproduce and predict the real-world response, and thus it need to be benchmarked against a field project.

PI Response:

Thanks for the thoughtful comment. We agree that a comparison with a field-scale project is needed. In fact, we are working with a geothermal company to develop a model based on their site allowing us to do pressure history matching and thermal performance prediction. It should also be pointed out that our effort until now has been focused on development of a computational test bed tool and it has only been possible in the past few months to pursue the type of comparison that the reviewer has suggested. It should also be mentioned that we remain on time in completing the tasks that were identified in the proposal for this project.

Reviewer 23532

Score: 4.0
Comment: The project appears to have made notable progress towards meeting the project's objectives. The model will be able to produce parametric models that should be useful for predicting how stimulation will progress depending on initial stress fields and pre-existing fracture systems. The model does not appear to be useful in its present configuration for studying the effects and history of field stimulations. However, this ability may be there although it was not apparent in the presentation. Usefulness in a field situation will be limited by knowledge of the pre-existing fracture system.

PI Response:

We appreciate the insightful comment. Our intent is to develop a computational test bed that becomes more sophisticated in its simulation capabilities with time. We have the capability now to do pressure history matching of stimulation tests which we are currently pursuing. While the development of a stochastic approach allowing quantification of the impact of uncertainty on our models was not part of the original proposal, we recognize the importance of doing this and are currently looking at different approaches to incorporating appropriate techniques in our computational test bed. This will allow us to depart from the deterministic approach used by virtually all geothermal simulators and perform evaluations of hydrofracturing techniques that are informed by estimating the impact of uncertainty that is inherent in our knowledge of a pre-existing fracture system.

Reviewer 23628

Score: 4.0

Comment: The principal objective for this project is to develop a computational test bed to evaluate fracture permeability enhancement mechanisms and impact on geothermal production efficiency. The outcomes of this project should have direct impact on the performance of geothermal systems immediately and for many year into the future. This project is unique among the other numerical simulation projects in that it is concerned with the simulation of fracture propagation and then the implementation of the permeability distribution into a continuum thermal, hydrological, and geochemical (THC) simulator. Although the project is not directly support this development, this project has been the seed for an internal initiative at LLNL for the development of these capabilities in three dimensions. The new three-dimensional simulator being developed is currently in its first year of development.

PI Response:

We believe the reviewer is correct in his summary assessment of the objectives and scope of this project. We also appreciate his recognition that the fracture-fracture interaction approach is unique among other numerical simulation projects. The reviewer also correctly points out our intent of coupling a modified fracture distribution resulting from hydrofracture/hydroshear with a THC simulator to evaluate the effect of hydrofracturing on heat extraction efficiency. Thanks.

Reviewer 23641

Score: 4.0

Comment: Relevance/impact of this work is high. The work is developing innovative ways to model fracture propagation and interaction.

PI Response:

Thanks for the kind words about our work. We also want to be innovative and hope that we can continue to meet the reviewer's assessment of our project.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23526

Score: 3.5

Comment: The approach taken is unique among the projects supported by the program. It is using largely previously developed tools and implementing them in support of fracturing and fracture-fracture interactions simulations via a node-splitting method for evolution of the fracture domain. This is important, as it can capture the physics of the process much better than constitutive relations related to a damage mechanics approach.

PI Response:

We agree with the assessment of the reviewer. Thanks.

Reviewer 23397

Score: 4.0

Comment: The technical approach to the project is good, with only minor room for improvement. As mentioned in the relevance comments, field-scale validation needs to be attempted. The use of a probabilistic approach as opposed to deterministic is commendable and necessary; however, this approach should also be applied to the system description as well. It may be a function of the limited data that can be presented in the merit review setting, but one of the major points of the presentation was the effects of the compressive shadow zone. It seems that this would be highly-dependent on the boundary conditions of the simulation, both the boundary stresses and the size of the simulation. As such, a sensitivity analysis should be performed to ensure that this is not a result of the system size and to determine the critical parameters that contribute to this shadow zone. This particular result is of greatest concern and interest as it could be a potential show-stopper for the stimulation of EGS systems and thus detailed study of this phenomenon is warranted.

PI Response:

We agree with the need for field-scale validation and have a task to do exactly this in our project. Because of the uncertainty that is characteristic of the description of any geothermal system, we think that our computational test bed must ultimately take a probabilistic approach as indicated by the reviewer. The stress shadow zone results are indeed interesting as they seem to suggest that, at least for the few cases we considered, the initiation of one hydrofracture can produce a compressive stress regime that may prevent others from occurring. The reviewer's suggestion of doing a sensitivity analysis parallels our own thinking as we have also considered issues of finite domain size and the occurrence of potential artifacts introduced by inappropriate boundary conditions applied to numerical models. As described in our publications, our typical simulation includes a core simulation zone covering the reservoir being simulated and an extension zone which is as much as 100 times larger than the core zone. In situ stress is only applied at the boundaries of the extension zone, so it is naturally handled as a true far-field stress. The mild stress and deformation gradients in the extension zone allow progressively coarser mesh to be adopted from the core zone to the extension zone boundary, thereby reducing computation cost. The sensitivity analysis approach suggested by the reviewer has been pursued and we found that our handling of the boundary conditions is appropriate, although we did not include the details of such analysis in publications or peer review materials owing to the limited space available.

Reviewer 23532

Score: 3.0
Comment: The project is well thought out and appears to be meeting its goals. The PI could have provided more information concerning the additional LLNL codes such as NUFT that this project will interface with. The ability to model flow in stochastically generated fracture systems coupled with rock properties and stress field will enable interesting stimulation scenarios to be modeled generating insight into the effect of stimulations in various geologic settings. It is not apparent whether or not the model considers variable fracture apertures in the pre-existing fracture system. This is important when modeling the potential for short circuiting.

PI Response:

We understand the reviewer's perspective and wish we could have given more information about the suite of codes used in the computational test bed. Unfortunately, we are limited by time and the number of view graphs that can be shown. As a result, we tend to focus the presentation on the code developed under this project rather than codes that were previously developed. Sorry. The fracture apertures vary in both space and time and we agree that it is important to include this characteristic in our modeling effort.

Reviewer 23628

Score: 4.0

Comment: The scientific approach provides a unique capability to numerical simulation and the research team is continuing to improve on its original algorithms by exploring new approaches (i.e., simplified method for estimating stress intensity factors). The researchers are required to convert the developed fracture network into permeability distribution to compute the resulting impacts on the geothermal system production. It would be interesting to more tightly couple the discrete fracture capabilities with the more conventional (THC) continuum simulation capabilities at least in a sequence fashion, between time steps. This could provide the team with a very unique (THMC) capability.

PI Response:

Interesting comment suggesting a strongly coupled M and THC approach that could best be achieved by integrating the mechanical and THC codes into one. Such a capability would definitely make THMC simulations much easier to do and should be seriously considered.

Reviewer 23641

Score: 4.0

Comment: Scientific/technical approach is sound. Level of sophistication of the modeling approach is high.

PI Response:

This is our goal at least. Thanks.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23526

Score: 3.0

Comment: The project appears to be progressing well and delivering results.

PI Response:

We agree with the reviewer's comment.

Reviewer 23397

Score: 3.0

Comment: This project has made significant progress toward the goals and objectives stated. The project has completed the development of the fracture propagation model and integration of the geomechanics model with a thermal model. The model incorporates both hydroshearing and hydrofracturing modes of stimulation and they have performed some simulations of stimulation response. Additional simulations are necessary in the future phases of the project that include a study of the thermal breakthrough and lifetime of an EGS system under different simulation scenarios as well as the reservoir pressure drop (which results in parasitic pumping losses).

PI Response:

We agree with the reviewer's comment.

Reviewer 23532

Score: 3.0

Comment: The project team has made at least seven presentations and has prepared three papers. This is significant. However, the project summary and presentation cite several papers scheduled for presentation in 2011. Were they made? This suggests a bit of carelessness in the preparation for the peer review. The presentations and papers appear to be closely related to the project objectives; at least a far as can be determined by the titles.

PI Response:

This effort has produced a number of presentations, conference papers and papers for peer-reviewed journals. When conference papers/presentations are listed, then they were indeed made. Our proof reading at the time missed what the reviewer did catch. Sorry for the error.

Reviewer 23628

Score: 4.0

Comment: The research team has applied its numerical simulation capabilities to a hypothetical fracture geothermal system, and has been very active in publishing its applications and algorithmic developments. The team has completed a

benchmark against a laboratory system, but is in need of field data to complete a reservoir-scale demonstration. It appears that the timing of the new 3D fracture propagation simulator will be appropriate for its testing against field data.

PI Response:

Thanks for the comment and we are working with data from a field-scale system as mentioned above.

Reviewer 23641

Score: 4.0

Comment: Compelling results from innovative fully-coupled modeling code. Numerical models have been tested against lab experimentation. Interesting path of research underway to compare EGS vs. un-enhanced conductivity and thermal performance.

PI Response:

We agree with the reviewer's summary. Thanks.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23526

Score: 4.0

Comment: Particularly well done here. The PI is not only integrated with industry, but also has engaged an academic advisor for what would seem to be a periodic reality check on the project.
PI Response:

Thanks

Reviewer 23397

Score: 3.0

Comment: From a budget standpoint, it is not clear how this project is progressing. Slide 14 states that this is a 4-year project while Slide 2 indicates it is a 3-year project to be completed in October, 2012. The budget slide overall is confusing as it indicates that the FY12 budget (current) is $0, while it also indicates that the overall budget is only 85% spent. It seems as if the project is progressing on time; however, there was no information provided to the reviewers to accurately assess this. We do not have the task plan nor a detailed indication of tasks completed versus tasks remaining. Slide 2 indicates that the project is 86% complete, with the remaining 14% to be completed. This is a reasonable amount of work to be completed and they are on budget. I would encourage the PIs to explore other industrial connections to obtain relevant field data for validation.

PI Response:

The budget and timing part of the project can indeed be confusing.The project as presented at the peer review meeting is a two-year project to which was added a cost-free extension of a third year. Therefore, most if not all milestones presented

in the summary and presentation assume a three-year timeline. Recently, an additional year of support was kindly provided by the Geothermal Technologies Office to allow us to pursue a test bed development plan that required three full years of support. We agree that industrial connections should be pursued where possible in addition to the ones that we have already made.

Reviewer 23532

Score: 4.0

Comment: The project management as presented appears to be outstanding as substantiated by the number of papers and talks and the progress stated in the peer review presentation. The PI seems to be thoroughly familiar with the work and results of the others on the project team.

PI Response:

Thanks for the supportive comment.

Reviewer 23628

Score: 4.0

Comment: The project team has managed its fund resources to achieve nearly linear progress and spending during the first three years of the project. The project was awarded a fourth year of funding, which this reviewer feels is appropriate. The outcomes of this planned fourth-year work (i.e., a publishable collection of industry-relevant cases addressing generation of fracture permeability enhancement & the creation of computational test bed) is anticipated to be beneficial to the program and the modeling working groups also.

PI Response:

We appreciate the reviewer's clear statement as well as his support of GTO's decision to award three full years for this project.

Reviewer 23641

Score: 4.0

Comment: Results and presentations indicate effective project management and coordination.

PI Response:

No response entered.

STRENGTHS

Reviewer 23526

Comment: Ability to leverage historic LLNL HPC resources, and bring them to bear on the problem of EGS.

PI Response:

No response entered.

Reviewer 23397

Comment: The strengths of this project include the technical approach and the progress made thus far. The project has completed the development of the fracture propagation model and integration of the geomechanics model with a thermal model. The model incorporates both hydroshearing and hydrofracturing modes of stimulation and they have performed some simulations of stimulation response. The use of a probabilistic approach as opposed to deterministic is commendable and the results and approach should be given more emphasis. Additionally, the adaptive remeshing module is a good approach to this problem.

PI Response:

We agree with the comment.

Reviewer 23532

Comment: This project may be limited by its apparent requirement for stochastically generated fracture domains but the code may provide a very useful tool for parametrically studying the affect of injection relative to well placement, fracture patterns, rock properties and stress field. Unless the code will have the ability to operate with known fracture data or a combination of actual and stochastic fractures the code may not be useful for simulating actual EGS operations.

PI Response:

The program allows mapping known fracture data into a computational domain.

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23641

Comment: Robust modeling code based on rigorous approach.

PI Response:

We agree with this view.

WEAKNESSES

Reviewer 23526

Comment: The lack of 3-dimensional simulation capabilities, and also potentially the inability to export the software outside the DOE system.

PI Response:

We hope to soon have access to a 3-D capability through the LLNL Strategic Initiative. Codes such as NUFT and TOUGH have managed to be exported outside of DoE. We trust that a similar fate will apply to the computational test bed.

Reviewer 23397

Comment: The weaknesses of this project mainly deal with the lack of real-world data to validate the model. The PIs need to take a more active approach to obtaining these data; otherwise it will be unclear if the project is a success. These types of predictive models cannot prove their capabilities unless they are shown to compare favorably with real data. The review presentation showed that the model was compared against laboratory results and closed-form solutions, but these are only for the small scale and not the reservoir scale.

PI Response:

We agree with the reviewer's point about the need to relate our test bed simulations to real-world data to validate our models. It is also true that the development and satisfactory testing of a simulation capability must take place before that capability can be applied to real world problems. According to schedule, we have only recently gotten to the place where we can do the type of comparison that the reviewer is requesting. Hopefully, we will have more to show in this regard at the next peer review.

Reviewer 23532

Comment: See strengths.

PI Response:

No response entered.

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23641

Comment: Not really a weakness, but the PI was of the opinion that his modest estimate of conductivity improvement through stimulation was optimistic, when in reality economic EGS typically will require an order of magnitude or greater

improvement. On one hand I would have expected the PI to be more aware of the EGS conductivity challenge; on the other hand, at least it confirmed that the results are being derived independently without regard others' expectations!

PI Response:

We just presented the result we obtained after hydroshearing a pre-existing distribution of fractures near the extraction well. We used the model to show how the computational test bed can be used and did not select any special initial fracture distribution or hydroshear scheme designed to produce a compelling result for EGS. The reviewer is most certainly correct in expressing that we have not intentionally tried to meet others' expectations. At this stage we are most interested in getting the fracture-fracture interactions right and then accurately translating the new fracture regime into the THC modeling capability. Once we have completed this, we can start looking more closely at the best ways to optimize an existing fracture regime to achieve the thermal efficiencies required.

IMPROVEMENTS

Reviewer 23526

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23397

Comment: As mentioned previously, the PIs need to take a more active approach in providing their model with realistic inputs from known geological settings. As a reviewer, I would expect to see some basic comparison of the model's predictive results with the results from a field-scale project such as Soultz or Cooper Basin. A sensitivity analysis should be performed to ensure that the compressive shadow zone is not a result of the system size and to determine the critical parameters that contribute to this shadow zone. This particular result is of greatest concern and interest as it could be a potential show-stopper for the stimulation of EGS systems and thus detailed study of this phenomenon is warranted.

PI Response:

We appreciate the reviewer's comment regarding the need to compare results from the test bed with real field-scale results. Indeed, we have been working with industry to provide the realistic inputs that the reviewer refers to. This is an activity that we have only started this year which is according to schedule. We agree with the reviewer that the general applicability of the shadow zone concept merits further consideration and additional study is needed.

Reviewer 23532

Comment: It is important to include variable fracture aperture in the initial stochastic model -- if it isn't already in the model.

PI Response:

We agree. It is already included as mentioned above.

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

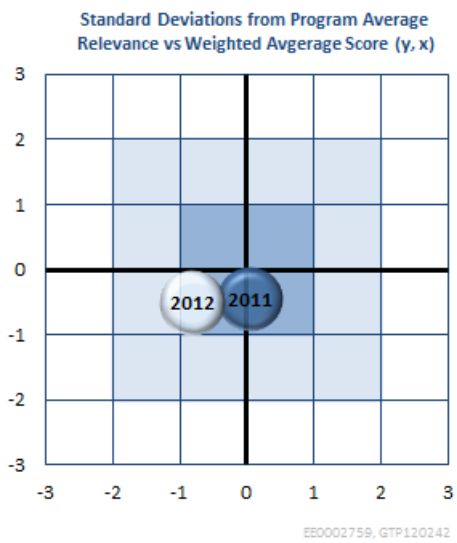
No response entered.

Reviewer 23641

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002759
Project: A new analytic-adaptive model for EGS assessment, development and management support
Principal Investigator: Danko, George
Organization: University of Nevada, Reno
Panel: Modeling

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23526

Score: 3.0

Comment: This is a modeling project--in the realm of stimulation/EGS prediction and performance, and as such, any results have the potential to quantify EGS recoverable resource base.

PI Response:

Agree, thank you.

Reviewer 23425

Score: 2.5

Comment: The main objective of this effort is to develop an in depth numerical, T-H-M-C model of EGS systems that will allow industry and researchers to more accurately predict how new fluid technologies would work in a reservoir. To achieve this, the project will test and apply the new model to cases with known solutions for benchmarking and comparison. Evidently, a secondary objective is to study new fluid flow applications and cooling technologies to improve geothermal power extraction from an EGS. This project could potentially have good impact in addressing the needs of industry to the extent that it can benefit from conventional but detailed thermo-hydrologic simulations.

PI Response:

Agree, thank you.

Reviewer 23583

Score: 3.0

Comment: The goal of this project is to develop a new 3D, THMC, numerical model of EGS systems, verify against known solutions and validate with known EGS sites, and finally, to study new fluid flow applications and cooling technologies to improve geothermal power extraction from potential EGS designs. If the project's goals are realized, notable progress and impact toward accomplishing GTO's EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment…" will be advanced. A verified, validated 3D THMC numerical model will notably reduce EGS hydraulic fracturing knowledge gaps and further the deployment of permeability-enhancement technologies.

As stated, this project will definitely improve understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing modeling tools to accelerate EGS implementation.

PI Response:

The reviewer is correct in stating that "If the project's goals are realized, notable progress and impact toward accomplishing GTO's EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment… will be advanced." The reviewer however, misreads the project objectives. He looks for a THMC numerical model to "notably reduce EGS hydraulic fracturing knowledge gaps and further the deployment of permeability-enhancement technologies". This is not what we are funded for by DOE.
Our model is to create a THMC model for an as-created EGS reservoir which already has one or multiple fractures, albeit unknown with extension(s) and aperture(s). Our THMC model helps in (1) finding about the reservoir's THM characteristics from measured injection test responses including its geometry dimensions, heat surface area and the like; and (2) predicting its long term behavior and thermal capacity, thermal drawdown and life-cycle expectancy.
Again, our model does not aim at "how to lower current EGS reservoir creation technology barriers". That would be a "hydrofrac" model. To be clear, a hydrofrac model does not have to be THMC, an HM model would be sufficient.

Reviewer 23532

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23628

Score: 2.0

Comment: This project has developed a modeling tool that allows the user to reproduce observed geothermal system responses once the observations have been either produced numerically using a separate numerical simulator or from field data. This reviewer did not have the impression that the developed modeling tool could be used in a predictive sense for new systems. The work does not appear to be addressing technical knowledge gaps, if it's truly only able to reproduce observed responses.

PI Response:

A new EGS fracture can be created in the field by "fracking" but we do not model this part. Our project is funded by DOE to model what happens next, after the fracture or fracture system is created. The reservoir needs to be characterized regarding (1) the size of the fracture; (2) the heat exchange surface; (3) fluid flow and distrbution; (4) the pumping energy cost; (5) the future behaviour of thermal drawdown; and (6) the life cycle expectancy. We do all (1) through (6) with the new T-H-M-C model.

We can characterize the as-created fracture from the injection data. MULTIFLUX then can be used to predict the performance of the modeled reservoir under different operating conditions and to optimize its performance and life expectancy.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23526

Score: 2.0

Comment: The approach taken by the team centers around linking mostly existing software packages together with a complex logic system. I was not convinced that the team is actually capturing the true physics of the problem, the calibration of the solution appears to be circular---which is great for matching existing discrete data in a simplistic system, but would likely offer little forward prediction capability.

PI Response:

There are new and unique model-elements (Notabley the mechanical and the chemical sub-models) that we had to add to the existing software package of MULTIFLUX for a complete, coupled T-H-M-C model. These alltogether capture the true physics of the problem and no component has been left out. More detail can be seen in our previous reports (we have submitted 9 quarterly and two annual reports on this project to DOE so far) and our upcoming 2012 GRC conference paper.

The model calibration of the field data from the injection tests is indeed an iterative, trial-and-error procedure, circular-yes, but un-ambigous as shown by the converged results.

After the model is used to match field data by calibration, it then forward-predicts the following items:

(1) The size of the opening for a given pumping rate.

(2) The size of the heat exchanger surface.

(3) The energy capacity of the planar fracture.

(4) Thermal drawdown of the reservoir.

(5) The life cycle expectancy.

(6) The best way to extract energy from the as-created EGS fracture.

Reviewer 23425

Score: 2.5

Comment: The approach is expressed as having Thermal-Hydrologic-Mechanical and Chemical capabilities in simulating stimulation processes in engineered geothermal systems. All these qualifications are true to some degree but this degree varies from code to code. It is likely that in this formulation the thermal and hydrologic capabilities are strongest and the mechanical and chemical or reactive transport capabilities are weakest. This is not a criticism but is just a statement of the reality that all complex codes are not equally developed in all possible areas of consideration. In many respects it seems that a conventional poroelastic approach has been taken in coupling thermal, fluid injection and mechanical effects. Fundamental fracture-fracture interactions are difficult to deal with in this type of modeling formulation. The formulation

appears to assume the existence of a fracture or set of fractures for thermo-hydrologic modeling purposes rather than simulating how fracture systems evolve during the injection process. It appears that the fracture aperture is capable of being adjusted by changes in fluid pressure. However, the assumptions on the fracturing side seem to represent a drawback to this approach.

PI Response:

Our model deals with the evolution (opening) of the fracture aperture during the injection process and also during energy extraction. Yes, the fracture aperture is being modeled as a variable of pressure and temperature, and therefore, the entire T-H-M-C processes is being modeled for the fracture during any simulated energy extraction scenario (the life-cycle model). Correct, we do not model the fracturing itself and never proposed to do it.

However, a fracture as created, is an almost closed crack in the ground without the injection flow and pressure applied and nobody can tell the fracture size and aperture that would evolve under flow and pressure conditions (and this depends on time and cooling as well !) without a model. Once the hydrofrac process is completed, the fracture (or fracture system) closes back and it has to be re-opened by pumping through it unless proppants are used (which were not in any of our application examples). Our model is the first in the world to do model a self-propped, self-opening fracture under injection flow. The model works very nicely and produces converged results and we have shown.

Reviewer 23583

Score: 2.0

Comment: The scientific/technical approach desires to model natural fracture complexity with a simple, single, planar (penny-shaped or lens-shaped) fracture (it is claimed that multiples are possible). Fluid flows towards the production well or into other pre-existing fractures or faults and THM processes drive faults and changes in the fracture aperture. The rock mass around the fracture is assumed to be impermeable (this assumption is changed later in the presentation). The model (MULTIFLUX) includes physical processes such as: storativity of the rock mass, changes in fracture aperture, permeability, and void volume, fluid compressibility in the fracture, fracture extension (radius) and surface area due to changes in dynamic flow rate and pressure. It is claimed that the coupling of the discrete fracture to the rock mass, will use a patented Numerical Transport Code Functionalization methodology (not explained) as well as the TOUGH2 model. A logical procedure was developed for comparison between the model and another code called 3DEC, but comparison results were not shown. Finally, it is claimed that the goal for year two is to develop a dynamic response functions to adapt model elements in the Geologic Heat Exchanger (GHE) that will produce a life-cycle model of an EGS. The relationship between MULTIFLUX, TOUGH2, TOUGHREACT in the context of GHE was not discussed.

This scientific/technical approach is neither clear nor understandable. Claims made about its capabilities are confusingly presented and inconsistent from slide to slide. The advantages of using a single fracture versus other approaches are not stated nor defended. The presentation is not focused and the design elements are not described in any clarity. Key technical barriers to achieving the project's objectives such as rock damage and stress dependent permeability are not presented in any detail necessary for evaluation. There are significant weaknesses and noteworthy areas for improvement in the design of the approach as presented. A clear, concise diagram of all the physics processes included as well as all the assumptions would be beneficial to any reviewer.

It is hard to judge the scientific rigor employed in the development of this model and verification results do not instill a feeling of confidence in the model's capabilities. The focus of the project is aimed at solving one of the major scientific barriers in EGS deployment, namely, "Can we correctly stimulate all the important EGS processes?" However, the execution of the approach to answering this question and the results have been marginal in relation to the resources expended and progress towards objectives and significant improvement is needed. The R&D research plan is not well

thought out as presented, the description of and logical connections between model components is incoherently presented. The project will marginally contribute to progress in overcoming stimulation barriers/knowledge gaps as presented.

PI Response:

We realize that it was difficult to understand the project from the presentation material with only 8 technical slides (slides 6-9 and 12-15). We assumed that access was provided to our technical progress and annual reports. We have submitted 9 Quarterly Reports and two Annual Reports from the start of the project until the time of this review meeting. Sorry for the difficulty if no access to these reports was provided, as implied from the review comments. The best way would be to request them from DOE or wait until the 2012 GRC meeting where we will have a paper which clarifies most of the technical concerns expressed in the review.

Reviewer 23532

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23628

Score: 2.0

Comment: The developed model appears to be one that requires 6 coefficients (i.e., 3 pressure related and 3 temperature related), which are determined from observed pressure response data. Given these coefficients the model is able to reproduce the observed behavior of the geothermal system, but would not be able to be used as a predictive tool for a new geothermal site. Without a theoretical understanding of the meaning of the 6 coefficients, there is little scientific knowledge gained the model. The researchers claim that the model can predict fracture geometries is dependent on a predefined fracture structure and shape.

PI Response:

The number of model input parameters for the complete T-H-M-C model has many more than 6 coefficients. The model parameters that can be calibrated against measured injection data are only used to characterize the fracture's T-H-M behaviour. After this calibration, the model forward-predicts the following items:

(1) The size of the opening for a given pumping rate.

(2) The size of the heat exchanger surface.

(3) The energy capacity of the planar fracture.

(4) Tthermal drawdown of the reservoir.

(5) The life cycle expectancy.

(6) The best way to extract energy from the as-created EGS fracture.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23526

Score: 2.0

Comment: The presenter stated that they heave completed their milestones regarding predicting predicting coupled THMC problems, and that they can simulate complex fracture-fracture and fracture-matrix interactions. I am not convinced that this is complete. Perhaps they have accomplished learning how to link some varying numerical codes together, but I don't see how all the physics are linked, and how the growth of complex fractures can be simulated or if/how detailed chemical evolution is captured.

PI Response:

All the model elements for each physical process are coupled and solved iteratively in MULTIFLUX, we have shown a few of the results. The slides showed results with coupled, converged solution. The reviewer is kindly asked for checking our reports submitted to DOE and following our publications, the next at the upcoming 2012 GRC meeting.

Reviewer 23425

Score: 2.8

Comment: It is difficult to fully assess the progress made with this project. The temperature and pressure response of fracture aperture is developed as well as the self-propping behavior of a fracture. The self propping response is compared with Fenton Hill results. Calibration work is done involving a THM model.

PI Response:

Correct, thank you.

Reviewer 23583

Score: 2.0

Comment: As stated in the presentation and summary, the project accomplishments include: MULTIFLUX can solve coupled THMC problems (though no evidence was offered to back this claim), chemical reactions will be calculated by TOUGHREACT and imported, HM model-elements were expanded to handle slow and rapid injection transients, a time-dependent tracer concentration capability was added, and finally, “surrogate THMC model-elements” (?) within MULTIFLUX can now can be calibrated against other codes such as TOUGH2, TOUGHREACT and 3DEC. The PI claims they are ready to go to Phase II which is “Develop the dynamic response functions to adapt and tune the model-elements in the Geologic Heat Exchanger (GHE) model for short- and long-term THMC fracture behavior, morphology change or degradation, and to produce a life-cycle model of the EGS.”

The accomplishments as presented are confusing and sometimes conflicting and, in summary, do not justify the claims made concerning progress. For example, verification results were not adequately presented and comparisons with other verified codes have not been done. Furthermore, the quality and significance of the technical accomplishments and results

are merely adequate in relation to the resources expended and technical progress towards project objectives; there is significant room for improvement. In addition, the productivity in work underway and future work and the value of the accomplishments compared to the schedule and costs reveals that marginal progress has been made.

PI Response:

The evidence of the solution of the coupled T-H-M-C problem is in the convergence of the results, and in the match between converged model predictions and measurement results. We have shown converged results for the model applications for Fenton Hill Phase I and another application for a Desert Peak EGS well.
The MULTIFLUX includes all T-H-M-C process model elements and all requires TOUGH2, TOUGHREACT or 3DEC, and for "tuning" the surrogate model-elements. The reviewer is kindly asked to request our nine Quarterly Reports and two Annual Reports from DOE. These provide much more details beyond the few technical slides that were allowed at the review meeting.

Reviewer 23532

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23628

Score: 3.0

Comment: This project was tasked with creating a geothermal system model with coupled capabilities for thermal, hydrological, geomechanical and geochemical effects. The researchers demonstrated the model for all but the geochemical effects. The researchers did use TOUGH-REACT to develop changes in fracture properties (i.e., permeability and porosity) with mineral dissolution/precipitation, but it was not obvious how these simulations had be incorporated into the developed model.

PI Response:

The geochemical process model element has been prepared for use in the coupled T-H-M-C model, and numerical examples were given in our Quarterly Reports to DOE. The reviewer is kindly asked to request our nine Quarterly Reports and two Annual Reports from DOE. These provide much more details beyond the few technical slides that were allowed at the review meeting.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23526

Score: 1.5

Comment: The project seems to be very heavily funded considering the scope and amount of university participation. In comparison with the other modeling projects that presented at the peer review, for the money this one seems to be delivering the least. The presenter mentioned LBNL participation, but I didn't see how this was integrated and funded, what exactly is LBNL providing, and for that matter, is ORMAT providing technical input or just access to data?

PI Response:

LBNL is a subcontractor of this project with two investigators helping with the TOUGH2 and TOUGHREACT modelling components of the project. ORMAT is our industrial partner providing technical input for the EGS sites being studied, such as Desert Peak site.

Reviewer 23425

Score: 3.0

Comment: Overall, the project management seems good with tasks met apparently in timely fashion. No remarkable management issues were reported.

PI Response:

Thank you.

Reviewer 23583

Score: 2.0

Comment: As mentioned above, the technical R&D plan is lacking clarity and focus; however, the PI claims the project is on budget, scope and schedule and no business or staffing plan problems were reported (estimates of work accomplished from the results presented speak otherwise). Spending is on track with scope and schedule, but prospective future plans are of adequate quality and might be effective in meeting the project's goals. The inclusion of appropriate and logically placed decision points that effect the future direction of the work were discussed briefly by the PI but conflicting information was presented regarding meeting Phase I goals (e.g., slide 16, first bullet says, "All tasks have been worked on…" which is not equivalent to "completed" as is suggested by the table). PI claims coordination of activities with collaborators and stakeholders is very effective. Better management practices are desirable in reporting accomplishments and results accurately.

PI Response:

We should have said completed or worked on the tasks according to the schedule.

Reviewer 23532

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23628

Score: 3.0

Comment: The project appears to be on schedule with respect to the proposed work and the proposed spend plan. The researchers have been collaborating both with their industrial clients and with their sub-contractors at a national laboratory.

PI Response:

Thank you.

STRENGTHS

Reviewer 23526

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23425

Comment: The PI is a well-respected and creative researcher in thermo-hydrologic studies. The THMC capability he is developing has many features some of which might be useful to industry. To his credit he is taking care to test and calibrate his simulation capability against other codes. The hydroshearing mechanical regime may be most accessible to this modeling approach.

PI Response:

Thank you.

Reviewer 23583

Comment: As envisioned, this project will definitely improve understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing modeling tools to accelerate EGS implementation. As stated in the presentation and summary, the project accomplishments MULTIFLUX can solve coupled THMC problems.

PI Response:

Thank you.

Reviewer 23532

Comment: I DO NOT HAVE SUFFICIENT UNDERSTANDING OF WHAT THIS PI IS DOING TO EVALUATE THE PROJECT.

PI Response:

We kindly ask the reviewer to request our nine Quarterly Reports and two Annual Reports from DOE. These provide much more details beyond the few technical slides that were allowed to use and present at the review meeting.

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23526

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23425

Comment: Of concern is the sense that conventional models of thermal and hydromechanical response may be inadequate to model the development of a fracture network by fracture-fracture interactions. It was difficult to determine the exact nature of the type of model that is being developed. At least one reviewer believes that only one planar fracture is being modeled and that fracturing is treated in some lumped sense. I hope that is not the case.

PI Response:

Certainly that is not the case and MULTIFLUX can handle multiple fractures of any shape and geometry. In Fenton Hill II, 3D, multiple, eliptical fractures have been modeled.

Reviewer 23583

Comment: This scientific/technical approach is neither clear nor understandable. Claims made about its capabilities are confusingly presented and inconsistent from slide to slide. The advantages of using a single fracture versus other

approaches are not stated nor defended. The presentation is not focused and the design elements are not described in any clarity. It is hard to judge the scientific rigor employed in the development of this model and verification results do not instill a feeling of confidence in the model's capabilities. The execution of the approach to addressing EGS knowledge gaps and the presented results have been marginal in relation to the resources expended and progress towards objectives and significant improvement is needed. The R&D research plan is not well thought out as presented, the description of and logical connections between model components is incoherently presented. As implemented, this project has not achieved significant progress and impact towards advancing GTO's EGS mission of significantly reducing EGS hydraulic fracturing knowledge gaps, and improving the program's understanding of how to lower current EGS reservoir creation technology barriers. The current scientific/technical approach, as presented, is neither clear nor understandable—not well thought out, piecemeal, and not likely to succeed at reaching project goals and objectives.

PI Response:

We beg to differ in many fronts, please see our previous responses. We firmly believe that we have developed a unique, first-of-a-kind EGS fracture model with two major features (1) the model can be calibrated from a few injection test results for an as created fracture (which has zero extension and aperture without injection). (2) the model can then be used to answer several questions (see before), pertinent to energy extraction capacity and life cycle expectancy. This is what we have done so far in two years, and we must have missed if anybody ever published similar results. Our model was demonstrated with two examples at the meeting, evidence for achieving converged solutions. The rest of our project tasks are on track to complete during the current, third year. Please keep up your interest and see us at the 2012 GRC meeting!

Reviewer 23532

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23526

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23425

Comment: The PI should consider writing up reports on the development of his capability that the reviewers can have access to as supplementary information. He might also want to evaluate the mechanical response of his model against a discrete fracture model to better determine its possible limitations. Also, he might consider a less deterministic and more stochastic approach given the uncertainty that is inherent to such complex models.

PI Response:

We thought the reviewers had access to all our nine Quarterly Progress Reports and two Annual Reports, submitted to DOE. Sorry to hear that this is not the case.

Reviewer 23583

Comment: A clear, concise diagram of all the physics processes included as well as all the assumptions would be beneficial to any reviewer. As well as clear identification of what each of the components of this code do what. A diagram showing the interrelationships between significant elements of the code would be beneficial. Finally, a clear and accurate description of what was done and what remains to be accomplished would be helpful. It is suggested that this project be put on hold until these issues can be mitigated. In addition, it might be useful in the future to put in control points to allow careful review of project results compared to goals and objectives before funds are released.

PI Response:

We thought the reviewers had access to all our nine Quarterly Progress Reports and two Annual Reports, submitted to DOE. Sorry to hear that this is not the case.

Reviewer 23532

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

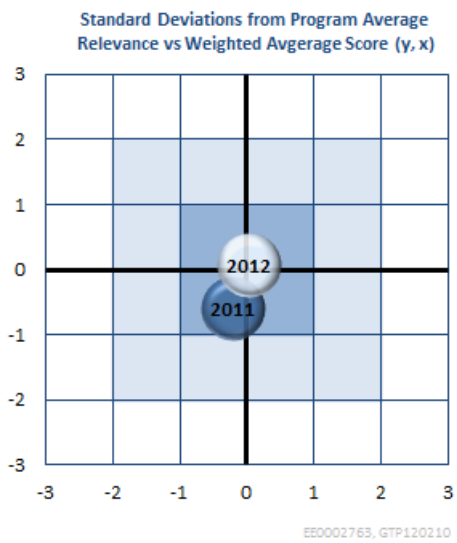
Reviewer 23628

Comment: This reviewer is very much in favor of the development of analytical models for understanding complex systems. The benefit of analytical models is there computational efficient. The most beneficial analytical models are ones that have parameters that can be quantified independently and have a theoretical basis. This project could be improved by developing either alternate techniques to quantify the 6 coefficients required for the model, or to theoretically define the meaning of the coefficients.

PI Response:

There is only one conceptual, analytical, self-propped T-H-M model-element capturing the elastic deformation of the self-propped fracture area. From that on, all model-elements are numerical. The analytically-based self-propped T-H-M model component, likewise, is used in the numerical model for each pixel of the discretized planar fracture domain, several thousand times for one EGS fracture. The self-similarity concept is used, namely, that the rock is homogeneous over the

entire fracture extension. The coefficients in the T-H-M model can be evaluated from 3DEC, but it will always have to be calibrated against injection test measurement results.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002763
Project: Development of an Advanced Stimulation/Production Predictive Simulator for Enhanced Geothermal Systems
Principal Investigator: Pritchett, John
Organization: Science Applications International Corporation
Panel: Modeling

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23526

Score: 3.0

Comment: As this project supports development and prediction of EGS reservoirs, it is relevant to the program. The impact can potentially be significant as well, but must be considered in relation to other modeling projects applying a similar approach--that is--linking separate simulators in order to do coupled modeling.

PI Response:

No response entered.

Reviewer 23583

Score: 3.0

Comment: The objective of this project is to develop a 3-D, THME ("E" for electrokinetics module) numerical reservoir simulator for EGS reservoir stimulation and long-term operation. Project's purpose is to reduce development costs and uncertainties for EGS by providing a predictive capability for the long-term performance of the underground "heat exchanger." If the project's objectives are realized, notable progress and impact toward accomplishing GTO's EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment…" will be advanced. A verified, validated 3D THME numerical model will notably reduce EGS hydraulic fracturing knowledge gaps and further the deployment of permeability-enhancement technologies. This project's objectives will definitely improve understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing modeling tools to accelerate EGS implementation.

PI Response:

No response entered.

Reviewer 23425

Score: 2.5

Comment: The stated objective is to develop a 3-D numerical EGS reservoir simulator to model the following aspects of reservoir stimulation and long term operation. The simulator is intended to take into account the effects of stress and temperature changes due to stimulation on the permeability field. In addition, it is supposed to include shear slippage

effects that might be the same as hydro shearing. It has separate modules for its approach to treating fracturing, flow and heat transfer, and electrokinetic effects such as streaming potential. The method seems largely conventional in its approach to dealing with modifying existing fracture networks and is subject to the limitations of such approaches. I would expect the impact to be average at best.

PI Response:

It is unlikely that any particular mathematical representation will prove optimal for each and every EGS application, but it should be pointed out that (1) the European Soultz EGS project is the only such project that has so far actually generated any electricity, and that (2) the 2005 Geowatt HEX-S simulation study of the dynamics of the Soultz fracture network is to date the only such model that has been shown to have predictive value. The approach to fracture network forecasting adopted for the present project is a substantial extension and elaboration of the original Geowatt HEX-S, and Geowatt is the principal subcontractor on the project.

Reviewer 23532

Score: 4.0

Comment: The project has made substantial progress and the only delay is caused by the lack of field data to validate the model. Hopefully data will soon be available from DOE supported field demonstrations. The code will be readily available to the public and should be usable. However, little data is available concerning the fracture capabilities of the code.

PI Response:

No response entered.

Reviewer 23628

Score: 3.0

Comment: The principal objective of this project is the development of a new numerical simulator for modeling geothermal systems. The emphasis with this new simulator will be in the coupling of thermal, hydrological, and geomechanical (THM) capabilities, with the geochemical capabilities being delayed. This simulator has four unique features: 1) nonequilibrium heat transport between the working fluid and host rock, 2) the use of permeability patches, 3) the ability to compute distribution of electrokinetic self-potential, 4) three unique grid structures between the different modules. The unique features of the simulator make it relevant the modeling goals of the Geothermal Technologies Office. As yet the coupled software development is not complete, although several self-standing modules have been completed and verified.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23526

Score: 3.5

Comment: The approach being taken is reasonable, sound, and well thought out. The PI has established expertise the area of reservoir modeling and is using largely well developed and well documented codes. The stand-alone nature of the individual programs being linked is a plus, as individual components can be examined in isolation to some degree.

PI Response:

No response entered.

Reviewer 23583

Score: 3.0

Comment: The scientific/technical approach is to "develop, test, validate, document and disseminate a new numerical simulator for use in EGS history matching and forecasting studies." The approach features an accelerated and efficient development schedule based on existing software and techniques that have already been developed by the project team, although software is being written from scratch using Fortran 90 for Linux. The code is divided into five modules that work together: thermohydraulic, constitutive, thermoelastic, electrokinetic and fracture. How the modules work together was not discussed, except that some of the modules use others output as their input and that some of the individual module computational grids are larger than others. A process flow diagram would be helpful.

The quality of the scientific/technical design is logical, thoughtful and effective in achieving the project's objectives. The approach is focused, succinct, and clearly presented—reasonable and defendable. The scientific approach to solving key technical barriers to achieving the project's objectives such as realistically modeling pressure/stress/temperature changes on the underground permeability are addressed reasonably well. The scientific rigor employed in the development of this model depends on how rigorous the original algorithms and techniques were; this information was not available. Most likely, these techniques and algorithms have had sufficient review and scrutiny to pass technical review, however, what was presented did not instill a feeling of confidence in the model's capabilities. The execution of the approach so far looks good as presented though more technical details, e.g., a diagram showing the interrelationship between modules, would have helped.

PI Response:

Here and subsequently, this reviewer expresses dissatisfaction because insufficient technical detail was provided to form the basis for a proper technical evaluation of this project. The PI agrees and recognizes the difficulty, but had little choice given the constraints of the Peer Review format. We were restricted to maxima of four pages of written summary material, fifteen (legible) PowerPoint slides, and a twenty-minute oral presentation - with at least half of the content of all three mandated to be non-technical. Given the multifaceted character and complexity of this project, a high-altitude technical overview was about all that was feasible under these circumstances.

Reviewer 23425

Score: 2.5

Comment: The approach involves developing, testing, validating, documenting and dissemination of a this new numerical simulator for use in EGS history matching and forecasting efforts. Much of the simulator will be based upon existing SAIC software. The simulator will consist of 5 modules representing different effects pertinent to history matching and forecasting. The most novel module is one involving electrokinetics which may be relevant to electromagnetic exploration methods.

PI Response:

Actually, the purpose of the electrokinetic (or "SP"; self-potential) module is to provide a history-matching capability for the deep SP transients that will occur during and after the early reservoir-stimulation phase - not exploration. See response to comments by Reviewer 23532, below.

Reviewer 23532

Score: 3.0

Comment: The approach of the project appears to be well thought out and effective in reaching the project goals. Inclusion of self-potential models is interesting and has been validated in early work of the PI. However, the usefulness of SP may be limited because of the relatively close coupling needed between the generated signal and the recording instrumentation. It should be noted that the PI did acknowledge this during his presentation.

PI Response:

This reviewer's comments about SP are quite correct. Previous studies have shown that hydraulic stimulation operations will cause SP transient signals to radiate outward from the fractured zone into the surrounding rock on time-scales of hours to months which, if recorded and properly analyzed, can provide useful information about the geometric and hydraulic properties of the stimulated region. But useful transient SP signals emanating from stimulation operations will only penetrate about one kilometer (or less) from the pressurized fractures. This means that downhole sensors in nearby shut-in observation wells will be required. The purpose of incorporating this capability in the new simulator is not primarily to support the single-well stimulation experiments presently being undertaken by DOE, but to consider larger-scale future "EGS power projects" involving numerous wells penetrating the reservoir. The inclusion of suitable observation wells in the drilling plan seems more probable when larger-scale projects are considered.

Reviewer 23628

Score: 3.0

Comment: The science being implemented in the new software is conventional, but the concept of using permeability patches for modeling a fracture system within a continuum numerical simulator is unique. The use of a parallel linear system solver was mentioned, but no details of the solver were provided. It's uncertain whether the code parallelization was limited to the solver, or if other components of the code would be implemented in scalable form. The research team is currently waiting for the availability of field data before continuing with the numerical simulator development.

PI Response:

The solver is called "PARDISO" and is a direct solver for large sparse linear systems of equations designed for multi-processor computer architectures. It is available in object-code form as part of the Intel Fortran library. Documentation is available on the Internet. One of the main reasons for the decision to develop the new software in Fortran 90 (instead of Fortran 77 as used in the earlier STAR, SPFRAC and HEX-S codes) was to take advantage of the built-in parallel matrix

operation capability of Fortran 90 and thereby to make optimal use of all of the processors available with the computing platform. Even low-end laptop PC's of recent manufacture will usually have at least two processors, and many PC's and Unix/Linux workstations have four, eight or more. Matrix operations are being used wherever feasible in the development of the Fortran 90 source code for the new simulator.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23526

Score: 3.0

Comment: The PI stated he is in a holding pattern while waiting for data from the EGS demonstrations. The progress to date is reasonable and on track.

PI Response:

No response entered.

Reviewer 23583

Score: 3.0

Comment: Project started late Jan 2010 and the scope is 60% done. Scheduled end date has been extended through Jan 2014, so the time used as of Apr 2012 is 60%. Sixty percent of the budget has been expended so the project is on schedule and cost. A six-month delay has been initiated due to a lack of field data for validation. Software development has made acceptable progress but scientific or verification results and outcomes were not presented—clearly progress towards the projects technical goals has been made but the scientific rigor and content cannot be evaluated. Nevertheless, the quality and the scientific reputation of the assembled technical team override this concern. The quality and significance of the technical accomplishments and results are very good compared to the costs expended to meet project objectives. In addition, the productivity in work underway and future work and the value of the accomplishments compared to the costs is good because most of the modules are completed awaiting testing.

PI Response:

No response entered.

Reviewer 23425

Score: 1.5

Comment: Development appears to have essentially stopped on this project based on the comments from the PI and information in the presentation. While no software development issues have been encountered, it seems that stoppage has occurred owing to the lack of suitable field efforts to test the code against. It looks like only work on the thermohydraulic module (1 of 5 modules) has been completed in the past year although the constitutive module is also evidently complete.

PI Response:

Yes, both the constitutive module and the "backbone" thermohydraulic module are complete. The other three sub-modules are in various stages of completion, as described in the presentation and in the written material that was submitted in advance. In all, it is estimated that the work is approximately 60% (not 20%) completed.

Reviewer 23532

Score: 4.0

Comment: Results and progress appear to be outstanding relative to the project resources and objectives. The model is essentially completed and will be finalized before data is available for validation of the code. No papers or presentations are available for this project but due to the relatively late start (mid 2011) that is probably to be expected.

PI Response:

No response entered.

Reviewer 23628

Score: 2.0

Comment: Accomplishments reported at the review were those as of October, 2011, as the simulator development team stopped work on the project. The geomechanical module of the simulator, however, appeared to be an active development effort, being conducted as a subcontract to an international agency. No progress was reported for this effort, but the research team did expect to receive working code soon.

PI Response:

Yes, the Geowatt effort continued in Switzerland at a fairly low level between October 2011 and March 2012 (when the materials for the Peer Review had to be submitted to DOE). Since March, work has started ramping up again slowly at SAIC as well, and we are now engaged in detailed discussions with Geowatt concerning integration of their latest fracture-dynamics software with the thermohydraulic model "backbone".

PROJECT MANAGEMENT/COORDINATION

Reviewer 23526

Score: 4.0

Comment: The PI is doing a great job managing the effort and coordinating among collaborators. He is also being very prudent is managing the project dollars, well done!

PI Response:

No response entered.

Reviewer 23583

Score: 3.0

Comment: As mentioned above, the technical plan for the R&D is good and the project is on schedule with no business or staffing plan problems at this time; except for the 6-month hiatus. The end date was moved forward to compensate. Spending plans are on track and future plans are of very high quality and will be effective in meeting the project's goals. The inclusion of appropriate and logically placed decision points that effect the future direction of the work were not discussed by the PI, but the PI did stop work until the validation data becomes available. Coordination activities with collaborators and stakeholders were not presented and could not be evaluated.

PI Response:

No response entered.

Reviewer 23425

Score: 1.5

Comment: Project is within budget and a one-year no-cost extension has been requested presumably to finish the effort owing to the lack of suitable field studies for testing the code. It seems problematic that the software development has not continued even taking into account the lack of suitable field studies. Given that more software needs to be developed to complete this project it is difficult for the reviewer to understand why the development tasks have not been continued.

PI Response:

See response to this reviewer's remarks under "Weaknesses" (below).

Reviewer 23532

Score: 4.0

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23628

Score: 3.0

Comment: This project has all of the required components in place for completing the development of a new numerical simulator, with its senior staff and recently hired junior code development staff. It's also using subcontractors to develop the geomechanical capabilities for the simulator. The principal investigator has considerable experience and expertise in developing and applying numerical simulation tools. It is anticipated that the team will be able to complete the proposed simulation code when the work resumes.

PI Response:

No response entered.

STRENGTHS

Reviewer 23526

Comment: Stand alone, modular approach. Including SP is very interesting and a good potential area for future monitoring of EGS.

PI Response:

No response entered.

Reviewer 23583

Comment: This successful project, as yet, not completed, has achieved notable progress and impact toward advancing GTO's EGS mission and significantly reducing EGS hydraulic fracturing knowledge gaps, and improving the program's understanding of how to lower current EGS reservoir creation technology barriers. The implemented scientific/technical approach is good—well thought out, reasonably likely to succeed and has been/should be effective in achieving the project's objectives. The quality and the scientific reputation of the assembled technical team is top notch. The project's accomplishments on the software development side of things has been adequate but verification results and validation results were not presented nor available, thus the quality and significance of the technical accomplishments and results cannot be evaluated. Project achievements suggest that project management has been effectual in getting the work done and plans to move forward are reasonable, logical, and likely to succeed.

PI Response:

No response entered.

Reviewer 23425

Comment: This will be a multi-capability, hybrid poro elastic code when completed using some software already developed and tested by SAIC. It has a unique electrokinetic module that may be helpful for modeling streaming potential effects pertinent to exploration.

PI Response:

Again, the electrokinetic module's purpose is history-matching and monitoring, not exploration. See response to this reviewer's comments under Question 2, "Scientific/Technical Approach", above.

Reviewer 23532

Comment: This is an interesting project which will provide a publically available code to simulate the simulation and production of an EGS. Based on other modeling projects of this PI the results should be easily useable by the industry and should be of great usefulness particularly since it will operate in the PC environment. Other more sophisticated codes may be developed later by other DOE funded projects. but there availability will be later.

PI Response:

No response entered.

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23526

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23583

Comment: The scientific rigor employed in the development of this model depends on how rigorous the original software techniques were, which was not available. In the future some discussion of the original algorithms is needed. Scientific and/or verification results and outcomes were not presented so the scientific rigor and content cannot be evaluated. The statement on slide 8 says, “Thermohydraulic module provides for conductive nonequilibrium local heat exchange between fluid and rock, using a MINC-like representation with one or more heterogeneously-distributed user-specified “fracture spacing” values” needs further elaboration. For example, “MINC-like” is not defined.

PI Response:

See response to this reviewer's comments under Question 2, "Scientific/Technical Approach" (above).

Reviewer 23425

Comment: The weakness largely seems to be in the project management component of this effort. There are software development tasks, data acquisition tasks and software testing tasks. It is unclear why software development stops because no data is available for evaluation. At the moment we have both an unfinished and untested product.

PI Response:

This assessment of our project management contrasts sharply with those provided by the other reviewers under Question 4, "Project Management / Coordination" (above). This reviewer, here and elsewhere, makes it abundantly clear that he disapproves of the PI's decision in October 2011 to put the project "on hold" pending clarification of the field data situation. The PI respectfully disagrees.

Reviewer 23532

Comment: This is more a statement of where we are in EGS rather than a critique of this project. However, validation of the code make take some time since development of a suitable data set may take some time. Perhaps the Soulltz data can be used even though this data provided the original model for the GeoWatt work.

PI Response:

Since the new simulator that we are developing amounts to a "superset" of Geowatt's HEX-S simulator, and since the original HEX-S has already successfully modeled the Soultz experiments, we felt that such a "test" would be fairly easy to pass, but would cost time and money and provide no new information. We still hope that one or another of the DOE field projects will come through in time, but otherwise we are now considering using suitable "synthetic" data sets (whose exact characteristics remain to be determined). Other existing numerical simulators (such as SAIC's STAR code, originally designed mainly for conventional hydrothermal systems) may be useful in formulating such synthetic data sets. As noted at the Peer Review, the new high-pressure constitutive package that was developed for our new EGS simulator was also rewritten into Fortran 77 for use by STAR last year, in anticipation of such a possibility.

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23526

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23583

Comment: More scientific/technical details are needed, e.g., a diagram showing the interrelationship between modules and verification or test problem results. How the modules work together was only briefly touched on. A process flow diagram would be helpful. Some technical terms need defining (see Weaknesses).

PI Response:

See response to this reviewer's comments under Question 2, "Scientific/Technical Approach" (above).

Reviewer 23425

Comment: The best suggestion for improvement that I can give is to finish the software. Where possible, test it using model problems. Devise tests using existing data that allow at least inferences about the performance of the code to be made. One final suggestion is to consider developing a Monte Carlo or stochastic module given that deterministic models of geothermal systems are never complete descriptions of the regime and that some estimate of error due to uncertainty in knowing parameters is required.

PI Response:

As noted above, the Geowatt effort has been ongoing all along, and we are now starting to pursue software development again at SAIC even though useful validation data has not yet materialized from the various DOE field projects. We have come to an agreement with DOE to extend our period of performance, which was originally scheduled to end in January 2013, to October 2013. We and DOE plan to revisit this question again next spring. If the current field data situation does not improve, we now tentatively expect to use synthetic idealized data sets for illustrative purposes.

Reviewer 23532

Comment: Reviewer did not provide comments for this criterion.

PI Response:

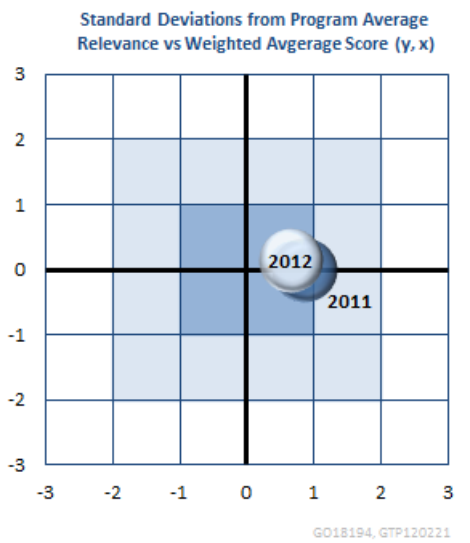
No response entered.

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18194
Project: Analysis of Geothermal Reservoir Stimulation using Geomechanics-Based Stochastic Analysis of Injection-Induced Seismicity
Principal Investigator: Ghassemi, Ahmad
Organization: Texas A&M University
Panel: Modeling

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23526

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Score: 3.2

Comment: The stated objective of this project is to develop an improved seismicity-based reservoir characterization (SBRC) technology. This will involve combining the principles of rock mechanics, finite element modeling, geostatistical concepts, and stochastic inversion techniques to establish relationships between micro-seismicity and reservoir geomechanical and flow characteristics. This work appears highly pertinent to developing a tool that can be used by industry to both predict stimulation behaviors and also develop improved poroelastic permeability distributions for evaluating flow in geothermal systems.

PI Response:

Reviewer 23583

Score: 4.0

Comment: The goal of this project is to develop a 3D geomechanical model to in the forward sense help better analyze reservoir stimulation processes and in the inverse sense use observed MEQs to predict permeability enhanced volumes during and after stimulation. Preliminary results demonstrate the forward model works and a single perfect data inverse model also works reasonably well. Thus these goals have been largely demonstrated, attaining substantial progress and impact toward accomplishing GTO's EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment." These achievements will significantly advance progress towards reducing EGS hydraulic fracturing knowledge gaps and further the deployment of permeability-enhancement technologies. This project will

definitely improve understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing modeling tools to accelerate EGS implementation.

PI Response:

Reviewer 23532

Score: 3.0

Comment: The project will meet the goals of the GTO to have a better understanding and ability to model stimulation of geothermal systems. The project may be somewhat duplicative of other modeling efforts but at this point in EGS technology development many models are needed so that several (at least 3 or 4) can ultimately become the standard codes. At least portions of this code development are being coordinated with AltaRock so industry apparently believes the work to have value.

PI Response:

Reviewer 23628

Score: 3.0

Comment: The stated objective for this project was to "develop a model for seismicity-based reservoir characterization (SBRC) by combining rock mechanics, finite element modeling, geo-statistical concepts to establish relationships between micro-seismicity, reservoir flow and geomechanical characteristics." This objective for the project brings a new perspective for using microseismic events to characterize the formation geology, contributing to the scientific understanding of these systems. It would be valuable to know if a more moderate level of characterization could be achieved through fewer number of microseismic events, making this a more predictive tool.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23526

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Score: 3.2

Comment: The project intends to consider thermo-poro-mechanical mechanisms associated with injection utilizing stochastic inversion methods. It will take into account pore pressure variations using Darcy's law, and include convective heat transport. Modifications to the permeability field by mechanical processes are controlled by a damage and permeability model which is based on experiments. In this modified poro-elastic model, the strain-stress behavior of rock is divided into an elastic phase and a damage phase. In the elastic phase there is no damage in the rock and no cracks propagate. However, the rock starts to fail by crack initiation when the stress conditions reach the failure level i.e., they satisfy the failure criterion (currently Mohr-Coulomb). The rock permeability model also considers altered permeability in the elastic and damage phase. This seems to be a hybrid poro-elastic approach that may be able to mimic fracture propagation, but it is unclear how well such a model will work with interacting fractures and propagation of new fractures into a system of existing fractures. The PI does indicate that a discrete fracture version of this will eventually be available. That would answer most of such concerns. This general approach, especially the inclusion of a stochastic approach, could well have significant impact on industry and the goals of DoE GTO.

PI Response:

Reviewer 23583

Score: 4.0

Comment: The implemented scientific/technical approach is clearly understandable, sharply focused, excellent in design and centered on key technical barriers to achieving the project's objectives such as uncertainty in model parameters, fully-coupled poro-thermoelastic constitutive equations and rock damage and stress dependent permeability. The scientific rigor employed in the development of the 3D model and verification results are of very high quality and instill a feeling of confidence in the end results. The focus of the project is sharply aimed at solving one of the major scientific barriers in EGS deployment, namely, "How can the stimulation be monitored and measured?" MEQs are the only real-time measurement available and inverting these into permeability enhancement is exactly what is needed. The R&D plan is well thought out, logical and all of the components of the project contribute to significant progress in overcoming stimulation barriers/knowledge gaps. The execution of the approach is outstanding with little room for improvement.

PI Response:

Reviewer 23532

Score: 4.0

Comment: Although I am not expert in development of this type of model, the modeling effort appears to be rigorous and should be suitable for ultimate use by the geothermal industry. The ability of the code to run on a desktop computer will make it more readily available to the geothermal industry.

PI Response:

Reviewer 23628

Score: 3.0

Comment: The numerical challenge that this research team has chosen is significant in terms of its complexity and compute cycles required to achieve results. It would be instructive to learn what level of characterization (i.e., grid resolution) could be achieved with a modest number of microseismic events (i.e., a short injection) period. It would be also interesting to learn if porosity characterization could simultaneously be achieved with the SBRC approach.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23526

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Score: 3.5

Comment: The project seems to be about 80% complete and has received an additional year of extension through 2012. The project has resulted in a 3D finite element capability based on a thermo-poro-mechanical coupled reservoir model. It takes into account damage, stress dependent permeability, heat transfer resulting from fluid flow, rock heterogeneity, and pressure and presumably shear boundary conditions. Injection experiments and the effects of thermal stress in the well bore have been simulated. The use of MEQ data has also been utilized to improve estimates of permeability distribution resulting from stimulation. Overall, progress appears to have been very good.

PI Response:

Reviewer 23583

Score: 4.0

Comment: It is difficult to analyze the budget, costs, scope and schedule for this project because it is an AOP project (aka, year-to-year funded), only Task 5 was reported on this year (as agreed to with GTO), project completion and budget are tied to all the EGS Demos, and the way the information is presented. However, it is possible to glean some information: 1) started Oct 2009, 2) maybe 60% done, depends, 3) total budget about $1M in FY11-12, 4) industry support $200K (Should this be added to or included in the previous number?), 5) Task 5 is $524K spent out of the total budget (unclear), and 6) there is an industry cost share of $396K. Consequently, though the project's accomplishments indicate notable progress and impact to its goals, it is impossible to comment on the resources expended and adherence to a project schedule.

The scientific accomplishments in 2D and 3D thermo-poro-mechanical model development, the remarkable results due to the adoption of a probabilistic framework for model parameters and a geostatistically-derived ensemble of rock mass permeability and criticality distributions to handle uncertainty, and the MEQ inverse permeability, cohesion and tensile strength outcomes are outstanding—clearly exceptional progress towards the projects technical goals. Project costs data was not presented but the project is on schedule.

The quality and significance of the technical accomplishments and results are very good, however, the costs expended to meet project objectives cannot be evaluated. In addition, the productivity in work underway and future work and the value of the accomplishments compared to the costs cannot be evaluated.

PI Response:

Reviewer 23532

Score: 3.0

Comment: Progress appears to be notable as evidenced by numerous reports and presentations from the project. The project appears to be somewhat delayed as evidenced by a request for extension.

PI Response:

Reviewer 23628

Score: 3.0

Comment: The research team is making good progress against the stated objectives. This is impressive considering that the bulk of the work is being conducted by graduate students. The team has demonstrated the SBRC approach and has plans to improve the finite-element-model and to extend the stochastic capabilities to three dimensions. The integration with the site field data appears to be delayed for this project.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23526

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Score: 3.5

Comment: Management and coordination seems very well done regarding collaboration, involvement with outside partners, integration of results into the geothermal community.

PI Response:

Reviewer 23583

Score: 4.0

Comment: As mentioned above, the technical plan for the R&D is outstanding and the project is on schedule with no business or staffing plan problems at tis time. Cannot comment on the spending plans, however, prospective future plans are of very high quality and will be very effective in meeting the project's goals. The inclusion of appropriate and logically placed decision points that effect the future direction of the work were not discussed by the PI. Coordination of activities with collaborators and stakeholders is very effective. Better management practices are desirable in reporting precisely the project's costs.

PI Response:

Reviewer 23532

Score: 3.0

Comment: The project appears to be well managed. However, there is some schedule delay as evidenced by the request for a project no-cost extension.

PI Response:

Reviewer 23628

Score: 3.0

Comment: This project has progressed slower than expected against the proposed schedule, but the project has remained within the proposed budget. Both the numerical and field work have progressed slower than expected, but the numerical side of the project has demonstrated good progress against the objectives and has received approval for a time extension. The numerical component of this research appears to be somewhat dependent on its industrial partner for the site field data.

PI Response:

STRENGTHS

Reviewer 23526

Comment: I have to abstain from this review for a potential COI--sorry.

PI Response:

Reviewer 23425

Comment: Professor Ghassemi has worked with GTO for many years and has produced high quality results. He understands the important issues that the geothermal industry faces in attempting to develop a reliable and profitable source of energy. His poro-elastic model with damage probably represents the pinnacle of what can be done with a conventional approach to simulating stress-induced permeability changes. It is also significant that he is including a stochastic approach in his modeling effort.

PI Response:

Reviewer 23583

Comment: This successful project, as yet not completed, has achieved notable progress and impact toward advancing GTO's EGS mission and significantly reducing EGS hydraulic fracturing knowledge gaps, and improving the program's understanding of how to lower current EGS reservoir creation technology barriers. The implemented scientific/technical approach is outstanding—very well thought out, reasonably likely to succeed and has been/should be effective in achieving the project's objectives. The project's accomplishments have been outstanding and the quality and significance of the technical accomplishments and results are very high.

PI Response:

Reviewer 23532

Comment: The project offers a rigorous method for simulating the effect of stimulating and operating an EGS. A notable strength is the operability of the code on a desktop computer.

PI Response:

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

WEAKNESSES

Reviewer 23526

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Comment: Overall, this is a very strong effort. The weakest part is probably the use of the hybrid poroelastic model in which fracture propagation is simulated using a damage model. Unclear how effective this can be especially regarding how fractures interact with each other. This is significant since evaluating the modification of a prefractured network is considered important for assessing how effective stimulation procedures can be.

PI Response:

Reviewer 23583

Comment: The level of productivity in work underway and future work and the value of the accomplishments compared to the costs cannot be evaluated. Model does not include chemical reactions, important in the long-term for optimizing reservoir operations. Control points should be added to the R&D plan.

PI Response:

Reviewer 23532

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

IMPROVEMENTS

Reviewer 23526

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Comment: Prof Ghassemi has already indicated that a discrete fracture approach is being considered. (See comments on weakness)

PI Response:

Reviewer 23583

Comment: Control points should be added and in the future, improved management practices should be established to better report the project's costs to budget.

PI Response:

Reviewer 23532

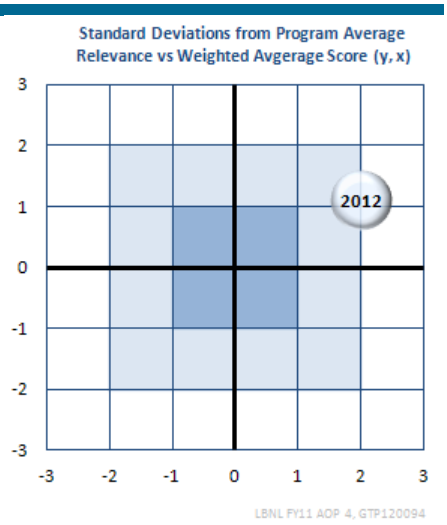
Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: LBNL FY11 AOP 4
Project: Modeling Supporting the Demonstration of a Deep Enhanced Geothermal System at the Northwest Geysers Geothermal Field, California
Principal Investigator: Rutqvist, Jonny
Organization: Lawrence Berkeley National Laboratory
Panel: Modeling

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23526

Score: 3.5

Comment: This project is interesting and is relevant to GTO. The PI is applying coupled numerical models to support the Geysers EGS demonstration. As for the overall relevance, I see it mostly helping guide Calpine in their efforts--what we need to be sure do to is capture the workflow and methodology, and provide this information back to GTO--in order to quantify at least at this level what it takes for numerical modeling support for an EGS project.

PI Response:

Reviewer 23425

Score: 3.5

Comment: The overall objective and long-term goal according to the PI is to develop and demonstrate the technology required to extract energy from the low permeability zones that are often associated with high-temperature geothermal systems. Specific goals include demonstrating the stimulation techniques to create an EGS in a deep, very hot, fractured rock system by the injection of treated wastewater at temperatures substantially lower (several hundred centigrade less) than the formation, investigate how such relatively cold-water injection affects the fractured rock system and contributes to the EGS mechanically and chemically, gain insights into underlying mechanisms of microearthquake events and their role in enhancing permeability and demonstrate the technology to monitor and validate the stimulation and sustainability of an EGS. In this significant stimulation project at the Geysers, LBNL performs modeling of stimulation and injection/production and analyzes field data for planning, design and validation of the EGS stimulation. The project's analysis role is critical to what appears to be an important project for understanding how to develop an EGS.

PI Response:

Reviewer 23583

Score: 4.0

Comment: This project conducted at the Northwest Geysers Field, will improve practical and scientific understanding of how cold-water injection, under low pressure, mechanically and chemically affects fractured high-temperature rock systems using validated 3D modeling techniques, gain insights into underlying mechanisms of microearthquake events and their role in enhancing permeability, and develop technologies to monitor and validate stimulation and sustainability of such an EGS.

[Note: For this review, the “Other technical objectives” as presented at the bottom of slide 3 of the presentation and page 1 of the summary, were selected as the main goals of this project by the reviewer. These are not the goals as stated in these materials, which seem to be the same as that of the EGS Demonstration at the Northwest Geysers (a different project). It is understood that the projects are linked very closely, however, it would be of benefit to all, if this project’s goals were more clearly and succinctly elucidated.]

To a greater extent these goals have been achieved by the project thus far, attaining notable progress and impact toward accomplishing GTO's EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment." When fully completed, these achievements will significantly advance progress towards reducing EGS hydraulic fracturing knowledge gaps and further the deployment of permeability-enhancement technologies. This project, if successful, will improve, significantly, understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing a modeling techniques and monitoring tools that will ultimately extend the potential of the resource at the Geysers.

PI Response:

Reviewer 23532

Score: 4.0

Comment: The project has made substantial progress and is conducting very interesting scientific work. The results of injection into the high-temperature zone at The Geysers has long been an interesting topic. This modeling project, based on the results of the field operations, should provide a well documented step forward in understanding the injection.
I have rated the project a 4 because the project is interesting scientifically. However, the results are likely to only be relevant to The Geysers since it is the only vapor-dominated field in the US. It is the largest operating geothermal field in the world so understanding of injection here is important. The methodology being used in the model should be widely applicable to geothermal fields.Project has made notable progress. The project has built on previous modeling of the effect of injection into the high temperature zone. This portion of the simulation is neither new nor novel. The project has, however, coupled chemical and mechanical simulation to the fluid flow models making possible greater understanding of the mechanics of rock movement and microseismicity and also dissolution-crystallization reactions.

PI Response:

Reviewer 23628

Score: 4.0

Comment: The full coupling of thermal, hydrological, geomechanical, and geochemical capabilities into a numerical simulator remains a challenge. This work provides those capabilities in a loosely coupled fashion, allowing scientists and

engineers to better understand geothermal systems today. The researcher has chosen a deliberate path to the simulation and understanding of a particular geothermal system, with plans to include all four modeling capabilities. The research plan is incremental, first addressing the THM coupling, with the full THMC coupling proposed for later years. I was particularly impressed with the use of the historical subsidence data to develop the geomechanical parameters for the system.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23526

Score: 3.0

Comment: The approach is sound and appears to follow high scientific principles and industrial standards.

PI Response:

Reviewer 23425

Score: 3.3

Comment: The scientific and technical approach is focused on design, validation and monitoring of an EGS system created by hydroshearing as a result of injecting cool water at relatively low pressure. The project appears to provide the necessary coupled reservoir and geomechanical modeling of stimulation and production. This is done through inputs from 3-D tomography (MEQs), INSAR, chemical and isotopic analysis and 3-D geologic constraints. Output of the modeling is the planning of stimulation procedures, EGS design, etc. The approach requires the successful interaction of several organizations which seems to be occurring.

PI Response:

Reviewer 23583

Score: 3.0

Comment: The implemented scientific/technical approach is very well thought out, reasonably likely to succeed and has been/should be effective in achieving the project's objectives. The scientific rigor employed in the development of the 3D model and validation results are of very high quality and instill a feeling of confidence in the end results. The focus of the project is strong, with the majority of the components of the project contributing to significant progress in overcoming barriers/knowledge gaps. The execution of the approach is good yet there is room for minor improvements.

PI Response:

Reviewer 23532

Score: 3.0

Comment: The approach is generally well thought out. However the presentation did not do a good job of tying together the simulation work, the InSAR study and the microseismic modeling. The seismicity and the InSAR data should aid the simulation effort but the connection was not carefully provided. Thus the project appears to be a bit unfocused. Available InSAR data seems to suggest that there is continuing movement in the study area under "natural conditions," i.e. before current injection. Is this caused by regional tectonism, fluid or pressure depletion of the study area by production to the southeast? If this activity is ongoing how will the signal of injection be isolated from the ongoing activity in order to isolate the movement caused by injection?

PI Response:

Reviewer 23628

Score: 4.0

Comment: The numerical simulator used in this work represents the state-of-the-art for geothermal systems. The inclusion of InSAR data, historical subsidence data, and pumping data prior to stimulation also demonstrates that the work also reflects the state-of-the-art for modeling geothermal systems. The researchers plan to improve the computational grid to more accurately reflect the sloped nature of the geological system, the inclusion of additional wells and the extension of the work to include geochemical effects, makes this modeling effort a new standard for approaching geothermal systems.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23526

Score: 3.0

Comment: The project is showing good, consistent results in support of the Geysers EGS demonstration. Demonstrating consistent results between MEQ (whether or not if predicted), InSAR, and numerical model is reassuring.

PI Response:

Reviewer 23425

Score: 3.3

Comment: Modeling shows reasonable match with observed seismicity. The simulator was able to match the behavior of pressure versus time between wells. Modeling shows that MEQs are caused not only be injection pressure but also by cooling. The project has been able to obtain accurate MEQ locations. The successful relationship of labs and industry should also not be overlooked as an accomplishment.

PI Response:

Reviewer 23583

Score: 3.0

Comment: It is difficult to understand the budget, costs, and schedule for this project as presented because it is so intimately connected to the main EGS Demo. For example, on slide 4 the PI lists the EGS Demo timeline and budget for this project but the question remains, is this project's budget included in the EGS Demo Project of $10.7 Million or does it have a separate budget? And what is that budget? The answer to this question is not clear from the information presented. However, it is possible to glean some information: 1) LBNL spent $327K from June 2011 to March 2012 (out of what?) and the presumption is these are FY11 funds (not clearly stated), 2) $500K is set for FY12. But FY12 is more than half gone. Maybe the $327K is delayed FY11 funds that aren't spent completely. Consequently, though the project's accomplishments indicate notable progress and impact to its goals, it is impossible to comment on the resources expended and schedule.

The quality and significance of the technical accomplishments and results are very high, however, the progress of the tasks in meeting project objectives cannot be evaluated because the scope and schedule are confusingly presented. The level of productivity in work underway and future work and the value of the accomplishments compared to the costs cannot be evaluated.

PI Response:

Reviewer 23532

Score: 3.0

Comment: The progress appears to be good. However, apparently the models used prior to the injection test were simplified models that did not include relief on the geologic units and temperatures at depth. (Apparently the gridding considered the temperature to be constant at any given depth.) However the new models will consider the temperature with depth variation throughout the reservoir and well as the changes in elevation of the normal reservoir, high temperature reservoir and the geologic units. The structure apparent on slide 7 does not appear to be present in the grid model used for simulations. Slide 10 however shows dipping contacts and surfaces. The graphics were illegible to the peer review panel as well as the audience.

PI Response:

Reviewer 23628

Score: 4.0

Comment: The accomplishments to date for this project are impressive in that they are focused on the proposed tasks and outcomes and have yielded results that are predictive and beneficial to understanding the geothermal system. It appears as if the researchers have had to deal with schedule changes due to changes in the field injection tests, but have managed those changes. This project has currently achieved the first half of its first technical objectives: To investigate how cold-water injection under low pressure mechanically and chemically affects fractured high temperature rock systems. The modeling process to address the chemical effects has been defined. Progress on the second half of its technical objectives are currently underway with the refinement of the geologic model, well trajectories, and computational grid: To investigate the technology to monitor and validate stimulation and sustainability of such an EGS.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23526

Score: 3.5
Comment: The PI appears to be in frequent communication with Calpine, and other groups involved in the project. I'm sure the support provided by the PI is invaluable to the demonstration, and is integral to their success.

PI Response:

Reviewer 23425

Score: 3.7

Comment: This project depends heavily on having good coordination with different organizations. Project management and coordination appear to be excellent. The PI has also adapted the project as necessary to deal with schedule changes and changes in stimulation design.

PI Response:

Reviewer 23583

Score: 3.0

Comment: Except for the fact that the PI has presented confusing data regarding the budget, costs and timeline for this project, so far, it looks like project management has been effectual in getting the work done and plans to move forward are reasonable, logical, and likely to succeed. Control points are not discussed probably because they are tied to the demo but this should be addressed in particular with regard to the InSAR data evaluation. Better management practices are desirable in reporting precisely the project's schedule, costs and budget.

PI Response:

Reviewer 23532

Score: 2.0

Comment: It is difficult to determine from the presentation and the summary document how the project is being managed and coordinated other than a comment on slide 6 that LBNL's "schedule has been repeatedly adapted to updated field work schedule…"

PI Response:

Reviewer 23628

Score: 4.0

Comment: The research team is effectively working with its industrial partner for the field work, and has also successfully contracted with a commercial client to collect surface deformation data using InSAR. Project coordination between the partners appears to be excellent.

PI Response:

STRENGTHS

Reviewer 23526

Comment: Coordinated approach, multiple data streams to support model predictions.

PI Response:

Reviewer 23425

Comment: This proposal involves several organizations providing inputs into an LBNL modeling capability. Communication is clearly a strength and may represent a model for interactions between government labs, unviersities

and industry. Modeling that uses the input is also a strength of the project. The modeling effort seems fairly complete and LBNL has a very good reputation in the general areas of seismic analysis and flow simulation.

PI Response:

Reviewer 23583

Comment: This successful project, as yet not completed, has achieved notable progress and impact toward advancing GTO's EGS mission and significantly reducing EGS hydraulic fracturing knowledge gaps, and improving the program's understanding of how to lower current EGS reservoir creation technology barriers. The implemented scientific/technical approach is very well thought out, reasonably likely to succeed and has been/should be effective in achieving the project's objectives. The project's accomplishments have been outstanding and the quality and significance of the technical accomplishments and results are very high. Project achievements suggest that project management has been effectual in getting the work done and plans to move forward are reasonable, logical, and likely to succeed.

PI Response:

Reviewer 23532

Comment: The scientific objectives of this project are well thought out and the science is very interesting.

PI Response:

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

WEAKNESSES

Reviewer 23526

Comment: Not necessarily a weakness, but I would urge you to continue with the InSAR analysis, and try to use it as a calibration target for the model.

PI Response:

Reviewer 23425

Comment: Project uses TOUGH linked to FLAC3D to calculate the thermo-elastic and poroelastic stress evolution as a result of “cold” water injection. This may be "state of the art" but it is a legitimate question to ask how adequate this approach is in coupling the thermal regme to stress effects up to and including fracturing. How adequate is the poroelastic approach to modeling pre-fractured systems and accounting for fracture-fracture interactions given that flow through fractures is by far the most important mechanism for mass and heat transport? Also, the model is deterministic and doesn't appear to provide industry with a sense of the likelihood that the model is applicable.

PI Response:

Reviewer 23583

Comment: The progress of the tasks in meeting project objectives cannot be evaluated because the scope and schedule are confusingly presented. The level of productivity in work underway and future work and the value of the accomplishments compared to the costs cannot be evaluated. Control points should be addressed in particular with regard to the InSAR data evaluation. Better management practices are desirable in reporting precisely the project’s schedule, costs and budget.

PI Response:

Reviewer 23532

Comment: Since The Geysers is a vapor-dominated field the scientific results of this project will have limited importance to other, liquid-dominated hydrothermal fields. However, The Geysers is the largest geothermal field in the world so its operation is of great importance. The modeling approach should be useful on all geothermal fields, just not the results injection into a vapor dominated system.

PI Response:

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

IMPROVEMENTS

Reviewer 23526

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Comment: Overall, this seems to be an excellent project and compared to many projects was a pleasure to review. Suggested ideas are to look more closely at the ability of poroelastic models to simulate fracture propagation and fracture-fracture interactions. Also, a departure from deterministic modeling by incorporating a Monte Carlo approach might be worth considering.

PI Response:

Reviewer 23583

Comment: Provide clear and succinct project budget, costs, scope and schedule information; control points should be addressed and in the future, improved management practices should be established to better report the project's schedule, costs and budget.

PI Response:

Reviewer 23532

Comment: No suggestions for improveent. This project appears to be on track and is well managed although the management was not well documented.

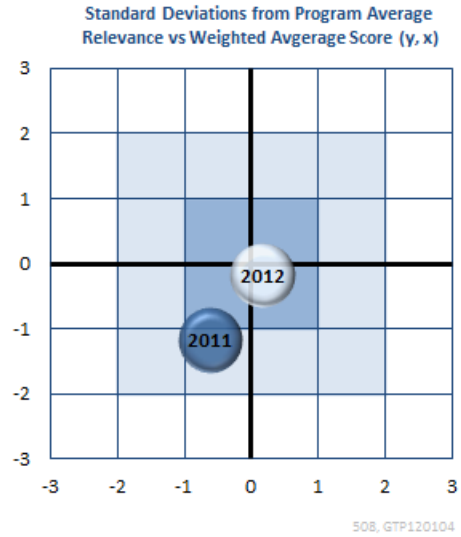
PI Response:

Reviewer 23628

Comment: Reviewer did not provide comments for this criterion.

PI Response:

SEISMICITY, FLUID IMAGING, AND RESERVIOR FRACTURE CHARACTERIZATION



Review: 2012 Geothermal Technologies Office Peer Review
ID: 508
Project: Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing
Principal Investigator: Templeton, Dennise
Organization: Lawrence Livermore National Laboratory
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23489

Score: 4.0

Comment: This program, although somewhat limited by data availability provided a significant advancement with the Match Field Processing approach. The outcome from this project may be the breakthrough in developing reserve estimates from resource numbers early in a geothermal field's development.

PI Response:

We would like to thank the reviewer for taking the time to review our project. We agree that the results from our test case in the Salton Sea Geothermal Field show that the Matched Field Processing (MFP) earthquake detection method can identify significantly more events than can be identified using traditional earthquake detection techniques in geothermal areas. This increase in information that can be extracted from the seismic data should increase the quality of the information that is input into subsequent technical and economic analyses.

Reviewer 23416

Score: 3.0

Comment: Developed a useful technique (MFP) for increasing detection capability of MEQ arrays. With further testing on EGS project data this should prove to be a useful contribution to MEQ processing toolbox. Usefulness will be measured by level of uptake of method by wider seismology community. Impacts on geothermal MEQ monitoring economics expected to be positive if not outstanding.

PI Response:

We would like to thank the reviewer for taking the time to review our project. We agree that further testing on EGS project data is necessary and have taken steps to obtain three seismic data sets that include observations during EGS stimulations. We plan to continue to publish and present our results at scientific meetings in order to further disseminate our technique and results to the wider seismological community.

Reviewer 23401

Score: 3.0

Comment: Too many words on the slides. Creates the impression of fuzzy thinking which is not justified.

PI Response:

We would like to thank the reviewer for taking the time to review our project. In the future we can streamline the text for better clarity.

Reviewer 23625

Score: 2.0

Comment: It is too early to assess the relevance of MFP with only one real data set processed (Salton Sea).

PI Response:

We would like to thank the reviewer for taking the time to review our project. We acknowledge that to date only one data set has been processed using the empirical MFP technique, however we believe that our test case example is representative of pre- and post-stimulation earthquake distributions. Since this test worked remarkably well, it was able to identify over 200% more events, we believe that our method would also work well in EGS reservoirs both pre-and post-stimulation. There are strong indications that the method should work well during stimulations as well, and we are currently in the process of obtaining seismic data sets to test this theory.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23489

Score: 4.0

Comment: Good approach that recognized the importance of blending time and signal characteristics into energy bands that ultimately can be linked to production characteristics and then to prediction of value of a geothermal project.

PI Response:

We agree with the reviewer that a more complete earthquake catalog and knowledge of the active areas of the EGS reservoir should provide better information which can then be used for a variety of purposes, including determining production characteristics.

Reviewer 23416

Score: 3.0

Comment: Method for detecting smaller events, thereby decreasing detection limit for locatable events was appropriate, well researched and rigorously undertaken. Novel use of existing underwater acoustics research.

PI Response:

We agree that this technique has proven to work remarkably well in the geothermal contex.
Reviewer 23401

Score: 3.0

Comment: Does not appear to have a rigorous way to distinguish artifact from uncommon wave forms in low amplitude signals.

PI Response:

In point of fact, the MFP method should be able to distinguish between artifacts and uncommon waveforms, such as tremor or low-frequency earthquakes, if these unusual events are included in the initial template creation step. However, in this study, such events were not explicitly included in the original processing and as such, both artifacts and uncommon waveforms were excluded. We did not initially attempt to include uncommon waveforms because previous investigations did not detect any such events in our study area. It is possible that only the occurrence of the nearby M7.2 earthquake caused these uncommon events to occur. This would be an interesting side topic to explore at a later date.

Reviewer 23625

Score: 2.0

Comment: As already mentioned, the best way too assess the relevance of MFP is the processing of the largest possible number of existing data sets. There are large microseismic monitoring data sets of EGS available, e.g. Soultz-sous-Forets in France and Basel, Switzerland.

PI Response:

As mentioned above, we are addressing the reviewers concerns by obtaining seismic data sets from EGS reservoirs on which to apply our method.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23489

Score: 4.0

Comment: The progress and accomplishments were significant enough, given the limits of sensor placement. The detail in the investigation technique was very strong, indicating that progress was being made in closing in on more accurate data collection. Letting master events set the frame work may be a problem but more data is needed to verify. Of the projects I saw at this conference this is one of about five that should be extended.

PI Response:

We agree that the results from our test case have been extremely positive. We are obtaining other data sets on which to apply the method for further verification.

Reviewer 23416

Score: 3.0
Comment: Successful completion of the MFP task was achieved, although further validation on EGS data set from Newberry would be preferable, depending on timing of Newberry stimulation (delayed). Postponement of completion date is therefore recommended to achieve this with remaining funds.

PI Response:

We are obtaining seismic data sets from EGS reservoirs on which to apply our method. However, we agree that it would be extremely interesting to apply our method on the DOE Newberry EGS stimulation. Initial methodology development has been completed for the empirical MFP method. Implementation to the Newberry site should be straightforward.

Reviewer 23401

Score: 3.0

Comment: See other remarks.

PI Response:

We addressed the reviewer comments in the appropriate other sections.

Reviewer 23625

Score: 3.0

Comment: The identification of 249% more events in the Salton Sea Geothermal Field sounds impressive. It is however difficult to relate this improvement to MFP only. We have little knowledge about the quality of the existing microseismic monitoring system at Salton Sea. It would be therefore very interesting to process existing EGS data sets, in particular as the Newberry stimulation may not be realized in the time envisaged.

PI Response:

As mentioned above, we are addressing the reviewers concerns by obtaining seismic data sets from EGS reservoirs on which to apply our method.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23489

Score: 4.0

Comment: The collaboration level and management were good - could have used a little more input from the oil & gas industry who use real-time, downhole microseismic to evaluate fracture development.

PI Response:

The reviewer is correct in that more collaboration with the oil and gas industry should prove to be very fuitful.

Reviewer 23416
Score: 3.0

Comment: Project was well managed and executed. Coordination and collaboration, where needed, was adequate. Examples of adaptability include use of Salton Sea data when Newberry data delayed. Future work arising from this project was identified, and looks promising.

PI Response:

We agree with the reviewer. Future work looks promising.

Reviewer 23401

Score: 4.0

Comment: Appears to be well-run project, overall.

PI Response:

We agree with the reviewer. The overall team has performed exceptionally well.

Reviewer 23625

Score: 2.0

Comment: Further testing of MFP relies on EGS projects that may be delayed (Newberry). Try to get access to existing EGS data sets.

PI Response:

As mentioned above, we are addressing the reviewers concerns by obtaining seismic data sets from EGS reservoirs on which to apply our method.

STRENGTHS

Reviewer 23489

Comment: The matched field processing made this project of significant value to at least two industries - geothermal and oil and gas. With some industry participation, the techniques developed here could see wide industry acceptance.

PI Response:

We agree with the reviewer. We will pursue further industry participation.

Reviewer 23416

Comment: Strengths included adaptation of underwater acoustic technology to seismic records. Could be taken up by wider seismology community to deal with multiple overlapping events (e.g. swarms or aftershock sequences). Usefulness to EGS is lower magnitude of completion and more small events to help track migration of IS in time and space.
PI Response:

We agree with the reviewer.

Reviewer 23401

Comment: High potential payoff in array cost and results.

PI Response:

We agree with the reviewer.

Reviewer 23625

Comment: Inexpensive and time efficient method. Does not require new instrumentation or new monitoring set up.

PI Response:

We agree with the reviewer.

WEAKNESSES

Reviewer 23489

Comment: Need to further develop the data gathering part by using deeper monitor wells and longer term monitoring for a wider set of data. This is not really a weakness - just a plea for this project ot go further.

PI Response:

We agree that using data from borehole stations would be extremely interesting and are currently actively pursing this possibility.

Reviewer 23416

Comment: Not yet fully tested on an EGS project.

PI Response:

We agree that this method should be tested on an actual EGS project. We are currently actively working on obtaining EGS seismic data sets.

Reviewer 23401

Comment: See other remarks.

PI Response:

We responded to reviewer comments in the other sections.
Reviewer 23625

Comment: Not enough data sets processed yet.

PI Response:

We agree that more data sets need to be processed. We are actively pursuing this possibility.

IMPROVEMENTS

Reviewer 23489

Comment: More data. Deeper monitor wells, longer monitoring times.

PI Response:

We agree that applying the method to more data, using deeper monitoring wells, and studying a longer monitoring data set would be very interesting. We are actively working on obtaining all three items.

Reviewer 23416

Comment: Recommend complete original intention of processing data from an EGS stimulation when data available.

PI Response:

We agree that this method should be tested on an actual EGS project. We are currently actively working on obtaining EGS seismic data sets.

Reviewer 23401

Comment: More error analysis would answer questions about validity of threshold data.

PI Response:

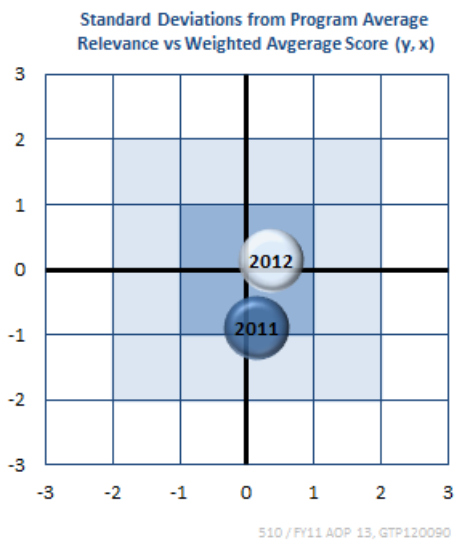
The reviewer is perhaps referring to a ROC curve. Although we performed the analysis, we did not show those particular results in the presentation. We will plan on presenting these results in future presentations.

Reviewer 23625

Comment: Mentioned before: Process as many existing data sets as possible.

PI Response:

We agree that this method should be applied to more data sets. We are currently actively working on obtaining more EGS seismic data sets.



Review: 2012 Geothermal Technologies Office Peer Review
ID: 510 FY11 AOP 13
Project: Joint Seismic-Electromagnetics Inversion for Iceland Geothermal Systems
Principal Investigator: Newman, Greg
Organization: Lawrence Berkeley National Laboratory
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 3.0

Comment: In theory coupling of em (MT & CSEM) and seismic should be extremely useful in imaging fluid flow, especially in time lapse mode. I think that if the use of CSEM can be successfully demonstrated there will be a significant improvement geothermal reservoir EM imaging. The use of Raft River data is likely to improve relevance of data and interpretations for EGS characterization if they can get data. The use of real data for a joint inversion methodology test is likely to be relevant and useful, especially given the iterative (reconfigured as new results and needs evolve?) nature of the effort. The discussion on geologic and reservoir permeability evolution details in a geophysics project is refreshing and improves the potential relevance of the work. The presentation of the MEQ data was reasonably thorough and tends to ensure utility and relevance. I believe it is important to keep this project funded to completion.

PI Response:

Reviewer 23550

Score: 3.0

Comment: This project is relevant to the Geothermal Program's mission and goals as it aims to develop a new generation of advanced geophysical imaging technologies for geothermal resource characterization. The development of a joint inversion framework (here using MT and seismic tomography) based on common structure could represent a very significant step forward in imaging geothermal systems using surface geophysical datasets. However, the specific focus of the work on characterizing fractures and flow in fractures seems unrealistic given the resolution limitations of EM datasets.

PI Response:

Reviewer 23521

Score: 3.0

Comment: Improved geophysical imaging methods for fluid locations identification, subsurface and fractures characterization are important to the geophysical community.
PI Response:

Reviewer 23641

Score: 4.0

Comment: Research addresses a key EGS challenge to utilize both MEQ and EM data to image fluid distribution in an EGS reservoir.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 4.0

Comment: The cross gradient structural approach to joint inversion seems to have the most potential and acceptance in the scientific community. The combined use of CSEM and MT while not unique, is likely to result in increased acceptance for reservoir imaging, especially when combined with good MEQ data inversions (which allow for "focused" EM work), injection production data and time lapse methodologies. Inversions based on differentials seem to be more robust in imaging changes that might reflect permeability or fluid distribution changes.

PI Response:

Reviewer 23550

Score: 3.0

Comment: The team has identified three geothermal systems to be studied. These are all field sites, two being in Iceland and one in the US. These field sites appear to have good seismic and MT data available to test the approach. However, it would have been useful to include some synthetic simulations in this work to demonstrate the value of the joint inversion approach directly. That said, the PI did provide the review panel with a conference paper evidencing that such synthetic simulations have been done. The technical approach is based on using state of the art EM and seismic datasets that are acquirable in the field. The joint inversion using structural constraints being pursued here clearly has promise for improving the imaging of geothermal systems. The same approach has been used effectively applied in other areas of earth sciences e.g. in near surface hydrogeological investigations. The transfer of this approach to the geothermal setting appears worthwhile.

PI Response:

Reviewer 23521

Score: 3.0

Comment: The team has a multi-step approach for combined analysis, starting with individual analysis of geophysical data, then performing an iterative analysis with the output of one method as input to the other (MT and seismic). A joint 3D image can provide better results with improved resolution and better 'structure'.

PI Response:

Reviewer 23641

Score: 3.0

Comment: Technical approach is valid. One risk is that the Raft River stimulation is untested and may not produce the desired reservoir behavior to represent a good test of the approach.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435

Score: 4.0

Comment: Given the funding uncertainty and its impact on team incentive, I would say that great progress has been made. The team (EGI especially) has demonstrated over the years a commitment to geothermal and ability to use their experience to make DOE funded projects work and be useful to the community. I strongly urge continued funding for this work.

PI Response:

Reviewer 23550

Score: 3.0

Comment: The team has generated some impressive looking geophysical models of the Coso field. However, the full implementation of the joint inversion based on a structural constraint sill appears to need work. The structural coupling using resistivity and Vp seems to have little effect on resistivity imaging; instead, the inversion seems to just be forcing the Vp structure to look like the resistivity model. In response to a question on this issue, the PI explained that the

structural constraint imaging has not yet been fully developed. Instead, the resistivity has been used as prior information such that structural similarity is being exclusively forced upon the seismic dataset but not on the resistivity. The PI emphasized that this is just the first step in the development of the structural inversion approach. In a true structural inversion, both datasets should be free to control the resulting Vp and resistivity images from which structure should be truly resolvable from the scatter plots generated. My impression is that there is still significant work needed to complete this joint inversion methodology. Assuming that Vp and resistivity are both being controlled by the same underlying structure, much stronger trends in the resistivity/Vp scatter plots should be inherent from the joint inversion, and these should define the underlying structure. In this respect I noted that the justification for the structural similarity is a bit vague, being somewhat loosely related to the faulting rather than to specific physical properties of the rock that both resistivity and Vp would both depend upon. However, the 3D resistivity cube produced for Krafia shows evidence for a structural coupling constraint being appropriate although results of the joint structural inversion have not yet been shown. I also noted that the interpretation of the resistivity structure for Coso was confidently given in terms of clay content and temperature, but it was not clear to me what constraints available to confirm this qualitative interpretation of the resistivity images.

PI Response:

Reviewer 23521

Score: 3.0

Comment: Three sites are under investigation that resulted in very interesting data. The work seems to progress according to plan, even if that change somewhat.
I had a slightly difficult time reviewing this project: (1) the slides I downloaded well before the meeting were completely different than what it was presented; (ii) the presented slides were slightly different than what I downloaded on site (If I remember right, there were at least two extra slides related to resistivity/vp, which are not in the online version).

PI Response:

Reviewer 23641

Score: 3.0

Comment: The project has successfully deployed the MEQ network and has collected CSEM and MT data. The MEQ network has collected data before and after the February 23 stimulation of RRG9. The project is awaiting the full stimulation experiment on RRG9 for a comprehensive test of the approach.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 4.0

Comment: Given funding issues, the project has leveraged its data and resources well to meet project commitments. The detailed Raft River field data is a testament to the team's ability to get the needed data.

PI Response:

Reviewer 23550

Score: 4.0

Comment: The presented timeline seems reasonable given the changes to the funding and delays experienced by the team and encountered along the way. This project shows evidence of strong Industrial and foreign collaborations that are benefiting the project. The plan for rescoring to deal with the reduced budget is reasonable. The team also makes a solid commitment to upload data (not propriety) to the relatively newly established National Geothermal Database. The team shows evidence of strong project management in that it has completed imaging of two of geothermal fields and has also sustained operation of a 14 station MEQ in Iceland, which is argued to be providing excellent data quality.

PI Response:

Reviewer 23521

Score: 3.0

Comment: The project seems to be managed just fine, including external collaborators.

PI Response:

Reviewer 23641

Score: 2.0

Comment: Delays in permitting of the RRG9 full stimulation experiment (beyond the control of the PI) has delayed testing of the scientific approach. Completion of the project will require an additional year of funding as a result of delays and the funding reduction incurred in FY11.

PI Response:

STRENGTHS

Reviewer 23435

Comment: The use of EM, CSEM and MEQ data in a time lapse cross gradient joint inversion model will be extremely useful. The apparent cooperation with Raft River is also a plus. The inclusion of some geologic data is reassuring with respect to generalizing the results to other geothermal fields and may in fact show how geologic conceptual models can improve inversion schemes.

PI Response:

Reviewer 23550

Comment: [1] project has potential to develop a new generation of advanced geophysical imaging technologies for geothermal resource characterization; [2] joint inversion using structural constraints being pursued here clearly has promise for improving the imaging of geothermal systems; [3] 3D resistivity cube produced for Krafia acquired to date supports argument that a structural coupling constraint is appropriate; [4] strong industrial and foreign collaborations appear to be benefiting the project; [5] sustained operation of a 14 station MEQ in Iceland appears to be providing excellent data quality.

PI Response:

Reviewer 23521

Comment: Very interesting work.

PI Response:

Reviewer 23641

Comment: Innovative approach to combining MEQ and EM data to image fluid flow.

PI Response:

WEAKNESSES

Reviewer 23435

Comment: More discussion is needed on exactly how the MEQ data will be inverted for "fluid flow" imaging. It is important to note that the MEQ location may no coincide with fluid change. It would be traigc if the EM inversion was focussed on non-fluid flow related seismicity.

PI Response:

Reviewer 23550

Comment: [1] the specific focus of the work on characterizing fractures and flow in fractures seems unrealistic given the resolution limitations of EM datasets; [2] synthetic simulations of geothermal settings are clearly required to demonstrate the value of the proposed joint inversion based on structural similarity directly; [3] the structural coupling approach is not yet fully developed e.g. the one example shown using resistivity and Vp seems to have little effect on the resistivity image; [4] one of the key datasets presented by the PI (a Vp-resistivity scatterplot) did not show strong evidence for the presence of a common structural constraint in the data; [5] the justification for the structural similarity is vague, being somewhat loosely related to the faulting rather than to specific physical properties of the rock that both resistivity and Vp would both depend upon.

PI Response:

Reviewer 23521

Comment: Everything was put together at the last minute, which is fine, but unfair to other colleagues that submitted everything weeks ago.

PI Response:

Reviewer 23641

Comment: Testing innovative approach at a field project in which stimulation approach is untested and uncertain. Success of this project reliant on a successful stimulation and resulting fluid flow changes. Project has been delayed by permitting challenges associated with the field project stimulation plan.

PI Response:

IMPROVEMENTS

Reviewer 23435

Comment: Ensure that all data are used to validate the relationship between MEQs and fluid flow so that the EM inversion is not forced in the wrong direction. More detailed MEQ analysis to differentiate between non-fluid and fluid flow related MEQs would be useful (and admittedly difficult). But with a good broadband array geometry there might be a chance.

PI Response:

Reviewer 23550

Comment: [1] be more honest in terms of what information on characterization of fractures and flow within fractures could really be expected from a time-lapse joint inversion using the structural constraint; [2] demonstrate the validity of the pursued approach using synthetic studies - the reprints of conference papers on this subject are reassuring, but the a few minutes of the presentation devoted to this issue would have been good; [3] continue to work on development of a true structural constraint inversion where both resistivity and Vp model parameters can be adjusted to enforce the constraint. Right now, the approach is biased towards adjusting the Vp images only in order to force this constraint; [4] justification for structural similarity is currently vague and should be better demonstrated e.g. the interpretation of the resistivity structure for Coso was confidently given in terms of clay content and temperature, but it was not clear to me what constraints are available to confirm this qualitative interpretation of the resistivity images.

PI Response:

Reviewer 23521

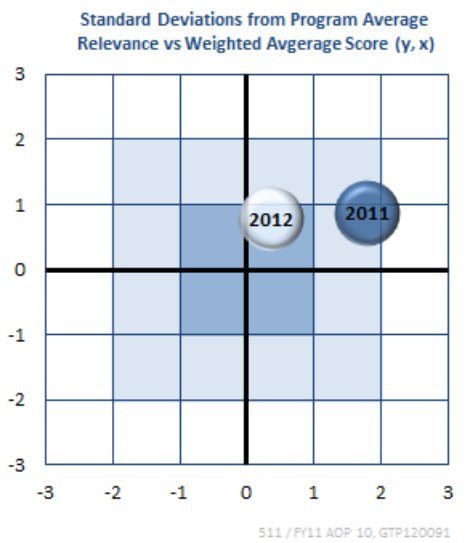
Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23641

Comment: Beyond the scope of this project, but comprehensive testing of the technique should include sites using a variety of stimulation techniques to increase probability there will be EGS reservoir creation and fluid flow for the technique to image.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: 511 FY11 AOP 10
Project: Application of Microearthquake (MEQ) Monitoring for Characterizing Enhanced Geothermal Systems
Principal Investigator: Majer, Ernie
Organization: Lawrence Berkeley National Laboratory
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23489

Score: 3.0

Comment: MEQ definitely has capacity to describe changes occurring during production of geothermal resources, Changes in reservoir flow properties during production and the domination of flow by certain zone characteristics will be a chief enabler or limiter in the recovery prediction (reserve estimation) of geothermal resources.

PI Response:

Reviewer 23583

Score: 4.0

Comment: This project is vital to GTO's EGS goals and has three major objectives: 1) to install, operate, and/or interface MEQ seismic arrays at all GTO EGS Demo sites and make these data available to all, 2) to develop and test advanced seismic instrumentation high-quality data at affordable costs, and 3) to develop reliable analysis techniques for understanding the performance of the EGS systems, while developing advanced induced seismicity mitigation techniques. Success in this project will vastly improve practical and scientific understanding of the role MEQs can play in monitoring for fracture enhancement and imaging of fracture systems for all EGS projects, both from a reservoir management and public acceptance point of view. For the most part, these goals have been achieved by the project thus far, attaining notable progress and impact toward accomplishing GTO's EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment." When fully completed, these achievements will significantly advance progress towards reducing EGS hydraulic fracturing knowledge gaps and further the deployment of permeability-enhancement technologies. This project, if successful, will improve, significantly, understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing advanced MEQ monitoring systems and analysis techniques to the geothermal industry.

PI Response:

Reviewer 23401

Score: 4.0
Comment: High-impact, high-reward project.

PI Response:

Reviewer 23625

Score: 3.5

Comment: Cost efficient, high precision monitoring of microseismic events during stimulation and operation of an EGS is crucial not only for the understanding of the reservoir, but in particular for public acceptance of hydraulic stimulation activities in the subsurface. This is not only true for geothermal applications, but probably even more for the shale gas industry. In this sense the relevance of this project goes beyond the GTO.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23489

Score: 3.0

Comment: The basic approach is satisfactory only for larger scale changes in the reservoir. Reasonable project advancement but still looking at MEQ without matched field processing and sensors close to the geothermal source. The remote sensors used in this project are a problem to picking up the small seismic signals (-3 to -1 Mm) that are descriptive in natural fracture activation. Sensors placed with the slim hole drilling technologies may be better at solving this problem. Need to go much deeper than a thousand feet with the sensors and look at the formation and fracture behavior over a longer time.

PI Response:

Reviewer 23583

Score: 4.0

Comment: There are three major goals for this project divided into six major tasks but only Task 5 was reported on this year: state-of-the-art and next generation instrumentation upgrade and deployment. The technical approach for Task 5 was thoughtfully planned, very effective in implementation, adaptable, and has succeeded in achieving the project's objectives. The technical/scientific rigor employed in advancing sensor and instrument frequency response, bandwidth and S/N are of the highest quality and several pathways have been discovered and being tested. The focus of the project is very effective, with the majority of the components of the project contributing to significant progress in overcoming

barriers/ knowledge gaps. The execution of the approach is outstanding, guaranteeing that the “backbone” MEQ information, critical for the success of all GTO EGS projects, will be state-of-the-art.
PI Response:

Reviewer 23401

Score: 3.0

Comment: Correctly focused on field results.

PI Response:

Reviewer 23625

Score: 3.0

Comment: The answer to better microseismic monitoring depends on number of recording stations and the instrument sensitivity. One key issue are instrumentation costs. The deployment of TDSA appears to be an extremely promising development. Besides of being low cost devices it would allow inexpensive slim holes. In future the regulator will demand detailed microseismic monitoring all geothermal projects. This will cut significantly in the economics of such projects, and cost reduction in microseismic monitoring are mandatory.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23489

Score: 3.0

Comment: Reasonable project advancement within the limits of the scientific approach. This project demonstrated good networking, collaboration and instrumentation selection (with my reservations about depth on sensor placement). However; I was left wondering how well the monitoring delivered did or even could fulfill the fracture description task on a scale suitable to assist in geothermal reserve estimation in an area.

PI Response:

Reviewer 23583

Score: 4.0

Comment: It is difficult to analyze the budget, costs, scope and schedule for this project because it is an AOP project (aka, year-to-year funded), only Task 5 was reported on this year (as agreed to with GTO), project completion and budget are tied to all the EGS Demos, and the way the information is presented. However, it is possible to glean some information: 1) started Oct 2009, 2) maybe 60% done, depends, 3) total budget about $1M in FY11-12, 4) industry support $200K (Should this be added to or included in the previous number?), 5) Task 5 is $524K spent out of the total budget (unclear), and 6) there is an industry cost share of $396K. Consequently, though the project's accomplishments indicate notable progress and impact to its goals, it is impossible to comment on the resources expended and adherence to a project schedule. All that being said, significant progress was demonstrated with Task 5: new sensors have been built and tested and new fiber optics-based devices have been identified. The quality and impact of these technical accomplishments and results are very high. The focus of the project is very effective, with the majority of the components of the project contributing to significant progress in overcoming barriers/ knowledge gaps. However, the progress of the tasks in meeting project objectives cannot be evaluated because of all the reasons mentioned above. The level of productivity in work underway and future work and the value of the accomplishments compared to the costs cannot be evaluated.

PI Response:

Reviewer 23401

Score: 3.0

Comment: Limited by EGS project partners.

PI Response:

Reviewer 23625

Score: 2.0

Comment: Difficult to assess from this single presentation.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23489

Score: 4.0

Comment: Good coordination - no problems in this area.

PI Response:

Reviewer 23583

Score: 3.0

Comment: There are three major goals for this project divided into six major tasks but only Task 5 is reported on this year: state-of-the-art and next generation instrumentation upgrade and deployment. Except for the fact that budget, costs and timeline for this project, cannot be quantified, so far, it looks like project management has been effectual in getting the work done and plans to move forward are reasonable, logical, and likely to succeed. Control points are not discussed probably because they are tied to the demos.

PI Response:

Reviewer 23401

Score: 3.0

Comment: Management presentation more confusing than necessary. Presentation not as sharp as the project work seemed to be managed.

PI Response:

Reviewer 23625

Score: 3.0

Comment: Highly professional management. Excellent network and coordination with industry, national and international researchers. From the presentation it was not clear how much cooperation in the development of tools exists with oil & gas services industry.

PI Response:

STRENGTHS

Reviewer 23489

Comment: The technical approach and the collaboration are the best atributes that enabled a good level of progress.

PI Response:

Reviewer 23583

Comment: This successful project, as yet not completed, has achieved notable progress and impact toward advancing GTO's EGS mission and significantly reducing EGS reservoir creation technology barriers. The implemented scientific/technical approach is very well thought out, reasonably likely to succeed and has been/should be effective in achieving the project's objectives. The project's accomplishments have been outstanding and the quality and significance of the technical accomplishments and results are very high.

Project achievements suggest that project management has been effectual in getting the work done and plans to move forward are reasonable, logical, and likely to succeed.

PI Response:

Reviewer 23401

Comment: See other remarks.

PI Response:

Reviewer 23625

Comment: Access to latest instrumentation technology.

PI Response:

WEAKNESSES

Reviewer 23489

Comment: First; to really describe the changes occurring during production of anything (fluids, heat, etc.) from a reservoir, the sensors must be close enough and sensitive enough to catch hundreds of microseisms in a few hours. Second; analysis of the points via a time/event linkage can follow trends of opening and closing of fractures and fluid movement and even flow path alteration over time. This project was limited in this effect although the data gathered might be re-processed easily.

PI Response:

Reviewer 23583

Comment: The progress of the tasks in meeting project objectives cannot be evaluated because the scope and schedule are difficult to communicate for several very good reasons. In addition, the level of productivity in work underway and future work and the value of the accomplishments compared to the costs cannot be evaluated. The project's schedule, costs and budget are difficult to evaluate. How does GTO know that the PI is doing an effective job?

PI Response:

Reviewer 23401

Comment: See other remarks.

PI Response:

Reviewer 23625

Comment: Possibly too much focussed on the Geysers monitoring network.

PI Response:

IMPROVEMENTS

Reviewer 23489

Comment: Use deeper placed instruments and re-process data with a matched field processing technique that focuses on linkages with time, fluid produced, heat changes, etc.

PI Response:

Reviewer 23583

Comment: Provide clear and succinct project budget, cost, and scope and schedule information and add control points, linked to the best available EGS demo project information, should be addressed in the future.

PI Response:

Reviewer 23401

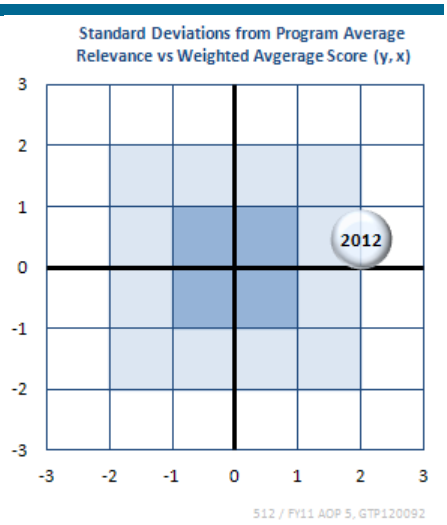
Comment: See other remarks.

PI Response:

Reviewer 23625

Comment: Try to implement as many TDSA arrays and set up as many slim hole monitoring arrays as possible at various geothermal sites, also in places where standard microseismic monitoring arrays are already in operation.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: 512 FY11 AOP 5
Project: Imaging Fluid Flow in Geothermal Wells Using Distributed Thermal Perturbation Sensing
Principal Investigator: Freifeld, Barry
Organization: Lawrence Berkeley National Laboratory
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 3.0

Comment: Extremely useful to know flow profile in such detail and logistically useful manner (with other tools and no likely well damage). Seems to handle temps up to 240c which is useful but needs to be proved. The work seems to be amenable to extension to acoustic measurements for very high frequency geothermal VSP, somewhat qualitatively validated with an independent geophone string. This aspect of the work needed more discussion. This acoustic imaging might be effectively coupled with flow measurements to quantitatively estimate productivity as a function of depth. I am not sure the PI fully grasps how this work could be extended. The Raft River deployment is essential in establishing the relevance of this technology. The real time monitoring of specific fluid flow points in a well (with little or no well or equipment risk!) would be an astounding achievement. An added an potentially game changing tool could result from the acoustic sensor capabilities (downhole VSP), again with little or no risk to the well or borehole equipment.

PI Response:

Reviewer 23563

Score: 4.0

Comment: Application of more measurements to help characterize properties of EGS which can yield models with more predictive power for management is high priority. This work is all about a heat pulse / flow sensor using fiber-optic distributed temperature sensing (DTS), which enjoys wide acceptance in the oilfield, to measure temperature profiles in a geothermal wellbore coupled with a temperature perturbation capability, a measure of local thermal conductivity. This is valuable data to constrain thermal heat transport models. Although not discussed, this technique could be deployed in horizontal wells spanning the geothermal reservoir, enabling a continuous monitoring of reservoir temperature profiles between the injection and production points. The advantages for monitoring thermal drawdown, a major interest, are apparent. In addition the temperature profiles could help extract more information from reactive tracers, since we could constrain the temperature profiles they actually experienced. This is a significant development if its costs can be made acceptable.

PI Response:

Reviewer 23425

Score: 3.3

Comment: Project focuses on using heat-pulse flow sensing in geothermal wells using commercial technology. It has been successfully used down to about 1.5km depth. New technology has been developed allowing incorporation of acoustic and heat pulse technology (DTS) into a single package. Package more robust than used previously. The remaining task described here is deployment of the fiber-optic imaging cable at Raft River. Heat-pulse monitoring will also be used for CO2 sequestration monitoring. This novel approach could be lead to a very significant method for estimating fluid flows in the vicinity of a borehole.

PI Response:

Reviewer 23550

Score: 4.0

Comment: This project involves novel instrumentation development with potentially high impact in EGS applications. It is well known that fiber-optic DTS can provide spatially extensive information e.g. when applied in a well. The deployment of a heat pulse in conjunction with DTS designed to be used in the conditions relevant to geothermal wells is a significant technological development that could have substantial impact. The team points out that all the components except the cable already exist for deep well DTS applications, including the heat pulse component. The team is making highly relevant contributions via the development of hardware to improve operational range of these technologies so that they can be used in the environmental conditions represented by a geothermal system. The product developed here clearly has strong potential for implementation as a new technology in geothermal exploration and the cables developed under this project appear to be ready for commercialization.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 3.0

Comment: An admirably opportunistic attitude and approach with respect to technology deployment but perhaps a bit weak (at least in the presentation) with respect to clear scientific bases. I did not see any peer reviewed literature cited here. Deployment in a hole with a well known flow (PTS) profile and borehole televiewer would validate the tool. The discussion of inversion was too limited to comment on.

PI Response:

Reviewer 23563

Score: 4.0

Comment: The approach is based on Distributed Temperature Sensing which is a mature technique used in oilfields. A bit of novelty is the temperature perturbation cable which will allow thermal conductivity measurements in the reservoir to made using the same cable. A next phase for this should include deployment in field tests. An added development phase should begin to look at horizontal well deployments. Temperature and thermal conductivity profiles across a reservoir interval should have high interest.

PI Response:

Reviewer 23425

Score: 3.5

Comment: Technical approach is novel. Such approaches are needed to make progress in tracking subsurface fluid movement. Heat-pulse imaging provides solution that can assess progress of stimulation effort while stimulation is occurring. Can spatially identify wellbore features with resolution of order centimeters according to PI. DC power usage allows deeper operation than previous versions of this technology. New cable was deployed successfully at Raft River. System can be installed permanently and powered remotely with solar panels. System can also function as an acoustic transducer owing to high sensitivity to strain.

PI Response:

Reviewer 23550

Score: 3.0

Comment: The incorporation of integrated acoustic sensing with a heat pulse DTS makes for a novel technology that has clear application to geothermal exploration and production. Although the incorporation of acoustic sensing within the instrumentation was not the primary project objective, this is a valuable approach that is being followed here. Most of the data acquisition components being utilized here are commercially available and the primary scientific approach involves integration of existing instrumentation. The major technological advancement being pursued by the team is the development of a new fiber optic cable with multiple functionality including heat pulse and acoustic sensing.
PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435

Score: 4.0

Comment: The project has clearly succeeded in modifying an existing technology for geothermal use. It seems to be on track to meet project objectives but coordination with Raft River is likely to be problematic. The Raft River validation and modeling is essential to establish this technology as a useful geothermal tool.

PI Response:

Reviewer 23563

Score: 4.0

Comment: This device and technique are ready for commercial demonstrations. Only thing left is field acquisition at the Raft River site. Can do distributed acoustics (with Silixa not originally funded) and DTS together. For example, perform DTS during fracture initiation in real time. One tool (1/4 inch diameter) with fiber and copper together with a 240 C rating which will go higher to 300 C. New 13 cm resolution will be very useful for packer locations and integration with acoustic sensing such as VSP. When queried, they said 6 km horizontal well deployment idea is in progress. Thermal conductivity can be radially profiled.

PI Response:

Reviewer 23425

Score: 3.3

Comment: System is successfully deployed at Raft River RRG-9. Example of novel technology using commercial technology that will increase reliability.

PI Response:

Reviewer 23550

Score: 3.0

Comment: The team has developed a unique tool that can handle high pressure and temperature and has the potential to image the development of fractures during EGS. The team has also identified other geothermal uses of the technology e.g. monitoring well cement installation and in situ characterization of a potential reservoir. The team has employed state-of-the art DTS technologies that offer high spatial and temporal resolution. Although the inclusion of distributed acoustics was not originally part of the project, significant progress in the development of an integrated cable has been made.

Although the cable not yet been run as a heat pulse in the field, the team has plans to do this shortly. The project summary specifically mentions development of an associated methodology for flow imaging, involving determination of in situ thermal conductivity and basal heat flux – it is not clear what progress has been made in this respect. Apparently, these tools already exist and are available to the project team and no progress was reported on this issue. Consequently, It was not clear to me how DTS data alone be used to determine this such information as DTS does not provide temperature changes away from the borehole. Some explanation of the interpretation tools that will need to go along with the measurements would have been useful.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 4.0

Comment: This project has clearly been successful in developing and deploying the technology. The collaboration with Silixa to leverage the data to VSP imaging is a great example of opportunistic project management.

PI Response:

Reviewer 23563

Score: 4.0

Comment: A very well run project with (in my opinion) a very valuable product.

PI Response:

Reviewer 23425

Score: 3.3

Comment: This flow or heat transport imaging approach seems to be a good deal considering the budget involved. Overall, management seems to be competent. Progress seems good in going from TRL4 to TRL8. This is a good example of what can be achieved when focusing on a single novel idea that benefits from recent improvements in hardware capability.

PI Response:

Reviewer 23550

Score: 4.0

Comment: The team reported good progress on spending given the maturity of this project. The team wishes to hold back on funds in order to take advantage of collecting a real dataset in a geothermal field via a no cost project extension. This seems like a very worthwhile objective. The team also reports good synergistic benefits of piggy-backing on other geothermal projects e.g. the project on micro earthquake networks (Majer, PI). Good evidence of project collaborators and also vendors for the product was presented. Links to opportunities to learn from CO2 sequestration studies using the technology were also presented.

PI Response:

STRENGTHS

Reviewer 23435

Comment: The development and deployment capabilities are real strengths.

PI Response:

Reviewer 23563

Comment: Very successful application.

PI Response:

Reviewer 23425

Comment: The method leverages on the novel characteristics of optical fibers and is a highly creative adaptation of the classic hotwire anemometer approach to obtaining important information about heat transfer and fluid flow in the vicinity of a geothermal well. The method might be useful for giving immediate thermal efficiency improvement information following the stimulation of a geothermal well. Significant "bang for the buck" given the cost of the project and enhancement of the TRL to date.

PI Response:

Reviewer 23550

Comment: Development of unique data acquisition hardware for acquiring distributed temperature and acoustic data in geothermal settings. Other strengths are clearly noted in the comments to other criteria.

PI Response:

WEAKNESSES

Reviewer 23435

Comment: The PI needs more exposure to existing geothermal data and models from similar work. There is also a need for the PI to demonstrate that the geologic and borehole complexities are understood well enough that he is not surprised as he proceeds with deployment and interpretation efforts.

PI Response:

Reviewer 23563

Comment: none

PI Response:

Reviewer 23425

Comment: Would like to see more modeling of results with TOUGH to better interpret the temperature fields obtained from the method. I realize this will come in the future, but it would be helpful to see how this data might be used.

PI Response:

Reviewer 23550

Comment: An explanation of the interpretation tools for modeling the datasets acquired from this hardware was missing. I noted few other weaknesses.

PI Response:

IMPROVEMENTS

Reviewer 23435

Comment: The tool should be deployed in a geothermal well where televiewer and PTS surveys have been done to compare results.

PI Response:

Reviewer 23563

Comment: Ready for commercial priactice - let that step guide further improvements.

PI Response:

Reviewer 23425

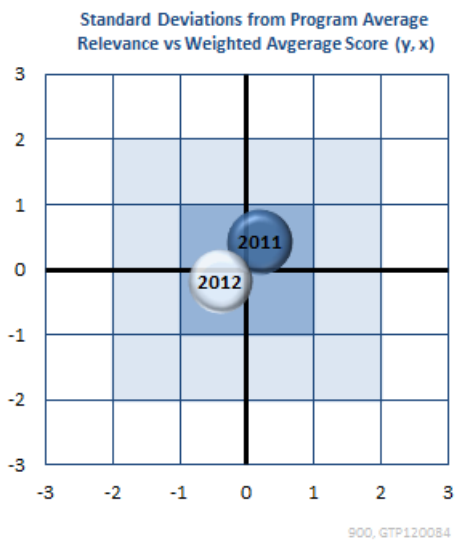
Comment: More forward models allowing graphical interpretation of temperature gradients in terms of changes in fluid flow and heat transfer would be helpful. You can't do everything for 321k but it would be helpful to have this at some point. It would also be a good selling point for industry to see what can be done with this type of data.

PI Response:

Reviewer 23550

Comment: Better integration with, and explanation of, the modeling frameworks that will be used to interpret the datasets acquired from this DTS system.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: 900
Project: Fluid Imaging of Enhanced Geothermal Systems through Joint 3D Geophysical Inverse Modeling
Principal Investigator: Newman, Greg
Organization: Lawrence Berkeley National Laboratory
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 3.0

Comment: If the joint imaging and full elastic MEQ inversions can be developed, it will be a significant contribution. I am not sure the team is focused and integrated enough and the cost will not improve acceptance of the technology. Double difference MEQ relocation is not new but it is good to see it applied to Coso. It would be more impressive if the range of MEQ magnitudes and error ellipses were shown. More discussion on the "common structure" joint inversion approach is required to determine its utility and relevance.
I am also concerned that the focus on Iceland is inappropriate given that there are few (if any) U.S. fields producing in basaltic/spreading center/near surface magma terrains. The Icelandic focus is arguably justified given the data availability but would this justification survive a cost benefit analysis?

PI Response:

Reviewer 23563

Score: 3.0

Comment: This project is all about geothermal fluid imaging. Seismic and EM methods have obvious applicability for characterizing EGS with both having complementary sensitivities to stricture and fluids distributions. Both are used individually, but this work joins other work to examine joint inversions incorporating data and modeling from both modalities. Microearthquakes can help locate fractures and EM methods are sensitive to fluids being transported in the fracture set, which may not include all fractures.Both areas of information are important to reservoir management. The impact is magnified by the goal to apply joint techniques to multiple sites, thereby gaining valuable experience. I want to caution that claims for imaging flow in individual fractures is unlikely (though highly desirable). Instead, a more realistic claim would be imaging fracture network flow patterns with greater resolution.

PI Response:

Reviewer 23425

Score: 3.0

Comment: The main objective of this project is to determine the feasibility of using data from MEQ and EM surveys to image the fluid distribution within Enhanced Geothermal Systems.This will involve developing new geophysical imaging technology to map fractures and fluids arising from EGS stimulation. The PI states the main challenge of this project is to develop a coupled imaging process using MEQ seismicity and EM resistivity surveys to map fluid bearing fractures as electrical resistivity and MEQ imaging on their own do not have sufficient resolution to map fractures. This is a novel project with potentially significant benefits for EGS if its objective can actually be achieved. However, this still seems necessary to demonstrate.

PI Response:

Reviewer 23550

Score: 3.0

Comment: This project has relevance to the geothermal program's mission and goals as it aims to develop better injection strategies for geothermal exploration/production that would be conditioned on the unique information obtainable from geophysical datasets. The development of geophysical techniques for visualizing the dynamics of fluid flow in geothermal systems would represent a significant scientific advancement over how geophysics is usually used in geothermal exploration for imaging of static geological structures. The team argues that the development of high resolution imaging of fractures is needed to map EGS fluids and that there is potential to do this with geophysics. However, the information content of the geophysical dataset is somewhat unclear in this regard. Currently, there is some ambiguity in what can really be expected to be resolved (in terms of fluid imaging) from such surface geophysical datasets given their inherently low resolution. This issue should be better addressed by the team.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 3.0

Comment: Given that the point of this work is joint inversion, I was surprised to see resistivity images without seismicity data (the exception being one Coso slide). The injection seismicity data would be improved with an injection well rate, volume and pressure history and seimicity distribution over time plot. The "joint imaging for common structure" was inadequate given that this is key element in the project deliverables. The full elastic MEQ inversions are potentially useful but the presentation failed to elaborate on how and where this would be done (hopefully Coso) and if data quality would be adequate to pursue these inversions.

PI Response:

Reviewer 23563

Score: 3.0

Comment: They plan a staged process to evaluate MEQ and EM techniques: MEQ and EM data individually, joint inversion of EM and MEQ data in a leap-frog fashion, fully coupled joint inversion of EM and MEQ data, fully coupled joint inversion using an elastic model in the acoustic domain. It is important to note that EM data in this context encompasses both MT and CSEM data. This progression makes sense and follows a line of attack that is similar to ongoing efforts in the oil industry. Also application to multiple data sets will expose deficiencies in data collection which should be carefully documented to guide future projects for the betterment of imaging.

PI Response:

Reviewer 23425

Score: 2.5

Comment: The PI states the main challenge of this project is to develop a coupled imaging process using MEQ seismicity and EM resistivity surveys to map fluid bearing fractures as electrical resistivity and MEQ imaging on their own do not have sufficient resolution to map fractures. A statement of how this should be done is provided in the 2012 summary to which the reader should refer. There appear to be separate inversions of EM and MEQ data presented with discussion but most of the work appears to be field oriented as opposed to development of a suitable computational imaging approach that couples MEQ to EM data. There is a plot of MEQ locations overlain on an EM inversion in the presentation, but this appears to be just a combined plot and not a joint inversion of EM and MEQ data sets. From what is presented, it is very difficult to judge what has really been done to date to achieve the main objective of the project.

PI Response:

Reviewer 23550

Score: 2.0

Comment: The scientific approach relies on combining microseismic and electromagnetics to improve mapping of fluid networks in geothermal systems. However, the objective to map fluid networks using EM is unlikely to be realistic given the inherently low resolution of this technique. The team plans an ambitious joint analysis/inversion of microseismic and electromagnetic datasets in a time lapse sense. The concept is novel and there is good potential here for joint inversion if both methods are sensing same physical processes. Although it is reasonable to argue that this may be the case, thus justifying the time-lapse joint inversion framework, the concept is not well demonstrated here. The team did present some information to show that they have made progress on this idea, primarily that the cross-gradient constraint used in the structural inversion seems to provide an opportunity to tighten the resolution of the EM imaging of the fluid dynamics around the zones of seismicity. Certainly, the improvement in the inverse methods for reconstructing images of geothermal structures, and changes in these structures over time would have broad impact to the geothermal program.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435

Score: 2.0

Comment: It is difficult to state that great progress has been made given the contents of the presentation. The EM inversions and MEQ inversions were not even on the same figure(s). It is a bit disappointing to see another DOE lab "we're almost there. trust us" in the "future directions" slide of the presentation. At this point in the project, a joint inversion should have been attempted and presented so that future work would be more efficiently focused on validating joint inversion results and identifying key uncertainties and methods for their mitigation and/or reduction.

PI Response:

Reviewer 23563

Score: 3.0

Comment: MEQ results do not show reservoir fluid mapping on their own. This is not surprising and of coarse motivates adding EM data which is sensitive to fluids, but not always as expected. Evidence found for using coupled MT and MEQ data. Aperture of MEQ networks are sometimes limiting, a data acquisition problem that needs to be corrected in the future. As models gain refinement, more realistic survey planning can be done. MT images of three sites done. Seismic data worked on for two sites. Joint inversions to come - MEQ and (MT & CSEM) - Big questions: where are the fluids, how are they changing in time, management of drilling. Don't expect resolution of individual fractures, but instead more smeared out fluid distribution. This overall effort seems well defined and making progress. Results will help set the stage to evaluate needed future developments in imagery.

PI Response:

Reviewer 23425

Score: 2.5

Comment: Project identified and instrumented Raft River site with EM and MEQ acquisition systems. Developed background resistivity model. Made observations about MEQ distribution pre-stimulation and during stimulation. Project has clearly produced some interesting results. While probably useful, it is not apparent how these results to date would be integrated into a tool or methodology used by industry.

PI Response:

Reviewer 23550

Score: 3.0

Comment: One key accomplishment is that MEQ and EM datasets have been collected at the Raft River site. Furthermore, the EM data include both TEM and MT measurements, being established techniques for geothermal exploration via geophysical measurements applied with sensors from the surface. The team has performed a 3D MT survey, which appears state of the art in terms of data acquisition, particularly given the fact that it is a time-lapse survey that has been acquired. The team has also developed a 3D image of the reservoir using combined MT and TEM datasets, although the benefits of the joint inversion based on a structural constraint have not been well demonstrated as of yet. More progress on the joint inversion could have been demonstrated by showing its performance on a synthetic dataset that could be designed to illustrate the validity of the joint inversion strategy being developed here. Although the team argued that the focus of the work performed on this project is the interpretation of the field dataset, a demonstration that the approach has merit using a synthetic study would have gone a long way towards removing uncertainty about the benefits of the approach. The team has also installed seismic stations for MEQ analysis and the acquisition of new datasets. However, there appears to be some limitations of the seismic modeling for source location based on this dataset.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 2.0

Comment: The fact that the EM inversions did not have MEQ data suggests that the work is not well coordinated. The work in Iceland shows good collaborative intent. There was insufficient discussion on how the applicability of the models would be demonstrated. Would the final models be tied to injection and production data or would the model itself demonstrate applicability?

PI Response:

Reviewer 23563

Score: 3.0

Comment: No discernable problems.

PI Response:

Reviewer 23425

Score: 2.0

Comment: This project is estimated to be 70% complete but would seem like we are still somewhat distant from the objective. Only a little over 10% of the funding appears available. It seems like a good plan to request a cost-free extension although somewhat limited support is left.

PI Response:

Reviewer 23550

Score: 2.0

Comment: The progress and management of the project was not very clear to me from the information provided by the presenter. I got the impression that progress was slow on the development of joint inversion, although the project team did present the reviewers with a conference paper that details the inversion development and includes a synthetic study. This team is seeking a project extension to develop the main elements of the project further. It appears that this need results from delays in the acquisition of the field data.

PI Response:

STRENGTHS

Reviewer 23435

Comment: The completed EM inversions are a potential strength and the coordination with Iceland is a marginal strength becaue the key differences between Iceland and U.S. geothermal fields were not discussed with respect to how those differences impact inversion results and applicability to U.S. fields. The double difference Coso MEQ relocation data was signficantly useful but would have been more impressive if we knew the eq magnitudes, focal mechanisms and number of events.

PI Response:

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Comment: The PIs are very competent and energetic experts in their respective fields. The problem they chose is admittedly a major challenge and I will be most impressed if they ultimately achieve it. It is important to aim high and they have. They seem to have access to good sources of EM and MEQ data. I think they are in a good position to make an eventual breakthrough with the development of a satisfactory approach to obtaining a joint inversion of the data.

PI Response:

Reviewer 23550

Comment: The development of geophysical techniques for visualizing the dynamics of fluid flow in geothermal systems would represent a significant scientific advancement over how geophysics is usually used in geothermal exploration for imaging of static geological structures. Other strengths are mentioned in the earlier criteria.

PI Response:

WEAKNESSES

Reviewer 23435

Comment: This project does not seem to be well coordinated given the joint inversion objective. Such an effort requires constant iteration internal coordination of efforts that seem to be lacking here as demonstrated by the EM inversions with no MEQ data. It should have been easy to produce such images if the team were effeciently coordinated.

PI Response:

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Comment: It is difficult to assess weakness or success in this project given the information provided. The project has a very significant objective, but it is somewhat unclear how much progress has actually been made toward this objective. A lot of information is presented about different things that have been done but it remains unclear how all this comes together to reach the final objective. This reviewer has been unable to isolate a coherent picture that will allow a full assessment of the project, which is unfortunate as a lot of work has clearly been performed.

PI Response:

Reviewer 23550

Comment: There is serious ambiguity in what can really be expected to be resolved (in terms of fluid imaging) from such surface geophysical datasets given their inherently low resolution. This issue should be better addressed by the team.

PI Response:

IMPROVEMENTS

Reviewer 23435

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Comment: The PI states the main challenge of this project is to develop a coupled imaging process using MEQ seismicity and EM resistivity surveys to map fluid bearing fractures as electrical resistivity and MEQ imaging on their own do not have sufficient resolution to map fractures. Given this very clear statement, I guess I would have expected a detailed discussion of the progress made in coupling MEQ to EM data. It seems that mapping fluid flow in fractures with field quality EM surveys and MEQs is going to be a major challenge. Possibly using synthetic data sets, can we say anything about the EM resolution required to do this in any meaningful sense? How can MEQs be utilized to address this resolution problem? Are geologic constraints or assumed models of fracture flow necessary to perform joint inversions? Should

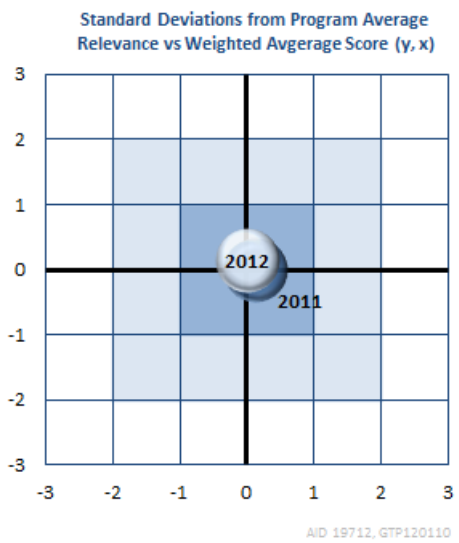
coupling TOUGH simulations to EM imaging and MEQ locations be considered as a way to link resistivity and seismicity?

PI Response:

Reviewer 23550

Comment: Justification of the proposed joint inversion strategy needs to be much stronger and limitations of the approach more clearly defined.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: AID 19712
Project: Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in Enhanced Geothermal Systems (EGS) Reservoirs
Principal Investigator: Huang, Lianjie
Organization: Los Alamos National Laboratory
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 4.0

Comment: There will always some issues associated with scaling core data to benchscale and field scale use. The use of reservoir fracture geometries is likely to be useful. The use of the Brady's #3 core and collaboration with Ormat and U of N geologists is likely to add relevance to the work, at least at the Brady's field. The quantitative estimation of a geothermal reservoir permeability structure would be a great accomplishment if it can be validated. The scaling and coupling of core data to fracture network to FEHM modeling would be a very useful exercise. The high resolution elastic waveform modeling coupled with the FEHM modeling could produce useful results and validate the coupling of MEQ and poroelastic/thermomechanical modeling.

PI Response:

Agree and thank you.

Reviewer 23563

Score: 3.0

Comment: Project addresses imaging and modeling of fracture networks and fluid flows in EGS reservoirs. Ultimate goal is to connect imaging results from a Double Difference elastic wave inversion procudure to coupled reservoir model dealing with fluid flow, heat transfer and rock alteration (LANL). This is an ambitious objective that won't be fully realized in this study (they are near the end of the project term), but some useful progress may be achieved.

PI Response:

Agree. Our goals were high, time is limited, and the budget was reduced. But we do hope to add significant results to the community prior to completion of this project.

Reviewer 23425

Score: 2.8

Comment: There are multiple objectives of this project. First is to develop quantitative methods for monitoring EGS reservoirs using innovative time-lapse seismics and elastic-waveform inversions. Another objective is to use discrete fracture network models based on known geologic features and on studies of recovered core. Third is to improve

predictions of flow, temperature and stress changes in geothermal reservoirs using the LANL FEHM code. These are lofty objectives, but it is not apparent to what degree they have been or can be met by the work that was presented.

PI Response:

See previous response, thank you.

Reviewer 23550

Score: 3.0

Comment: The objective of this project is to advance the monitoring of EGS reservoirs by developing quantitative interpretational techniques. The project has significant potential impact with respect to improving the management of EGS reservoirs. However, I felt that the actual impact of this project has not yet been fully demonstrated by the team, although some significant steps have been. The development of state-of-art numerical modeling frameworks, including a discrete fracture network model, could have significant impact by providing enabling tools for reservoir management. The actual impact in this respect has not yet been fully recognized but the potential for technology transfer appears good.

PI Response:

Agree, and increase in the technical transfer as the project ends is expected.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 4.0

Comment: The fact that several elastic waveform inversions are being tried is a positive indication of PI flexibility. Validation of a model with a model, may not be the best validation of the methodology. The development of a "discrete fracture network" is admirable but there are significant uncertainties associated with such sub surface models. It is important to be aware of those uncertainties as other inversions proceed. It would have been useful to see alternative models of the discrete fracture network that could be used if inversions did not correlate with the one presented. The validated use of 13 core samples is a great improvement over past efforts. More discussion should have been provided on how to scale these core properties to field scale.

PI Response:

Our validation of imaging is to compare our inversion results with known results. The core to field scaling required is difficult in any geologic setting, and doubly so in EGS settings where geomechanics and fracture flow are dominent. We appreciate the reviewers understanding of the complexities involved in this endeavor.

Reviewer 23563

Score: 2.0

Comment: They are testing time-lapse imaging with a new elastic waveform inversion using a double-difference technique which is useful for recognizing changes in small regions. They plan to combine this with a discrete fracture

network model in a Finite Element High Temperature flow model (LANL) for history matching actual field data. This is an ambitious goal which could add good value if successfully completed. I doubt this is possible in the time they have left. It might have been better to focus on the imaging and compare the double-difference technique with other inversion approaches on various models (maybe some syntheic models with progressive complexity) to understand where this technique brings differentiated value and why and the impications for acquiring P- and S-wave data.

PI Response:

This is always an issue with research, but we do hope to accomplish as much our initial project goals as possible. We presented the comparison of the results of our inversion methods with other inversion approaches during last year's peer review meeting, and demonstrated the significant improvement of our new inversion methods.

Reviewer 23425

Score: 2.5

Comment: The PI has chosen some very challenging objectives. However, terms such as "high resolution flow imaging" suggest a capability that seems different from that presented. I don't know how seismic methods will ever be able to do actual high resolution flow imaging. How can seismic methods say anything about local flow velocity or direction? Pumping fluid into a geothermal zone may well change its seismic properties allowing the perturbed volume to be identified which might result in obtaining a sense of where injected fluid flow is going. This seems reasonable and may be what the PI is referring to. Developing discrete fracture network models that match injection pressure versus time histories may be useful but such models are likely to be highly non-unique without including many geologic constraints. LANL's FEHM is a good code but the prediction is only as good as the model used. Deterministic models of highly under-determined geologic regimes must be treated cautiously and are likely to be rather limited in their ability to characterize a number of different parameters in an engineered geothermal system.

PI Response:

During the stimulation in an EGS reservoir, fluid injections lead to changes in geophysical properties within EGS reservoirs. Our initial goal is to obtain changes in geophysical properties quantitatively. The relationship between the geophysical property changes and the fluid saturation/temperation changes can be obtained from core studies. Modeling of geologic systems is a difficult task. We have endeavored to constrain our models with the best available data from University of Nevada and ORMAT. The comments regarding FEHM modeling are valid in regards to any modeling. We agree with the cautions recommended by the reviewer regarding underdetermined models, however, such remarks are applicable to nearly every technique available for study and analysis of geological systems. Modeling makes important contributions to the overall effort and provides an approach for integrating some of the system information.

Reviewer 23550

Score: 4.0

Comment: The technical approach being followed by the team is to develop elastic waveform inversion methods that can improve quantification of EGS systems. The team has performed both experiments on cores and numerical modeling to build a discrete fracture network model for the Brady’s EGS field. The numerical modeling framework being developed appears to be state of the art. However, how the model was parameterized (e.g. using measurements from the core data and the well log data) was not very clear to me.

PI Response:

Core data was used to guide fracture density values at depth in the discrete fracture network model.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435

Score: 3.0

Comment: The project has made significant advances in and met its data and methodology milestones. Key issues that might impede progress were not discussed such as the impact of problematic or relative eq location, ability to resolve stresses given low magnitudes and whether the FEHM code can handle the creation of fractures near the well bore.

PI Response:

FEHM is a continuum code and does not explicitly model individual fracture creation near the wellbore. Rather, the approach taken is to represent the influnce of such fractures on the mass and energy transport equations through prescribed functional dependancies of the various parameters such as permeability.

Reviewer 23563

Score: 2.0

Comment: Double difference seismic inversion techniques (with new regularization) were tested for the Brady model with some success.This was followed by construction of a discrete fracture network model for the Brady field as well as relevant core analyses. However, the Brady field was not used in the FEHT modeling - they mentioned it being done for Desert Peak with some success in history matching. The reason stated was lack of data for the Brady site. There was no discussion of how the imaging/inversion, discrete fracture model construction and core analyses impacted the Desert Peak FEHT results - we were just shown a history match which left more confusion than anything else. There is no clear plan to extend this to other EGS sights to grow the experience developing FEHT models. More generally, I suggest that history matched models of the kind attempted in this study be considered to test some of the tracer interrogation ideas seen in other tracks. Although the model is more expensive to run, it combines use of realistic background geology with a deduced fracture network construction and heat flow to test scenarios for thermal drawdown discrimination, reservoir changes from additional enhancements, drilling decisions, acquisition design for imaging techniques, etc. In other words it becomes a computational testbed. Other site models could be added an similarly use.

PI Response:

Desert Peak was considered as an anlogue site because of it's proximity and simillarity to the Brady's site. The suggested modeling would be a valuable contribution to the planned work at Brady's. Expanding this work to other sites would be an excelling new project that we would be excited to participate in.

Reviewer 23425

Score: 2.8

Comment: The project team has done a lot of analysis of cores and seismic and porous flow modeling. Rather than develop a generalized method that can be applied to any geothermal system, the results obtained seem to be most valuable for assessing the specific systems that were studied (Brady's and Desert Peak). This might well be very useful as a basis for developing a general method for EGS assessment by industry.

PI Response:

Thank you. Detailed study of these systems to validate the generalized methods is one of the primary goals of this project.

Reviewer 23550

Score: 3.0

Comment: The team has conducted some very nice experiments that are providing new information on the elastic velocities of reservoirs; such information could be used to better parameterize models of EGS reservoirs. For example, fundamental laboratory datasets of Vs and Vp changes in response to pressure and temperature have been acquired. They have also demonstrated the use of state of the art imaging technologies to obtain information on the changes in pore structure in response to temperature and pressure changes. A nice element of this project is that important information is being acquired at multiple scales. The team has also presented a nice use of synthetic datasets that demonstrate the potential ability to quantify reservoir changes in terms of elastic velocities as a result of stimulation, based on a simple reservoir model. Furthermore, they have made good progress on model development for imaging both S and P waves. One particularly significant accomplishment is the construction of a discrete fracture network model – such models are critically important for improving the modeling capabilities of EGS reservoirs. One thing that was not entirely clear is how the experimental data are being coupled or fed into the numerical modeling effort. It seems that a lot of information is fed into the modeling framework from the core data. This raises the usual questions about upscaling and the use of a limited number of cores. This is not a criticism, just a comment on a well known problem. The team could do a better job of clarifying exactly what quantitative information is being obtained from the core data.

PI Response:

Thank you. With the short time available during the peer review there was only so much information that could be covered. A large amount of information was obtained from the core samples, including mineralogical analysis via thin sections, porosity and permeabilty measurements of the matrix material, and hundreds of images taken of core to determine fracture density. The porosity and permeability were used to guide the design of the bulk rock properties within the discrete fracture network model while the fracture density was used to help design the flow paths within that model. Mineralogical information could be used in the future to help constrain the strength/stiffness properties of the FEHM model, though limited time did not permit such a detailed use of the data over the course of this project.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 3.0

Comment: Coordination has been good and all the players involved seem to providing data and input as needed. The seismic component was not well represented in this talk which could be an indicator of poor coordination in this area.

PI Response:

The Brady's model with steep faults used to test seismic imaging methods was provided by Hi-Q Geophysical, Inc. that conducted seismic suveys at the Brady's EGS site and worked closly with Ormat and University of Nevada to obtain the model.

Reviewer 23563

Score: 2.0

Comment: This is a comment on the technical plan, its execution and especially its communication for this review. The project as presented left a confusing message. Most of the work on characterization (imaging/core analyses) was done for Brady while FET (the modeling goal) was shown for Desert Peak with no detail. Maybe if they can do some FET for Brady(?) the message will become clearer.

PI Response:

Desert Peak was considered as an anlogue site because of it's proximity and simillarity to the Brady's site while the related information for Brady's site has not been available. The suggested modeling would be a valuable contribution to the planned work at Brady's. We are sorry for any confusion in the presentation. Again with limited time to present a great deal of information some things did need to be glossed over.

Reviewer 23425

Score: 3.0

Comment: The project management appears to be good overall. The effort appears to be commensurate with the amount spent as this project approaches its conclusion. The number of organizations involved is impressive and the project has strong outreach to industry and universities.

PI Response:

Thank you.

Reviewer 23550

Score: 4.0

Comment: This project is largely complete in terms of budget expenditures and appears near completion. The impression given is that the project was well managed. For example, good evidence of project management and coordination of collaborating efforts between various team members was presented. Furthermore, there is strong collaboration between industry, university and federal partners, and mentorship of postdocs and early career scientists. Finally, good evidence of data sharing in terms of sharing of core samples and log data, as well as numerical and experimental datasets was presented. Overall, the project management appears excellent.

PI Response:

Thank you.

STRENGTHS

Reviewer 23435

Comment: The attempted coupling of core, field, and seismic data with the FEHM model could result in a validation of the approach. If the work is validated with data from Brady's operations, it will be a great benefit to the geothermal program. Having such good core data is also a significant strength.

PI Response:

Agree. Access to core data from ORMAT's site was a huge benefit to this project.

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23425

Comment: The PI has been impressive in pursuing a rather diversified number of tasks involving lab studies, seismic data analysis, elastic wave-form modeling and flow simulations. Some interesting results come out of each of these areas that have been considered. The project effort reliably demonstrates just what can be done with the methods that have been employed in analyzing a geothermal system. This work may well provide a basis for developing more generalized approaches ultimately useful to industry.

PI Response:

Thank you. We do hope that our efforts will result in a useful method for industry as well.

Reviewer 23550

Comment: [1] development of state-of-art numerical modeling frameworks, including a discrete fracture network model; [2] team has conducted some very nice experiments that are providing new information on the elastic velocities of reservoirs; [3] a nice use of synthetic datasets that demonstrate the potential ability to quantify reservoir changes in terms of elastic velocities as a result of stimulation, based on a simple reservoir model; [4] construction of a discrete fracture network model; [5] , good evidence of project management and coordination of collaborating efforts between various team members ; [6] strong collaboration between industry, university and federal partners; [7] good evidence of data sharing in terms of sharing of core samples and log data.

PI Response:

Thank you very much.

WEAKNESSES

Reviewer 23435

Comment: The reliance on one realization for the discrete fracture network could be an issue and lead to false correlations. I was also disappointed that there was no attempt to quantitatively scale core observations to field scale parameters.

PI Response:

There is only one realization of the fault network in the DFN model. There were multiple stocastic fracture network realizations used in the development of the DFN model shown in the peer-review. We are sorry we did not cover the model creation in greater detail.

Reviewer 23563

Comment: Results would be more cohesive if they could focus on one field study. Reported results for Brady, but FEHT study applied to Deserk Peak with littel explanation.

PI Response:

We could not apply our reservoir modeling to the Brady's site because the related information has not been available.

Reviewer 23425

Comment: What has been done so far is mostly reasonable. There are significant concerns about scaling from cores to geothermal sized regimes and the accuracy of deterministic models that depend on such scaling. I am sure that other geologic/geophysical constraints are also employed in producing such models. It would be good to understand how this has been done as this will be necessary for developing any generalized method of model building. Even with many geologic constraints, any model will be non-unique meaning that a given deterministic model is only one of many that can match a certain criterion (e.g., parameter history) but that will exhibit very different behaviors when attempting to match other parameters in a geothermal system. It is not clear how useful such deterministic models will be for industry.

PI Response:

There is only one realization of the fault network in the DFN model. There were multiple stocastic fracture network realizations used in the development of the DFN model shown in the peer-review. We are sorry we did not cover the model creation in greater detail.

Reviewer 23550

Comment: [1] the actual impact of this project has not yet been fully demonstrated by the team; [2] approaches to model parameterization (e.g. using measurements from the core data and the well log data) are currently unclear; [3] upscaling core data to be relevant at the field-scale is unclear.

PI Response:

A large amount of information was obtained from the core samples, including mineralogical analysis via thin sections, porosity and permeabilty measurements of the matrix material, and hundreds of images taken of core to determine fracture

density. The porosity and permeability were used to guide the design of the bulk rock properties within the discrete fracture network model while the fracture density was used to help design the flow paths within that model. Mineralogical information could be used in the future to help constrain the strength/stiffness properties of the FEHM model, though limited time did not permit such a detailed use of the data over the course of this project.

IMPROVEMENTS

Reviewer 23435

Comment: More discrete fracture network geometries should be generated prior to other inversions. I would also recommend attempting to scale up core data to reservoir scales. This might be done by applying power law relationships scaled via Guttenberg-Richter statistics for the seismic data (see Shapiro in the Leading Edge, 2010 for example). There are other approaches.

PI Response:

Thank you.

Reviewer 23563

Comment: Make and report a cohesive study for one field.

PI Response:

That is our goal if the data from Brady's site are available.

Reviewer 23425

Comment: I would encourage the PI to consider a more stochastic approach. Monte Carlo methods might be used to do sensitivity studies to determine what parameters are most important and what parameters can be neglect in constructing a geothermal model. From this we can also learn about the effects of uncertainty which are inherent to the nature of geothermal systems. Before completing the project, it would be good to write a paper or report on how to build a geothermal model with all the considerations that must be made.

PI Response:

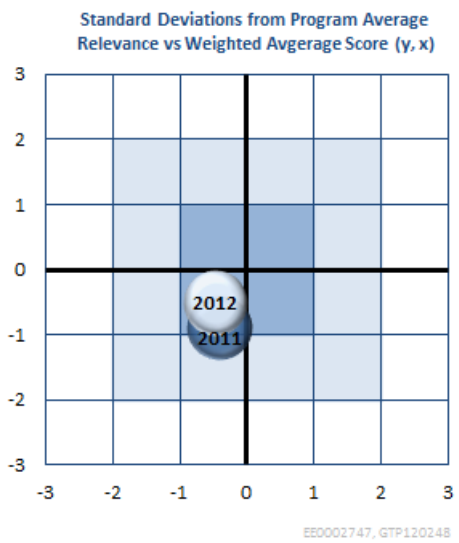
Monte Carlo silulations would add value to the work.

Reviewer 23550

Comment: More consideration of limitations of small scale core datasets when applied to larger scale models; [2] better clarification of exactly what quantitative information is being obtained from the core data is required.

PI Response:

Agree.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002747
Project: Characterizing Fractures in Geysers Geothermal Field by Micro-seismic Data, Using Soft Computing, Fractals, and Shear Wave Anisotropy
Principal Investigator: Aminzadeh, Dr. Fred
Organization: University of Southern California
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23471

Score: 3.0

Comment: This project is relevant to GTO goals in that it can map the distribution of seismic anisotropy at depth (a potential indicator of fracture alignment) and facilitates time-dependent mapping of hypocenters for defining structures and seismic tomography for defining variations in fluid pressure/saturation at depth. However, the presentation contained numerous physical interpretations/conclusions that were poorly justified, as noted below. Thus, more attention needs to be paid to model validation and the physics on which these interpretations are based in order for these results to have the desired impact on GTO goals.

PI Response:

Three independently derived indicators are used to validate the model of fracture network and its propagatation into the high temperature zone. Those include fractal dimension of 2.6 for microseismic distribution which is the same as the nucleation and growth of fractures in random media, significant movement of microseismic fuzzy clusters in high temperature zone and correlation between velocity anomalies with this movement Cross validation of these phenomena would give us a high level of confidence of the ture fracture network model and the areas with higher densities. Also results have been cross validated with other authors like Elikibbi about fracture density.

Reviewer 23583

Score: 3.0

Comment: The goal of this project is to develop better understanding of the mechanisms for the stimulation of existing fractures in the northwest portion of the Geysers field. If the project's goals are achieved, notable progress and impact toward accomplishing GTO's broad EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment…" will be realized. A better understanding of mechanisms to activate existing fractures at The Geysers will notably reduce EGS hydraulic fracturing knowledge gaps and further the deployment of permeability-enhancement technologies in general. This project's goals, as stated, will definitely improve understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing a better understanding of the mechanisms for fracture activation.

PI Response:

Agree.

Reviewer 23412

Score: 2.0

Comment: It has been the intent of operators at The Geysers of use the MEQ data to define structure and connection to injection and production activities. The project results graphics vaguely made any conclusion. The most important part of the project was the Auto picker algorithm and is a deliverable.

PI Response:

With the specific limits of slides, it is our best to present most out of our accomplishment. In our future publications at GRC, and AGU we will issue your concern. The autopicker development has progressed substantially with studies on fuzzy segmentation and neuro-fuzzy autopicker implementation under progress.

Reviewer 23641

Score: 3.0

Comment: Relevant research in MEQ approaches to characterize fractures. Several useful outcomes with near term application to MEQ fracture characterization including auto picker, fractal analysis, time lapse velocity tomography, anisotropy mapping.

PI Response:

Thanks.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23471

Score: 2.0

Comment: This project employs a clever phase picking algorithm, which is then used for improved earthquake locations and to produce maps of P- and S-wave velocities as a function of time, with mapping out of shear wave splitting/anisotropy a work in progress. Other than this, the interpretations of b values, fractal dimension, and stress regime indicators were presented without sufficient physical explanation or justification, and were unconvincing. What, for example, is the physical basis by which one can infer hydrostatic and extensional stresses from P- and S-wave velocities alone? Also, b values ranging from 1.1 to 1.4 were cited by the speaker as evidence that these earthquakes were induced, yet no discussion was presented on key issues widely recognized to be important in b-value analyses, such as magnitude of completeness and the related issue of variation in b values with earthquake magnitude range. Finally, the fractal dimension in and of itself has little physical significance, and in future work I encourage these investigators to explicitly relate fractal dimension to more meaningful parameters related to the fracture population or earthquake frequency-magnitude relations.

PI Response:

We have posted our results and all physical meaning of b-values and Fractal Analysis into our last year annual report to DOE which is avalilable to the public. With the limited slides we were not able to cover all of them. We have also cover most of b- value and fractal part in our previous presentations.

Reviewer 23583

Score: 2.0

Comment: The scientific/technical approach consists of several tasks to better exploit MEQ data at The Geysers: develop a new autopicker using hybrid neuro-fuzzy logic techniques, map fractal structure of network using induced seismicity, develop a Kriged velocity model to observe time-dependence of fracture network and infer stress and rock properties from tomographic inversion results and, finally, verify and fine-tune velocity anomaly maps using anisotropy mapping and fractal results.

This scientific/technical approach is a little disjointed. Why develop a new autopicker? There are many out in the literature, devising a new one for this project was not justified when the goal was to understand fractures. Also, analysis of data to support claims made about its capabilities being better were not offered. Motivation to perform fractal analysis and correlate with b values at The Geysers was not discussed not easy to infer from the materials presented. Determining whether or not the seismicity was triggered versus induced is important but the background for such a statement was not revealed; does 2.6 D really mean induced? What about 2.5D? Finally, Kriged, time-dependent velocity models and inferred rock properties and stresses are important but very little discussion of how the tomography was accomplished and very little interpretive discussion on what the results might mean.

Key technical barriers to achieving the project's objectives such as better descriptions of fracture activation mechanisms were not presented in any detail necessary for evaluation. All in all, there are significant weaknesses and noteworthy areas for improvement in the design of the approach as presented. It is hard to judge the scientific rigor employed in the analyses presented when very little information is provided to evaluate the claims made, furthermore, verification and validation results were not presented, so the overall sense of the presentation did not build confidence in the conclusions. The R&D research plan is not as well thought-out as it could be, the description of, and logical connections between, these different analyses to the overall goal of the project is missing in the presentation, certainly in the interpretation of the results. The project, as presented, will contribute to progress in overcoming stimulation barriers/knowledge gaps.

PI Response:

The development of a new autopicker was considered vital in getting the best possible inversion results. This was to minimize the error that propagates (as a result of picking errors) into subsequent processing steps. The use of the new autopicking algorithm has shown substantial improvements in results, particularly for noisy datasets. The Fractal value is not exact. 2.5 or 2.6 is not make difference about induced sesimicity. Although we comparing the value of 2 with these numbers which is significantly lower. The background of this statement has beed revealed in our last year annual report and our publication at GRC. Tomography part has not been done internally by USC people, we only use velocity models generated by LBNL scientist in our innovative workflow and show how to use these valuale data. The full interperation of velocity models have been published in three different conference paper and will be available in our final report to DOE. with limited slides and time of presentation, we can not fully include our result and interpretation.

Reviewer 23412

Score: 2.0

Comment: After the auto picker development the project should have been considered complete.

PI Response:

Agree.

Reviewer 23641

Score: 4.0

Comment: Impressive scientific/technical approach that has yielded useful advances in MEQ fracture characterization as well as techniques (autopicking) to facilitate and lower cost of this type of work.

PI Response:

Thanks.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23471

Score: 1.0

Comment: The project has made reasonable progress in achieving its stated goals, with phase-arrival autopicker and fractal/b-value analyses already completed. Anisotropy mapping and time-lapse velocity tomography are in progress and are to be completed later this year. The velocity tomography results presented for The Geysers are promising, and appear to show low velocities associated with injection of cold fluids (although I could not tell which velocities, P or S, since the figures were not labeled). However, the physical interpretation of many of the other results presented was questionable, as noted elsewhere in this review, and was presented in a black box fashion, with little obvious attention paid to statistical uncertainties, uniqueness of interpretation, or the physics of the processes being addressed. Unfortunately, two of the papers listed in the Publications and Presentations section of the report are submitted for publication, and the other products consist of titles or abstracts only. Thus, it was not possible for me to investigate further the scientific quality of the work that has been performed under this contract to date (all I could find to look at was a very short AGU abstract written in 2010, which was not very helpful).

PI Response:

We included all of our b-vlaue and fracal result in our last year DOE annual report. We will also publish our result on velocity tomography in GRC this year which the full paper will be availbe online. We have different convinving logic behind our interpretation of velocity models which will be presented in our next year report as well as one of USC student PhD thesis.

Reviewer 23583

Score: 3.0

Comment: As stated in the presentation and summary, the project accomplishments include: a new, validated neural network first arrival auto-picker for MEQ data using a neuro-fuzzy approach, confirmed the induced nature of seismicity

at the Geysers field from the b values and the fractal dimensions of MEQ's, based on LBNL velocity inversions developed Kriged velocity, stress, and rock property fields and analyzed the changes with time to establish the impact of high temperature fluid movement in the rocks on the velocity field.

The accomplishments as presented are minor when compared to addressing the goal of the project, and, in summary, do not justify the claims made concerning progress. For example, in future directions work planned slide 14; many of the tasks proposed do not address the goal of the project. They might be interesting things to do, but do not shed light on the fracture mechanisms at The Geysers. Furthermore, the quality and significance of the technical accomplishments and results are not equal to the resources expended and technical progress towards project objectives—there is significant room for improvement. In addition, the productivity in work underway and future work, and the value of the accomplishments compared to the schedule and costs, reveals that much more progress needs to be made.

PI Response:

No response entered.

Reviewer 23412

Score: 3.0

Comment: With the development of the auto picker completed, the project has accomplished a deliverable.

PI Response:

Agree.

Reviewer 23641

Score: 4.0

Comment: Impressive results in several areas with useful accomplishments ranging from practical aid (autopicker) to new imaging apporach (time lapse velocity changes).

PI Response:

Thanks.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23471

Score: 4.0

Comment: This project appears to be well managed and is proceeding according to schedule. This project is also very inexpensive for DOE, and yet is receiving matching funds from USC, LBNL and Calpine. Partnerships are listed as having been established between the lead investigators at University of Southern California (USC), Calpine and LBNL. However, it was hard for me to figure out what other members of the partnership were doing scientifically, since the four publications/talks listed had the same first three authors, all of whom are at USC and only one non-USC person is listed

on any of the pubs/talks. Given the low cost of this project, I do not consider this to be a real concern, but something that should be clarified in future presentations.

PI Response:

No response entered.

Reviewer 23583

Score: 2.0

Comment: The PI claims the project is on budget, scope and schedule. However, if only 15% of the budget is left and many of the analyses are not completed (see the future work list) then it looks like the project is over spent to the scope. Considerable time and effort has been made but project goals have not been reached. Prospective future plans are of adequate quality and may be effective in meeting the project's goals but so much work for 15% of the budget.

The inclusion of appropriate and logically placed decision points that effect the future direction of the work were discussed but only briefly and the PI claims coordination of activities with collaborators and stakeholders is very effective. Better management practices are desirable in getting the project on to the original overall goal as well as speed-up the productivity.

PI Response:

No response entered.

Reviewer 23412

Score: 3.0

Comment: The completion of the auto picker has been the goal of this project.

PI Response:

Agree.

Reviewer 23641

Score: 3.0

Comment: Results are indicative of a well managed project.

PI Response:

Thanks.

STRENGTHS

Reviewer 23471

Comment: The earthquake location algorithm results are interesting and show some promise for identifying time-variations in P- and S-wave velocities and shear-wave anisotropy within The Geysers geothermal field, as well as defining the seismogenic structures at depth.

PI Response:

The final project deliverables include improved understanding of the fracturing as well as a better understanding of the flow pathways and their time - variant devalopment. Results involving fracture zone identification and integrated analysis involving shear wave splitting studies provide promising results. Some results will be shared at the GRC annual meeting this year.

Reviewer 23583

Comment: As envisioned, this project will definitely improve understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing modeling tools to accelerate EGS implementation. The scientific/technical approach consists of several tasks to better exploit MEQ data to better understand fracture mechanisms at The Geysers. As stated in the presentation and summary, there have been several project accomplishments such as: a new auto-picker for MEQ data, and time-dependent, Kriged velocity, stress, and rock property maps.

PI Response:

Thanks.

Reviewer 23412

Comment: The strength of this project is that it has finished the auto picker.

PI Response:

Work on a more complex hybrid autopicker using a neuro-fuzzy approach is still in progress.

Reviewer 23641

Comment: Mix of practical tools and approaches with bigger picture, more speculative technique development.

PI Response:

Thanks.

WEAKNESSES

Reviewer 23471

Comment: The physical significance of several of the interpretations presented is unclear, especially the claim that b values determined at The Geysers were indicative of an induced origin for the seismicity and that P- and S-wave velocities could be used to infer attributes of the in-situ stress state (i.e., extensional vs hydrostatic stress). The b-values fell in the recognized range of values observed for tectonic events elsewhere, with no discussion of statistical uncertainties or variation in b value with earthquake magnitude range. Also, the stress interpretations based on seismic velocities were poorly justified, and should have been validated against more widely recognized means for inferring the in-situ stress state, such as earthquake focal mechanisms.

PI Response:

We have posted our results and all physical meaning, Interpretation of b-values and Fractal Analysis into our last year annual report to DOE which is avalilable to the public. The stress and velocity models has been cross validated with other phenamena like shear wave splitting and fuzzy clustering.

Reviewer 23583

Comment: This scientific/technical approach is a little disjointed. There was no discussion of how the tomography was accomplished and little interpretive discussion on what the rock properties maps might mean with regards to fracture mechanisms. The accomplishments as presented are minor when compared to addressing the goal of the project, and, in summary, do not justify the claims made concerning progress. The project has had minor achievements compared to project goals and considering resources expended.

PI Response:

Tomography part has not been done internally by USC people, we only use velocity models generated by LBNL scientist in our innovative workflow and show how use these valuale data.

Reviewer 23412

Comment: The weakness of this project is the other interpretation of MEQ.

PI Response:

No response entered.

Reviewer 23641

Comment: None.

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23471

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23583

Comment: Better management practices are desirable in getting the project on to the original overall goal as well as speed-up the productivity. Interpretation of results with regard to fracture mechanisms is needed.

PI Response:

No response entered.

Reviewer 23412

Comment: The improvement to this project is that it is complete.

PI Response:

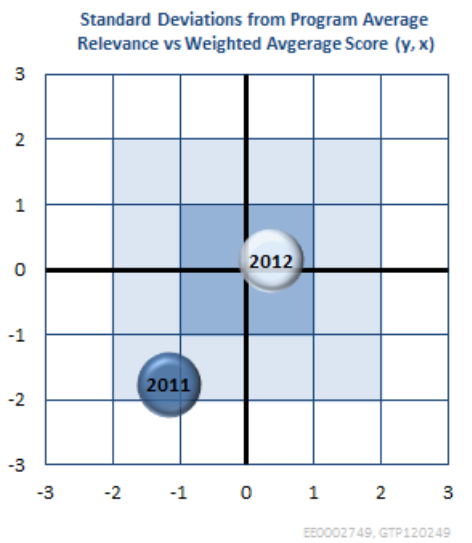
No response entered.

Reviewer 23641

Comment: None

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002749
Project: Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-Exposed High-Velocity Rocks
Principal Investigator: Hardage, Bob
Organization: University of Texas at Austin
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23471

Score: 3.0

Comment: This is a project to improve the quality of active source seismic imaging techniques across geothermal prospects, focusing on multicomponent analyses and extracting S- and well as P-wave information from traditional vertical-force vibrators. This is highly relevant to GTO goals in that S-wave imaging can offer better structural delineation of fluid-filled fractures than imaging only with P-waves, without necessarily requiring expensive multicomponent sources. In future presentations, however, it would help to have a more complete description of the state of the art in using vertical-force sources to acquire S-wave images, since this has been done before and it was at times difficult to ascertain which aspects of the data acquisition and (especially) processing undertaken in this study were truly new.

PI Response:

Reviewer 23505

Score: 3.0

Comment: The importance of improving the resolution of surface seismic and VSP in geothermal environment is very high. It is not clear at this point if this project will have a significant impact because it is not far enough along to answer that question. The proposed method to use vertical point sources to produce multi-component data has been investigated by others and used when it is successful. This approach can significantly lower costs of acquisition, but past studies have had limited success.

PI Response:

Reviewer 23412

Score: 3.0

Comment: The relevance of this project is the interpretation of VSP surveys with a known granitic outcrop. Also data aquisition with vibra-seise techniques were investigated.

PI Response:

Reviewer 23641

Score: 4.0

Comment: Very relevant and potentially high impact research. Vertical source s-wave approach could be a major cost savings in acquiring s-wave data for geothermal imaging.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23471

Score: 3.0

Comment: Although it has been recognized for some time that vertical-motion vibrators also radiate horizontal "lobes" of S-wave energy, much of this S energy is trapped in low-velocity near-surface deposits or converted to surface waves and is not terribly useful in imaging deeper structure. When high-velocity materials are present at the surface – as is often (but certainly not always) the case in geothermal systems – then this is not as much a problem and the types of special processing being developed by this team can extract useful images from the direct S-wave energy. This improved S-wave imaging capability requires removal of backscattered noise produced by surface waves, and is also enabled by development of a cable-free 3-component receiver array for greater station coverage at lower cost.

PI Response:

Reviewer 23505

Score: 2.0

Comment: It was not clear from the presentation that the project may lead to progress for geothermal areas. This method may only be applicable to non-geothermal environments or in geologic types that are relatively homogenous and competent. Areas of future study would be a more systematic approach to examining the hypothesis put forward by doing limited field experiments and full waveform models/synthetic modeling. Also, if they could obtain more data sets that have already been collected by others (which there are many) and where there has been ground, may be of value. It also seemed that the difficulty of imaging in geothermal environments seemed to be a surprise to them. Many papers have been published to demonstrate this.

PI Response:

Reviewer 23412

Score: 4.0

Comment: The newer scientific approach to acquire and interpret processed data is straight forward and should be disseminated to the seismic geophysical community.

PI Response:

Reviewer 23641

Score: 4.0

Comment: Sound technical/scientific approach employing experience from petroleum seismic to geothermal settings.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23471

Score: 3.0

Comment: This project has faced serious delays due to temporary or permanent loss of three members of the six-person research team due to personal injury/illness or spousal illness, which put them about three months behind schedule. In spite of this, they seem to be back on track and progressing well. Progress to date has been good, with promising images obtained from their test line demonstrating that vertical-force vibrators can produce good S-wave images akin to those obtained with horizontal-force sources. A PhD thesis is being written based on these results, which should be finished in December 2012, and an article is being prepared for The Leading Edge. Based upon this research, this team is also considering modifying vertical-force sources to enhance the efficiency with which they generate S-waves.

PI Response:

Reviewer 23505

Score: 2.0

Comment: Results presented are limited due to some to events beyond their control, but 70% has been spent. It was not clear from the results presented that much progress has been made. It was not also clear that if the results could be applied to geothermal environments or was being developed for oil field applications.

PI Response:

Reviewer 23412

Score: 4.0

Comment: Results of the out crop test will applied to Soda Lake.

PI Response:

Reviewer 23641

Score: 4.0

Comment: Encouraging demonstration of the potential value and cost reduction of acquiring s-wave data through vertical source. Preliminary results on Soda Lake example are encouraging but ultimate success at imaging below high velocity surface remains to be demonstrated with 30% of project yet to go.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23471

Score: 4.0

Comment: This is clearly a well-managed project, with the PI having long years of experience in seismic data acquisition and processing and project management. The team has established good collaborations with various geothermal energy companies, which provide software, data and processing assistance, and has clear plans to apply this technique to 3-component, 3-D seismic data acquired at Soda Lake NV and Wister CA.

PI Response:

Reviewer 23505

Score: 2.0

Comment: Some uncontrollable events seemed to have disrupted the project and there has been difficulty in making progress. Not sure what oil companies' involvement is contributing.

PI Response:

Reviewer 23412

Score: 4.0

Comment: Project management had some unforeseen snags but did manage to complete a product.

PI Response:

Reviewer 23641

Score: 3.0

Comment: Overcame challenging staffing situation and kept the project moving forward.

PI Response:

STRENGTHS

Reviewer 23471

Comment: This is a strong project achieving innovations in the use of traditional vertical-force vibrator sources to generate both S- and P-wave images in selected geothermal prospects using a cableless 3-component receiver array and new processing techniques.

PI Response:

Reviewer 23505

Comment: None

PI Response:

Reviewer 23412

Comment: Applies proof of concept to data acquisition and interpretation.

PI Response:

Reviewer 23641

Comment: Interesting opportunity to reduce cost of s-wave seismic surveying in geothermal settings with simpler source configuration.

PI Response:

WEAKNESSES

Reviewer 23471

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23505

Comment: Very worthy goals. It is not clear at this point if the hypothesis addressed will work in geothermal areas, and using single (vertical) component sources to extract horizontal data is valid. This may be an example of trying to evaluate a large project ($1.7M) with a four page write up and a 20 minute presentation. More detailed evaluation may prove that the hypothesis is very valid and useful.

PI Response:

Reviewer 23412

Comment: This project has no apparent weaknesses.

PI Response:

Reviewer 23641

Comment: Delays in project (managing difficult staffing challenges) make ultimate results of vertical source s-wave survey approach applied to Soda Lake dependent on further work.

PI Response:

IMPROVEMENTS

Reviewer 23471

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23505

Comment: None

PI Response:

Reviewer 23412

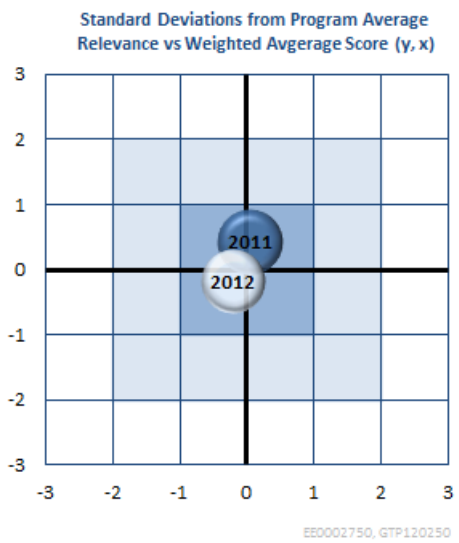
Comment: No improvements have been identified.

PI Response:

Reviewer 23641

Comment: It would be interesting if the PI did some scoping quantification of the potential cost savings of using simpler source configurations (vertical source) compared with multiple x-y-z source to collect shear data.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002750
Project: Fracture Network and Fluid Flow Imaging for Enhanced Geothermal Systems: Applications from Multi-Dimensional Electrical Resistivity Structure
Principal Investigator: Wannamaker, Phillip
Organization: University of Utah
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 4.0

Comment: The direct use of existing data ensures relevance. The refinement to account for topographic effects is likely to result in significant imaging improvements. The progress made in improved computation methods and faster run times will be useful.

PI Response:

No response entered.

Reviewer 23563

Score: 3.0

Comment: Impact will be 3-D EM imaging applied to MT data. The focus is on developing 3-D simulation code which also emphasizes handling of surface topological effects and updating inversion kernels for efficiency. Want to develop a general analysis tool which will reduce risk in exploration, development and management. New capability will be applied to two EGS fields with existing MT data. Very surprised 3-D modeling capability with realistic topography has not been generally available by now. This will be a useful (and needed finally) addition if the tool can get general dissemination.

PI Response:

No response entered.

Reviewer 23425

Score: 3.0

Comment: The main objective of this work is the development of a high-resolution, 3-D EM analysis tool that takes into account topographic effects. Electrical resistivity methods are important for geothermal exploration and the PI recognizes the need to deal with the mathematically under-determined and ill posed nature of the method as well as high cost and slow turnaround regarding the time required to obtain results. If the tool can ultimately be produced with the improvements proposed, this would be a significant achievement. EM methods or any geophysical method for geothermal exploration or evaluation will always produce results with significant uncertainty, but the results of an EM survey,

considered in the context of other information, could be valuable for reducing exploration costs and geothermal energy development.

PI Response:

No response entered.

Reviewer 23550

Score: 2.0

Comment: The primary relevance of this project to the Geothermal Program's mission and goals is that it has potential to advance the imaging of geothermal systems using EM geophysical methods. The project is motivated by the traditional arguments that are made for development of geophysical technologies i.e. that non-invasive information obtained can be used to improve the characterization and monitoring of geothermal systems. The relevance/impact of the research depends on the project goals. These were not entirely clear to me as the title of the project (and some of the motivation in the project summary) is inconsistent with the project tasks that have been performed to date. The title of the project clearly implies that EM methods will be advanced to characterize fracture networks and image fluid flow. This would represent a ground-breaking advance in the application of EM in geothermal systems, but it this is likely to be infeasible given resolution issues with 3D EM. The actual project impact is likely to be much more modest. The work is primarily focusing on improving/developing EM modeling capabilities to incorporate topographic corrections to EM data. Currently, the need for this work has only been demonstrated via a synthetic study.

PI Response:

I believe the examples presented of the inversion capability to date as applied to the Coso and to the Raft R geothermal systems demonstrate the strongly positive value of EM methods to delineate fluid flow paths and structures serving as conduits or barriers to fluids. The correlation with seismicity is particularly valuable.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 4.0

Comment: The PI's experience in developing EM codes and positive track record in producing scientifically defensible results is reflected in the proposed work and methodology. The adaptation of flexible mesh grids for topographic and statics corrections will lead to wider acceptance of EM inversions. Such acceptance has been hindered by the known issues with topography and static effects which often cause downward continuation of surface structures obscuring EM structure at depth and decreasing resolution. Thus, this work has the potential to improve inexpensive em data interpretation resolution and confidence that reservoir scale features and targets can be identified. Slide 6 is particularly elegant in this regard. The ability to identify code problems and work around them is typical of flexibility and efficiency that we expect of geothermal scientists.

PI Response:

No response entered.

Reviewer 23563

Score: 3.0

Comment: New conformal grid technology (non-rectilinear elements) will be introduced to describe complex surface and subsurface boundaries for 3-D EM forward modeling. Work will entail much testing of grid generation, computational accuracy and computational efficiency. Algorithmic concerns that have been identified should be tested and resolved on simple models before attempting realistic field situations. Later analyses will compare new topological approach to flat earth models and document differences and added value especially in rough terrain. Other work on code optimization (efficiency) is following a path similar to many code development projects. The key deliverables we are looking for here is how much topology matters (probably a lot) and the accuracy of the results. Need to select a final simulation algorithm strategy and code from the two choices. They seem close to doing this. Parallelization of the inversion kernel will be useful for efficiency, but this part is pretty standard.

PI Response:

We believe we are the first to implement, and certainly to publish, parallelization of the parameter step matrix solution on affordable multi-core workstations.

Reviewer 23425

Score: 3.0

Comment: The approach is to develop a 3-D computer code for simulating EM responses at the surface of the Earth. It appears that this code will then be integrated into an inversion program for producing solutions or maps of the subsurface using EM field data. The 3-D simulations or forward models will be used to guide the inversion of the EM field data and reduce, as much as possible, the ill posed nature of the 3-D inversion or imaging problem. The resulting integrated program will be parallelized and used to develop subsurface maps of existing data sets. In developing the 3-D simulation code, the PI is focusing on the need to better handle topographic effects. The approach seems reasonable in dealing with problems inherent to 3-D EM imaging.

PI Response:

No response entered.

Reviewer 23550

Score: 2.0

Comment: The scientific approach is based around the development of 3D parallelized code for EM modeling that incorporates topography using a deformable FEM and/or a finite difference model. It is clear that topography (when it is significant) must be accounted for in order to optimize the modeling and imaging capabilities of EM methods. In fact, the use of a deformable FEM to model topography is common for DC resistivity in near surface applications, makes sense to transfer this approach to the much more challenging EM modeling problem. I had a hard time following the discussion of the inversion approach being utilized here. Specifically, it was not really clear to me what code has been developed under this project, versus what has been brought in from previous projects. In this respect, the team is tackling an extremely challenging EM modeling problem that should advance the EM method in geothermal exploration; however, the team needs to better clarify what advancements have been made under this particular project, versus what is just applying existing codes.

PI Response:

A primary goal of the project always has been to start with an existing 3D code (Loki) that appeared to give good results for magnetic field simulation with topography and to high resistivity contrasts. It, however, did not compute the electric field due to a fundamental approximation in deriving the E-field from the initial vector potential. After substantial investigation and testing, it does not appear that this code computes the initial potential stably enough to suffer the double spatial differentiation needed for E.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435

Score: 4.0

Comment: The project has successfully met objectives to date and exceeded normal expectations regarding flexibility in dealing with unexpected complications, such as the loki code problem. The PIs have clearly identified (via forward models and conceptual model mathematical verification) and resolved (or on their way to resolving) key problems on schedule. The parallelization efforts are notable and on track to advance the project and validate this computational methodology for others.

PI Response:

No response entered.

Reviewer 23563

Score: 3.0

Comment: Parallelization going well as expected from following well understood practices. Analysis of a synthetic 2-D model showing the need to account for topography is valuable and could benefit from other examples (at least one 3-D) to clearly re-enforce the impression that surface statics matter. Comparisons of algorithms seems nearly completed - they will abandon Loki. A full 3-D site analysis with surface topography is planned and will be the key accomplishment along with its dissemination.

PI Response:

No response entered.

Reviewer 23425

Score: 2.0

Comment: The project is now into its third year of support (Jan/Mar of 2010 to Mar of 2012 with end Jan 2013). Progress in terms of work presented seems reasonable but a lot still seems necessary to do before the objectives are achieved. The PI indicates on slide 2 that only 25% of the work has been performed to date. If this percentage of achievement is correct, this seems problematic as roughly 70% of the time has passed. Possibly a no-cost extension can be requested.

PI Response:

Yes a no-cost extension will be requested. We have been completely upfront about timing issues involving other time-critical commitments such as data campaigns.

Reviewer 23550

Score: 2.0

Comment: The team has developed an impressive looking image for the Coso geothermal field, although it was again not clear whether this was developed as a result of current work. I could not determine how much of the code development is in the algorithm that was used to develop this image. That said, the images do show nice evidence for clustering of seismicity around strong contrasts in resistivity i.e. margins of low conductivity zones. The other major accomplishment is that the team has demonstrated how incorporation of topography can improve imaging of conductivity features, although they need to extend this to the 3D platform. Although the team has presented some nice examples of the application of code to field data, the improvements exist that would result from incorporating topography have yet to be demonstrated on field scale 3D datasets. This is a limitation of the project progress to date. The team has also demonstrated that a well established EM code (LOKI) is probably not going to be appropriate for meeting the objectives of this project, thereby justifying the work to build an alternative modeling approach.

PI Response:

No disagreement there; 3D topo is the key.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 4.0

Comment: The PIs have done an outstanding job maximizing their contributions given the numerical and computational challenges. They have clearly been in detailed and productive discussions with other internationally recognized researchers and modelers. It is imperative that the final algorithm be validated as proposed.

PI Response:

No response entered.

Reviewer 23563

Score: 3.0

Comment: No discernable problems.

PI Response:

No response entered.

Reviewer 23425

Score: 2.0

Comment: Management and coordination with other projects is a bit concerning given the apparent degree of overall accomplishment (25%) relative to objectives. It seems like progress on the project depends on whether time is available to work on it according to the Overview Slide. Support remaining for the project seems commensurate with what still needs to be done to achieve the project's objectives. A no-cost extension seems one way to deal with this situation.

PI Response:

See response to previous topic.

Reviewer 23550

Score: 2.0

Comment: This project appears to be significantly behind schedule, and this was explained by an avalanche of projects coming to the team along the same timeframe. It was not clear why it is this particular project that had to suffer in terms of schedule relative to the other projects that the team is administering. The subtask dates have been pushed back considerably because of these delays. The data sharing statement was vague in terms of who will have access to algorithms developed as a result of this work. This is often a problem with work funded to develop code. Some informal collaborations are described e.g. with CSIRO but it was not clear how concrete these collaborations are likely to be.
Note: Based on the project title and what was presented in the progress presentation I am dubious that the original project goals are being followed (I have not seen the proposal, but the title seems unrelated to what has been presented e.g. where are the ‘fracture networks’?). I cannot imagine that EM imaging could really resolve ‘fracture networks’ – but perhaps this is just a terminology difference between the PI and me.

PI Response:

Whether the title is appropriate to the research issues addressed is a matter that is to be judged during the original proposal review process, not after the fact.

STRENGTHS

Reviewer 23435

Comment: An outstanding team of theoretical and applied geophysicists and mathematician. Phil's experience in geothermal and research EM is clearly being efficiently leveraged here. The commitment to field test and validate the code is a positive and likely to happen given the PI's reputation.

PI Response:

No response entered.

Reviewer 23563

Comment: Adds topography to EM imaging in 3-D. But should have been done before now by the community.

PI Response:

No response entered.

Reviewer 23425

Comment: The PI is tied both to the geothermal EM modeling and field communities which is a very strong point of this effort. These associations should allow for a high degree of integration between the tool development and modeling tasks. Understanding geothermal exploration issues will also help the PI to stay on track in his tool development effort. An EM approach seems to be currently one of the two best means of obtaining information about engineered geothermal systems. It is to the PI's credit that he is considering issues like the impact of topography which might be overlooked by a less experience project leader.

PI Response:

No response entered.

Reviewer 23550

Comment: [1] project has the potential to advance the imaging of geothermal systems using EM geophysical methods; [2] a strategy for dealing with topography (when it is significant) is being developed to optimize the modeling and imaging capabilities of EM methods; [3] impressive images for the Coso geothermal field have been obtained; [4] new evidence for clustering of seismicity around strong contrasts in resistivity (i.e. margins of low conductivity zones) has been obtained; [5] team has demonstrated how incorporation of topography can improve imaging of conductivity features.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23435

Comment: None

PI Response:

No response entered.

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23425

Comment: The main weakness identified here is that progress is slow evidently because of competition with more time-critical projects. The importance of this situation and its relevance for GTO's own schedule is ultimately up to GTO management. Again, a no-cost extension seems to be one solution for dealing with this problem. Another possible solution is to add qualified students/postdocs, but that may not be so easy given the specialized nature of this work.

PI Response:

A NCE is the appropriate step to be taken.

Reviewer 23550

Comment: [1] project tasks performed to date do not seem consistent with project title and project motivation presented in the project summary; [2] imaging of fluid flow within fractures in a geothermal system does not seem feasible with the EM technique; [3] unclear what specific advances with modeling codes is being made relative to codes already developed by the team; [4] benefits of including topography in the imaging need to be demonstrated on field datasets; [5] project appears to have fallen significantly behind schedule.

PI Response:

Same as previous reply; that was a matter for the original review.

IMPROVEMENTS

Reviewer 23435

Comment: It is important to line up a validation site ASAP so that inversion limits can be assessed with respect to anticipated field conditions.

PI Response:

No response entered.

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23425

Comment: It would help the reviewers to see more benefits of the approach taken by the PI. He shows how topography corrections may be important. Are there other examples of features in his code that are clear improvements? Regarding the cited example of Maris, does this image benefit from the forward modeling or simulation capability? The problem of a slipping schedule seems somewhat serious. Fixing this is probably the most major recommendation that can be made.

PI Response:

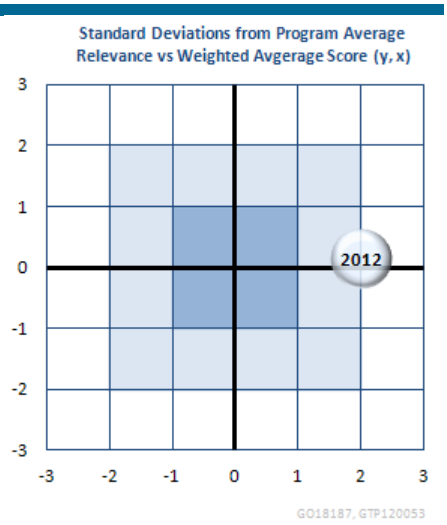
A NCE is the appropriate step to be taken.

Reviewer 23550

Comment: [1] better link development of codes that incorporate topography to improved imaging of fluid flow in geothermal systems; [2] better clarification of what advancements have been made under this particular project, versus what is just applying existing codes; [3] demonstrate improvements that would result from incorporating topography into modeling of field scale 3D datasets; [4] better clarify data sharing in terms of who will have access to algorithms developed as a result of this work; [4] solidify collaborations and value of these collaborations to the project.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18187
Project: Micro-earthquake Technology for EGS Fracture Characterization
Principal Investigator: Foulger, Gillian
Organization: Foulger Consulting
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 4.0

Comment: A good recognition of the need for absolute microearthquake locations makes relevance of outcomes more likely. The extension of net forces into MEQs to account for fluid flow might be useful if validated. The relevance of the work is somewhat weakened by an assumption that MEQ location is fluid flow location. MEQs can result from diffusive stress and strain resulting from pressure and thermal transient superimposed on critically stressed fractures distant from the fluids. Injection seismicity data have disappeared, Rangely, Denver, etc. i.e. data as young as 10 years old. Use DOE geothermal database for archive for induced siesmcitiy? It is absolutely essential that DOE provide some resources to capture and provide access to as much induced seismicity data as possible, including injection rates, volumes, locations.

PI Response:

We postulate, and hope to test, whether the very short-term seismic transients that correspond to injection-induced MEQs are associated with fluid flow. However, we do not suppose that fluid flow occurs ONLY at the MEQ locations as we are aware that post-seismic, and other related processes, also affect neighboring regions. To account for spatially distributed sources would require higher-degree moment tensors, and is not a goal of the current project. Furthermore, it is likely that determining net forces will require inversion of complete waveforms, and not merely amplitudes, because far-field signals are plroportional to force and to moment rate.
We are actively working on several DoE data-collection experiments and are in the process of contributing to the USGS-UCB Northern California Earthquake Data Center (Desert Peak, Nevada, data).

Reviewer 23550

Score: 3.0

Comment: This project is very relevant to the geothermal program's mission as it seeks to improve microseismics for studying earthquakes within a geothermal context. The team has identified three clearly stated specific challenges that must be overcome to further the use of microseismics: [1] improving sensitivity to absolute locations of earthquakes,[2] moment-tensors do not adequately describe hydrofracture, and [3] local earthquake tomography cannot see shallow earthquakes. The potential impacts of improved MEQ location are well identified by the team and include the fact that improvements in MEQ locations could reduce EGS production costs substantially. Furthermore, the approach could potentially provide better information for tracking the fate of fluids, and also determine modes of fractures induced.

PI Response:

We appreciate these positive comments.

Reviewer 23583

Score: 3.0

Comment: The goal of this project is to develop EGS-tailored MEQ techniques. Specifically the project will develop: high-resolution absolute hypocenter methods, include net forces in MEQ mechanisms, and combine data from local & regional earthquakes to determine deep structure. If the project's goals are realized, notable progress and impact toward accomplishing GTO's EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment…" will be advanced. Better MEQ locations, hypocenters and tomography will notably reduce EGS hydraulic fracturing knowledge gaps and further the deployment of permeability-enhancing technologies. As stated, this project will improve understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing modeling tools to accelerate EGS implementation.

PI Response:

We appreciate these positive comments.

Reviewer 23641

Score: 3.0

Comment: The project has achieved the anticipated innovations. Previously unrecognized omission in ACH theory is a significant accomplishment. Extension of tomography program to use distal events to see deep structure has potential as tool for reservoir definition. Application to real world data sets will be an important step in developing this technique.

PI Response:

We appreciate these positive comments.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 3.0

Comment: The PI's long history in geothermal seismicity, application of scientific methods in a constrained environment with respect to data quality (which the PI's have uniquely evaluated and accounted for) and availability is well reflected in their work. The methodology directly addresses the most scientifically challenging aspects of induced seismcity characterization, especially absolute eq location and resolution of forces to imply fluid flow. A weakness is that their work is not coupled with a broader perspective of stress changes and poroelastic and thermomechanical effects which provide some additional constraints on their methodology.

PI Response:

We appreciate the comment that integration of our work into broader perspectives of stress changes and poroelastic and thermomechanical effects would be an important step forward. In fact, we have reached this conclusion also ourselves. While this work is outside the remit of our current, already ambitious project, we are in active discussions with Prof. Ahmad Ghassemi (Texas A&M University) and his group to do this work under future awards. As part of this effort we

will deliver, with Prof. Ghassami, a workshop at the 2012 Annual General Meeting of the GRC, where we will integrate our approaches with those of his group.

Reviewer 23550

Score: 3.0

Comment: The team has focused on modeling development to [1] use both relative and absolute travel times to improve resolution of absolute location of earthquakes; [2] include net forces in MEQ mechanisms in order to describe flow following fracture; [3] integration of data from distant and local earthquakes to better define deep geothermal structures. However, I did not see any strong evidence (e.g. using synthetic datasets) to show the improvements in MEQ location that can result from applying these three developments. As these define the key objectives of the work, I feel that this should have clearly been demonstrated in this presentation. On questioning, the presenter assured me that demonstrations of the improvements in MEQ location resulting from the three technical advancements are available, but just were not shown here. The main technical approach described by the presenter was a review of the basics of seismic tomography, where it was hard to follow the main argument being presented due to problems with the slides. However, it is clear that the general idea of the team is to develop short cuts in computations involved in seismic tomography as part of this project.

PI Response:

Improvements in MEQ location techniques were completed in Year 1 of this Award (2009) and described in past Quarterly and Annual Reports, and in our presentation at the DoE GTO Peer-Review meeting at Crystal City, May 19, 2010. The target date for completion of this module of work was 9/30/2009, and this was achieved. In our current presentation, we showed a figure illustrating those result on our title slide, but in the body of the presentation we focused on work currently in progress. This is tomography development, application to data from Desert Peak, and outreach. Our tomography-related goals are not primarily to develop computational shortcuts (though we do so where possible) but to improve tomographic methods and to provide useful, well-written, tested, and documented programs.

Reviewer 23583

Score: 3.0

Comment: The scientific/technical approach has three components: extend hypocc code to use absolute as well as differential arrival times, extend focmec code to include net forces in source mechanisms, and incorporate distant events into time-dependent tomography code tomo4d. This approach is clear but not understandable in the sense that making the changes they suggest to these codes will have a significant impact on the problems they are trying to solve. The supplied materials do not substantiate claims made about capabilities and improvements. However, there are no significant weaknesses for improvement in the design of the approach as presented, it is that the results presented were not convincing regarding the claimed improvements. It is hard to judge the scientific rigor employed in the development of these techniques and presented results do not instill a feeling of confidence in these improved capabilities, however, the focus of the project is aimed at solving one of the major scientific barriers in EGS deployment, namely, improved MEQ analyses and the project team has a very good track record. The execution of the approach to answering this question is good but the results have been marginal in relation to the resources expended and progress towards objectives. In summary, the project will contribute to progress in overcoming stimulation barriers/knowledge gaps as presented.

PI Response:

All changes we make to programs are backward-compatible. New abilities have been added; old ones have not been lost.

In past presentations and reports we have delivered evidence that integration of absolute arrival times into hypocc improves locations and thus makes a significant impact on the location program. We also included a figure showing these results on the title slide of our current presentation, but the allocated space did not permit us to talk extensively about it. Our work including net forces in source mechanisms showed that exceptionally high-quality data are required, which are not currently available. We thus defer full exploration of the potential impact of that development on the problem of understanding source processes. Our current work in hand, developing our tomography code tomo4d is still a work in progress during this, the final year of the Award, and we anticipate being able to assess its potential impact when this work module is complete.

Reviewer 23641

Score: 4.0

Comment: Technical approach is of high quality.

PI Response:

We appreciate this positive comment.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435

Score: 4.0

Comment: The code modification work is a significant accomplishment as is the identification of a key weakness in the assumption of Aki et al. 1976. They are also to be commended for modifying the data source to high quality Desert peak data.

PI Response:

We appreciate these positive comments.

Reviewer 23550

Score: 2.0

Comment: The team is working on applying these methods to an EGS Injection experiment at Desert Peak. Here, they appear to be making use of a unique dataset with thousands of travel times recorded. Extensive work appears to have been performed on the dataset acquired from this seismic network. Preliminary results from EGS related earthquakes at Desert Peak were shown in the presentation. However, it was unclear to me whether the stated improvements that result from the three methodological developments that form the motivation of this work exist or are demonstrated in this field study. It seems that some comparison of the inversion results with and without the proposed methodological developments would be needed here. In summary, I could not clearly tell from the presentation what accomplishments had been achieved with respect to the three stated objectives.

PI Response:

The reviewer is correct that the methodological developments we have so far made on the current Award have not yet been applied to the Desert Peak data shown in the presentation. We presented the initial, basic results, and the enormous number of moment-tensors determined (80) constituted a huge effort. Refined processing of this data set using the methods we have developed will occur during the last half of 2012, the final year of the Award.

Reviewer 23583

Score: 3.0

Comment: As stated in the presentation and summary, the project accomplishments include: all methodologies and coding targets for improved relative and absolute MEQ hypocenter locations are done, the software has been tested on several existing datasets, moment-tensor error assessment targets have been reached but data needed to use this techniques are not available today, and local plus regional software is running and being tested with synthetic data. The results as presented, do not justify the claims made concerning achievements. For example, verification results were not presented and comparisons with other data to demonstrate improvements were not done. Furthermore, the quality and significance of the technical accomplishments and results are adequate in relation to the resources expended and technical progress towards project objectives; there is significant room for improvement. The productivity in work underway and future work and the value of the accomplishments compared to the schedule and costs reveals that good progress has been made.

PI Response:

As stated above, verification results of our improvements in location capability were shown only briefly on our title slide, and have been presented at greater length in prior Reports and our 2010 presentation to the GTO at Crystal City. The requirement for higher-quality data than are currently available for our moment-tensor developments was an unexpected result, but this is not unusual in cutting-edge research. We are currently in the process of completing testing and application of our tomography program and expect to present application to a real dataset before the end of the Award.

Reviewer 23641

Score: 4.0

Comment: Project innovations (relative and absolute arrival times to improve hypocenter accuracy, net forces in MEQ mechanisms to account for fluid flow, distal seismic event analysis to interpret deep structure) are significant and useful. recognition of omission in ACH theory is significant and publishable advance.

PI Response:

We appreciate these positive comments.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 4.0

Comment: The project is on schedule, a commendable achievement given the complexity and surprises (Aki eqn error and data quality issues that always seem to plague such efforts for example). A significant and relevant list of collaborators was presented. It is clear that the PI's are actively collaborating in an opportunistic manner (use of the Desert peak data for example).

PI Response:

We appreciate these positive comments.

Reviewer 23550

Score: 3.0

Comment: The project team claims to be fully on schedule in terms of expenses. This is a project that is in its final year, and with few issues noted. The funds on the project appear to be largely depleted. A long list of collaborators was noted in the presentation; however, it was not clear what these collaborators are bringing to the table with respect to advancing the progress of this projects. Good evidence of dissemination of results via presentations at meetings, publications and a planned workshop was given. A large amount of future research was presented as planned – it seems unlikely that it would all be met in the remaining months of the project. Perhaps the team needs to request a no cost extension if this research is supposed to be done under this project.

PI Response:

The progression of the work, and application of resources, staff time etc. has been carefully planned throughout the 3.5 years that have currently expired, in order to keep the project on schedule. This is reflected in the proportionate depletion of the budget. We expect to fully achieve the planned research goals by the end of the Award, which is the end of calendar year 2012. Nevertheless, the Reviewer's suggestion of a no-cost extension is an interesting one which we will consider.

Reviewer 23583

Score: 3.0

Comment: The project is on budget, scope and schedule and minor problems were reported. Spending is on track with scope and schedule, and prospective future plans are of good quality and will be very effective in meeting the project’s goals. The inclusions of appropriate and logical decision points were in place and effectively used. The project team is top-notch and coordination of activities with collaborators and stakeholders is very effective. Better management practices are desirable in reporting accomplishments and results to better defend claims.

PI Response:

We appreciate the positive comments. We note the final statement that better management practices are desirable in reporting accomplishments and results. We suspect that this relates to accomplishments and results that were reported in

earlier Reports and at the GTO meeting at Crystal City in 2010. In future DTP Peer-Review meetings, we will include a more substantial overview of accomplishments made prior to the year in progress, in order to present total project accomplishments to date.

Reviewer 23641

Score: 3.0

Comment: Project appears to have been managed and coordinated to a high standard.

PI Response:

We appreciate this positive comment.

STRENGTHS

Reviewer 23435

Comment: The PI's have efficiently and effectively proceeded down a scientific, pragmatic and opportunistic path to achieve project objectives. The thoroughness with which they have evaluated data and assumptions and taken corrective action is commendable. They also have an excellent plan for sharing data and even providing training in geothermal MEQ work.

PI Response:

We appreciate this positive comment.

Reviewer 23550

Comment: [1] high relevance to the geothermal program's mission as it seeks to improve microseismics for studying earthquakes within a geothermal context; [2] well identified specific challenges to be addressed and overcome; [3] potential impacts of improved MEQ location are obvious; [4] approach could potentially provide better information for tracking the fate of fluids, and also determine modes of fractures induced; [5] short cuts in computations involved in seismic tomography will be developed; [5] good application of methods to an EGS injection experiment in the field setting; [6] good evidence of dissemination of results via presentations at meetings, publications and a planned workshop.

PI Response:

We appreciate these positive comments.

Reviewer 23583

Comment: As envisioned, this project will definitely improve understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing improved MEQ analysis tools to accelerate EGS implementation. There are no significant weaknesses for improvement in the design of the approach as presented. The focus of the project is aimed at solving one of the major scientific barriers in EGS deployment, namely, improved MEQ analyses and the project team has a very good track record. The productivity in work underway and future

work and the value of the accomplishments compared to the schedule and costs reveals that good progress has been made. The project is on budget, scope and schedule and minor problems were reported.

PI Response:

We appreciate these positive comments.

Reviewer 23641

Comment: Strengths include accomplishment of the targeted innovations and additional unanticipated advance in the ACH theory.

PI Response:

We appreciate this positive comment.

WEAKNESSES

Reviewer 23435

Comment: Significant advances are being made in stress field perturbation characterization and poroelastic and thermomechanical modeling associated with geothermal production and injection. These advances might provide useful insights to the PI's.

PI Response:

We agree. This work is outside the remit of the current Award, but we nevertheless are actively pursuing doing this work under a future Award.

Reviewer 23550

Comment: [1] no strong evidence (e.g. using synthetic datasets) to show improvements in MEQ location that can result from applying the three developments was demonstrated; [2] unclear whether the stated improvements that result from the three methodological developments that form the motivation of this work exist or are demonstrated in this field study; [3] difficult to tell from the presentation what accomplishments had been achieved with respect to the three stated objectives; [4] unclear what collaborators are bringing to the table with respect to advancing the progress of this projects.

PI Response:

[1] Improvements in MEQ locations were planned to arise from our work in extending program hypocc, not in all three methodological developments; [2] As stated above, the evidence required for improve locations was presented in earlier Reports and the Crystal City presentation. Production of evidence for the effectiveness of our tomography developments is currently work in hand; [3] response as for [1]; [4] In future GTO presentations we will include an overview of all accomplishments to date, rather than focusing on work achieved during the current year.

Reviewer 23583

Comment: This approach is clear but not understandable in the sense that making the changes they suggest to these codes will have a significant impact on the problems they are trying to solve. The supplied materials do not substantiate claims made about capabilities and improvements. The moment-tensor error technique requires data not available today.

PI Response:

As stated above, the changes we make to programs only add to, and do not detract from, the range of problems that can be solved.

In future GTO presentations we will include an overview of all accomplishments to date, rather than focusing on work achieved during the current year to date. Our moment-tensor error technique does NOT require data currently unavailable. We have demonstrated its application to datasets in past reports and presentations, including papers in the Proceedings of the Annual Stanford Geothermal Workshop.

Reviewer 23641

Comment: Weaknesses include limited opportunity within the scope of the project to apply the innovations to real world data sets to validate their value.

PI Response:

We have so far processed several data sets with our techniques, and presented those results earlier. The ambitious and time-consuming nature of our methodological development goals, and the related programming, have left little time for processing of data sets not originally planned. Some work has nevertheless been achieved on a new, originally unanticipated dataset from Desert Peak, Nevada.

IMPROVEMENTS

Reviewer 23435

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No comment.

Reviewer 23550

Comment: [1] team needs to clearly demonstrate evidence (e.g. using synthetic datasets) to show the improvements in MEQ location that can result from applying the three developments proposed in this study; [2] some comparison of inversion results with and without the proposed methodological developments would be very useful to demonstrate value of technique; [3] the large amount of future planned research seems unrealistic - team should narrow down key objectives to meet during remainder of the project duration.

PI Response:

[1] & [2] In future presentations we will cover the accomplishments of the entire Award to date, and not confine ourselves only to the current year; [3] We agree, and it is our current plan to focus for the remainder of the Award period on the promised Award deliverables, and not branch out into the fresh research avenues that have arisen.

Reviewer 23583

Comment: Better management practices are needed in reporting results to defend claimed accomplishments.

PI Response:

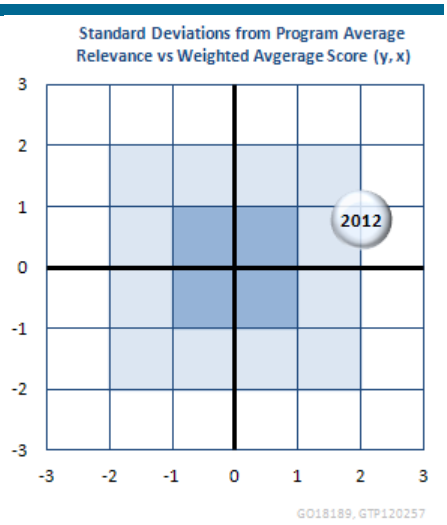
Given the reviewer criticisms to which we have responded above, we agree with this point. In future GTO presentations we will ensure that we cover the accomplishments of the entire Award to date, and not confine ourselves only to the current year.

Reviewer 23641

Comment: Improvements include testing of the MEQ fracture identification and location tools to real world data sets. Acknowledged that this is beyond the original scope of the project and a basis for further work.

PI Response:

We agree with this comment, and expect this work to comprise continuation of this research after the end of the current Award.



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18189
Project: The Role of Geochemistry and Stress on Fracture Development and Proppant Behavior in EGS Reservoirs
Principal Investigator: Moore, Joseph
Organization: University of Utah
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 4.0

Comment: The long history or Joe Moore in this type of geothermal research is well reflected in the proposed and completed work. The asserion that propant behavior under EGS conditions is poorly understod and needs to be investigated is likely true and adds to project relevance. A good unerstanding of previous related oil and gas and geothermal work is demonstrated and built upon. The demonstrated degradation of self propping permeabiity over time is useful in demosntraing project relevance. The use of large scale samples and realistic temperature, pressure, strain(?) conditions, flac modeling and acoustic emissions recordings offer a great deal of data likely to yield results at field scale relevance.

PI Response:

Reviewer 23550

Score: 3.0

Comment: This project seeks to advance the understanding of water-rock-proppant interactions; this is an interesting and challenging scientific problem with clear relevance to the geothermal program's mission and goals. The work is relevant as it is leading to improved understanding of role of proppant (Bauxite in particular) in maintaining fractures. It is addressing established barriers to EGS by improving understanding of proppant behavior in maintaining connectivity of fractures that would permit economical extraction rates.
Given that the use of proppant is a potential technology recognized by DOE with application to the geothermal community, the findings of this work could have high impact. Specifically, the use of proppants to develop fracture surface area and maintain fracture connectivity is a valuable area of research. This project aims to better explore challenges and constraints on effective proppant placement.

PI Response:

Reviewer 23411

Score: 4.0

Comment: This is an important project relative to efforts associate with the development of engineered geothermal resources; namely, the development of sustainable fracture permeability. The geochemical work looking at dissolution of proppant material and test specimens yield results that were not unexpected to this reviewer, but are important nonetheless. It is suggested that proppant materials and size distributions other than sand and bauxite be examined (ceramic materials were not tested) and that this would be a better path than testing bauxite and sand in different sedimentary rock types. The work laboratory flow experiments have shown interesting results, notable was the loss of hydraulic conductivity in self propped fractures. The experimental efforts with propped fractures have also shown important results and should be continued. The reviewer is pleased that numerical simulations are being employed in an effort to understand experimental results but the simulations to date appear more novel than insightful at this time. With the project being about 60% spent, one would expect that this effort will result in additional work of significant importance.

PI Response:

Reviewer 23641

Score: 4.0

Comment: Highly relevant research on proppant behavior in geothermal setting with high potential impact.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 4.0

Comment: The commitment to build upon past geothermal and oil and gas experience ensures that the results will be relevant. It is extremely useful to have propants evaluated under geothermal conditions with geothermal fluids. The combination of the lab data and FLAC3D and PFC3D is an excellent methodology that will ensure positive feedback between the two efforts. The lab derived properties are likely to be more useful than most given they were derived under geothermal conditions.

PI Response:

Reviewer 23550

Score: 4.0

Comment: The scientific approach being adopted is to examine the fate of proppants that could be used to maintain effective open and connected fractures in a geothermal system. The team recognizes a need to examine the mechanical characteristics of proppant, along with geochemical issues (precipitation and dissolution) that will arise under the high pressure and temperature conditions of a geothermal system. The focus on permeability enhancement is important as this is clearly the critical issue when considering economic costs of an EGS. The technical approach has significant merit as it is building on experiences and lessons learned from oil and gas development.

PI Response:

Reviewer 23411

Score: 3.0

Comment: The scientific approach to this effort appears to be robust. They have conducted important laboratory experiments that will provide data and may provide insights into the evolution of fracture permeability at temperature. They have also initiated efforts to model the physical processes associated with flowback that may yield significant results relative to the possible use of proppants in geothermal stimulations. With respect to the geochemical work, this reviewer asks if it is possible to model these processes as well (particularly with respect to dissolution and deposition)? If so, they may want to consider doing so. Additionally, as noted in the relevance section, it may be more worthwhile considering a wider range of proppant materials.

PI Response:

Reviewer 23641

Score: 4.0

Comment: Strong scientific/technical approach.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435
Score: 4.0

Comment: All project objectives are on schedule. This is notable given the complexity and thoroughness of the lab and modeling work under geothermal conditions, not an easy task.

PI Response:

Reviewer 23550
Score: 4.0

Comment: To date, the team has performed some impressive experiments on proppant flow at up to 230 degrees C and depths to 10,000 ft, and they have also developed some modeling capabilities to interface with the experimental datasets. The static experiments on water-proppant-rock interaction using Bauxite as the proppant have clearly demonstrated concerns for the long-term integrity of such proppants in a geothermal system. This is an important finding. Impressive laboratory flow through experiments have also been performed at high pressure and temperature, including an examination of hydraulic conductivity as a function of P and T. These experiments are producing results that help to evaluate the effectiveness of self self-propping at high temperature. The large scale block tests seem to be particularly impressive and have leveraged technologies developed in the petroleum industry. Flow through experiments have produced interesting results suggesting that there may be channels in proppant that could assist in maintaining hydraulic conductivity. Measurements on such large-scale blocks are likely to provide more meaningful datasets than what would be obtained on small cores. The subsequent experiments that couple microseismic data with proppants to illustrate better understanding of flow rates in relation to proppant are interesting, but details were not clear. Specifically, it was not clear what information is actually being obtained from the seismic data. The team claim to have also developed modeling capabilities to understand integrity of proppants – describing a "proppant sandwich". Details of the modeling framework were vague and it is not clear what is actually being modeled, i.e. what observations are being predicted and what the model parameters are.

PI Response:

Reviewer 23411

Score: 3.0

Comment: This reviewer is confused by the schedule on Slide 2. It shows a 4-year timeline but the dates indicate 3 years. While this may have been explained it was missed by the reviewer and the assumption is that the project has been extended an additional year at no cost. While the progression of the project appears to be behind the plan, the accomplishments and progress are good and offset the delay in activities.

PI Response:

Reviewer 23641

Score: 4.0

Comment: Useful results that build on oil and gas and geothermal experience, applied in geothermal conditions. Progress in comprehensive set of areas including geochemical studies, baseline conductivity measurement, large scale flow experiments, and numerical simulation.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 4.0

Comment: All of the partners have been efficient and productive in their collaboration as demonstrated by the results obtained under unique geothermal conditions.

PI Response:

Reviewer 23550

Score: 3.0

Comment: The management of this project was well described by the team. The team has shown good leveraging of academia at University of Utah, including access to instrumentation required for this project. The team has a cost-share industrial partner (Terra Tek), who have carried out large-scale block testing – e.g. a polyaxial vessel for testing of large-scale samples. This is an impressive achievement in effective project management. Furthermore, the team has also interacted with proppant manufacturers. The future plans for the remainder of the project are reasonable, with more experiments to look at proppant behavior in different rock types e.g. carbonates, during extension phase. However, the team should consider looking at some different proppants if possible. The team has decided that Bauxite is the proppant of choice, apparently based on their own desktop study.

PI Response:

Reviewer 23411

Score: 3.0

Comment: Project appears to be well managed (despite the assumed delay). It is not clear why John McLennan is not named on Slide 3.

PI Response:

Reviewer 23641

Score: 4.0

Comment: Evidence of effective project management and coordination evident in the peer review presentation and reports.

PI Response:

STRENGTHS

Reviewer 23435

Comment: The use of geothermal materials under geothermal conditions is a big plus. The lab experiments are well designed and focused on geothermal issues. The coupling with numerical codes should prepare these and other geothermal workers for use and integration of these data into reservoir modeling and permeability creation assessment.

PI Response:

Reviewer 23550

Comment: [1] investigation of proppant behavior has clear relevance to the geothermal program's mission and goals; [2] clear focus on permeability enhancement, a critical issue when considering economic costs of an EGS; [3] impressive experiments on proppant flow at up to 230 degrees C and depths to 10,000 ft have been performed; [4] static experiments on water-proppant-rock interaction using Bauxite as the proppant have led to an important finding regarding concerns for the long-term integrity of such proppants in a geothermal system; [5] Impressive laboratory flow through experiments have also been performed at high pressure and temperature, including an examination of hydraulic conductivity as a function of P and T; [6] impressive large scale block tests that have leveraged technologies developed in the petroleum industry; [7] good evidence of effective project management, including leveraging of academia at University of Utah, resulting in access to instrumentation required for this project.

PI Response:

Reviewer 23411

Comment: As noted in pervious comments, the project is addressing critical issues relative to EGS development and has found some insightful results. While just one aspect of this effort, the currently accepted EGS protocol of self propping fractures through shear destabilization has been questioned as part of the laboratory results - this is a provocative and important result. The team is strong, but the reviewer is concerned that John McLennan should remain engaged (he may be, just an observation from the slides).

PI Response:

Reviewer 23641

Comment: Comprehensive scientific approach combining laboratory efforts with simulation.

PI Response:

WEAKNESSES

Reviewer 23435

Comment: None

PI Response:

Reviewer 23550

Comment: [1] experiments that couple microseismic data with proppants to illustrate better understanding of flow rates in relation to proppant are unclear, particularly with respect to value of seismic information; [2] Details of the modeling framework are extremely vague and it is not at all clear what is actually being modeled in the system; [3] focus on just one particular proppant (Bauxite) is questionable.

PI Response:

Reviewer 23411

Comment: Additional proppants beyond those examined should perhaps be tested.

PI Response:

Reviewer 23641

Comment: None.

PI Response:

IMPROVEMENTS

Reviewer 23435

Comment: None.

PI Response:

Reviewer 23550

Comment: [1] The modeling framework should be expanded better clarify what observations are being predicted and what the model parameters are; [2] the team should consider looking at some different proppants if possible.

PI Response:

Reviewer 23411

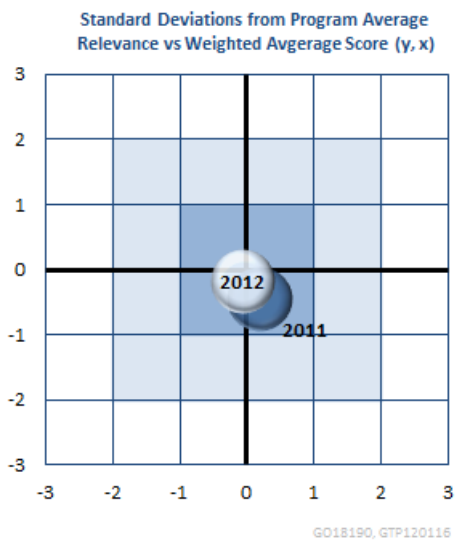
Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23641

Comment: None.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18190
Project: Detection and Characterization of Fractures for the Development of EGS
Principal Investigator: Toksoz, M. Nafi
Organization: Massachusetts Institute of Technology
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 4.0

Comment: Very well integrated dataset resulting in very useful example of how microseismic data can be effectively resolve important geothermal structures. The core Vs and Vp measurements made under varying geothermal conditions are extremely relevant. The 3-d velocity model tomography is particularly impressive and relevant technology. This should be applied in other geothermal systems. The future tasks are important and logical extensions of completed work and must be supported.

PI Response:

Reviewer 23550

Score: 2.0

Comment: The primary objective of this project is to use multi-method geophysical techniques to better characterize a geothermal reservoir. The primary relevance/impact of this work to the geothermal program's mission and goals would be improved resource characterization of the Cove Fort geothermal well field. The main impact to date would be that the team has apparently identified a target within the Cove Fort field that they consider suitable for development. The team also mentioned vague plans to provide their dataset for inclusion in the national geothermal database. The impact of this project is limited by the fact that it is unclear how this project could result in the development of tools for broader application at multiple geothermal sites.

PI Response:

Reviewer 23505

Score: 3.0

Comment: The objectives are very relevant to EGS/Geothermal goals, (specifically the combination of MEQ, seismic and potential field methods are needed). Also, the systematic investigation of this technology is necessary to understand why and when they could be applied and is very relevant for both EGS as well as exploration.

PI Response:

Reviewer 23641

Score: 3.0

Comment: Potentially useful tool, a combination of MEQ and gravity inversion tomography with rock physics in situ experiments.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 4.0

Comment: The best integrated geophysical and core data models I have seen. The seismic tomography is particularly outstanding, it includes ray paths (potential error geometries) which should be included in all such seismic tomographic models but often is not. The stress field determination and tomograms are particularly robust. The demonstrated ability to generate depth slices is a refreshing advancement at Cove Fort. The use of core to determine Vp as a function of depth and temperature is extremely useful.

PI Response:

Reviewer 23550

Score: 2.0

Comment: The technical approach is based on analyzing a wide range of field measurements from established surface geophysical techniques used in geothermal exploration, coupled with rock physics work done on surrogate cores by New England Research. A weakness of this project is that it currently has the feel of an expensive case study application of geophysics whereby many geophysical methods have been applied to try to interpret geology. The scientific approach would have seemed much stronger if the team focused on describing the advanced methods for integration and joint interpretation of multiple datasets, and also how the core measurements (petrophysics) have been used to provide new insights into understanding a geothermal system.

PI Response:

Reviewer 23505

Score: 3.0

Comment: Very good approach. Integrated models and technique applications of multiple methods, well thought out and supported by laboratory results. Investigation of full waveform moment tensor methods is severely needed. This is still not a solved problem by the seismic community in general. Inclusion of anisotropy is also needed and this is examined in their project.

PI Response:

Reviewer 23641

Score: 3.0

Comment: Solid technical/scientific approach combining MEQ/gravity inversion with rock physics in situ testing.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435

Score: 4.0

Comment: All technical targets have been met. The only missing element is an explicit discussion on seismic anisotropy.

PI Response:

Reviewer 23550

Score: 3.0

Comment: Multiple geophysical datasets have been acquired over the Fort Cove field including heat flow, gravity data, seismic tomography data (from US array), etc. To date, the team has provided a qualitative presentation of geophysical datasets with anomalies being interpreted as evidence of the presence of heat sources. However, they have developed some joint inversion approaches e.g. to jointly invert gravity and seismic velocity data. Further details of such efforts to develop an interpretation of the site based on an integrated treatment of the datasets would be a good step forward. Currently, it is not immediately clear how much information is coming from the different datasets acquired. The value of the measurements on samples from Cove Fort as a function of temperature were uncertain based on the details presented. More significantly, the value of these core data for improving the interpretation of the field datasets was unclear. Apparently, the cores were not actually acquired from the Fort Cove field, but instead represent surrogates that are

deemed representative. Apparently, true cores from the site may exist. It is unfortunate that these cores are unavailable to the project team. The interpretation of the seismic data seems to have led to some intriguing results regarding Vp and Vs structure at depth, contrary to what might be expected i.e. presence of a high temperature anomaly that has been qualitatively described by the team.

PI Response:

Reviewer 23505

Score: 3.0

Comment: Good progress towards objective, especially the integration of lab based data to interpret field results. Good correlation between MEQ results and velocity structure demonstrating the different scales of measurement and the importance of scaling properties. A very important component and result is the inclusion of efforts to examine full waveform moment tensor inversion. This provides further proof that current methods are inadequate and there's a need to obtain higher resolution, (band width and sensitivity) data for MEQ data (for events less than magnitude 3.0).

PI Response:

Reviewer 23641

Score: 2.0

Comment: Good work has been completed but ultimate achievements from this project appear uncertain. As the PI indicated: "We have been able to generate an excellent data set, a good model for the region and a motivated and experienced team. Unfortunately, we are running out of time and have run out of money. During this period of "no-cost" extension, we supplemented the DOE budget with MIT funds as much as possible. If we could raise some support, we could improve the resolution of tomographic models, complete the source mechanism of all events to determine the stress tensor, the primary direction of fractures and use anisotropy analysis to validate fracture direction." I have reservations about how far this project will be able to go with the approach given time and budget constraints.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 4.0

Comment: The project has delivered an excellent multi scale set of data and models.

PI Response:

Reviewer 23550

Score: 2.0

Comment: Project management is hard to assess as the PI did not give the presentation and the replacement presenter skimmed over this material. However, this project is now in a no-cost extension. The presenter gave the impression that no publications have yet been produced from this work. However, there are publications listed in the summary for this project. Clarification of what products and presentations have resulted from this work would be helpful. It is unfortunate that the team was unable to acquire cores from Cove Fort system – the reliance on surrogates for the petrophysical measurements is a weakness. The presenter did not elaborate on the "problems encountered" that prevented these cores from being obtained and available to the project effort. It is frustrating that the project timeframe presented to the reviewers was wrong; it should not be difficult to include a correct timeframe that shows the team is on top of project management. All reporting requirements claim to have been met and all funds have been spent. I feel that the PI should have been present to give this report, as the speaker was not entirely comfortable with the material being presented.

PI Response:

Reviewer 23505

Score: 3.0

Comment: Well managed and progress within limits of constraints. Logical and balanced approach. The project is ending soon and if continued, this is a good time to focus on the important findings.

PI Response:

Reviewer 23641

Score: 2.0

Comment: See remarks under Accomplishments, Results and Progress. Good work but does not appear that applicable results will come from it given time and funding constraints.

PI Response:

STRENGTHS

Reviewer 23435

Comment: Excellent and timely use of multiple data and models at multiple scales with superior defensibility and internal consistency. The project seems to have actually identified a drilling target!

PI Response:

Reviewer 23550

Comment: [1] will lead to improved resource characterization of the Cove Fort geothermal well field; [2] multiple geophysical datasets have been acquired over the Fort Cove field including heat flow, gravity data, seismic tomography data; [3] interpretation of the seismic data seems to have led to some intriguing results regarding Vp and Vs structure at depth, contrary to what might be expected.

PI Response:

Reviewer 23505

Comment: An impactful project with results that will benefit the Geothermal Program. The strengths are the integrated approach of the lab, field, models and processing results. Provides a path forward to address the important element of joint imaging.

PI Response:

Reviewer 23641

Comment: Solid approach to combine inversion with rock physics simulations.

PI Response:

WEAKNESSES

Reviewer 23435

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23550

Comment: [1] it is unclear how this project could result in the development of tools for broader application at multiple geothermal sites; [2] project is that it currently has the feel of an expensive case study application of geophysics whereby many geophysical methods have been applied to try to interpret geology; [3] value of these core data (surrogates of the site) for improving the interpretation of the field datasets was unclear; [4] team was unable to acquire cores from Cove Fort system – the reliance on surrogates for the petrophysical measurements is a weakness; [5] joint inversions for an integrated treatment of the datasets are not well developed.

PI Response:

Reviewer 23505

Comment: Should focus on the integration of anisotropy and inversion methods. Also focus on methods to extend moment tensor inversion for full waveform lower magnitude events that are common to many geothermal areas.

PI Response:

Reviewer 23641

Comment: Project does not appear to have the legs to achieve the desired results and get them to a state of maturity that will help other efforts.
PI Response:

IMPROVEMENTS

Reviewer 23435

Comment: I hope that there will be validation of this work with drilling, production and injection data. At that point, it would be useful to consider coupling with a poroelastic/thermomechanical model to see if predictive permeability changes as a function of injection can be made.

PI Response:

Reviewer 23550

Comment: [1] team should focus on transferability of measurements/approach being developed to other sites; [2] scientific approach would be stronger if team focused on advanced methods for integration and joint interpretation of multiple datasets; [3] integration of core measurements (petrophysics) to provide new insights into understanding a geothermal system should be worked on; [4] development an interpretation of the site based on an integrated treatment of the datasets would be a good step forward; [5] the value of th core data to improving the interpretation of the field datasets should be made clearer.

PI Response:

Reviewer 23505

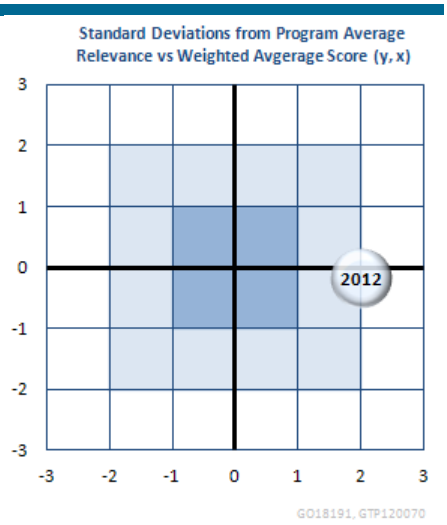
Comment: See "weaknesses" section.

PI Response:

Reviewer 23641

Comment: Difficult to develop suggestions for improvements without knowing more about the management of this project, Appears to have led to some promising avenues (such as s-wave anisotropy to image fractures) but I am not confident the project has sufficient time or funding to bring these avenues to fruition.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18191
Project: Seismic Fracture Characterization Methods for Enhanced Geothermal Systems
Principal Investigator: Queen, John H.
Organization: Hi-Q Geophysical Inc.
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23583

Score: 3.0

Comment: Type or Paste Text HereThe goal of this project is to make seismic techniques work in geothermal areas to image faults, routinely accomplished in the O&G business, and further, realize the dream of characterizing fractures. One of the mysteries of geothermal exploration is: “Why has there been little positive outcomes in the use of seismic techniques in geothermal areas, when, theoretically, seismic techniques have the highest spatial resolution?” This project is attempting to answer this question. If the project’s goals are realized, notable progress and impact toward accomplishing GTO's EGS mission "...to improve performance, reduce cost, and facilitate technology validation and deployment…” will be advanced. Better imaging of faults and fractures will notably reduce EGS hydraulic fracturing knowledge gaps and further the deployment of permeability-enhancing technologies. As stated, this project will improve understanding of how to lower current EGS reservoir creation technology barriers (reduce costs and boost performance) by providing seismic techniques and interpretation tools to accelerate EGS implementation.

PI Response:

No response entered.

Reviewer 23412

Score: 3.0

Comment: The relevance of this project to use seismic surveys to help characterize geothermal resources with other geophysical measurement especially where volcanism and dense faulting have occurred. This project is a good demonstration of data processing and interpretation. The seismic community consider processing and interpretation as separate activities.

PI Response:

The seismic community consider survey design, acquisition, processing, and interpretation all to be separate activities.

Reviewer 23641

Score: 3.0

Comment: Project has achieved anticipated results and no cost extension will enable completion. Near offset VSP and swath seismic techniques appear to have been useful improvements in resolution in the Bradys data set are are relevant tools for use in other geothermal trends. Sawth seismic may have application in more exploratory settings where 3D seismic is prohibitively expensive and 2D has limited resolution.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23583

Score: 3.0

Comment: The scientific/technical approach, in general, experiments with source and receiver geometries quite different from those used in O&G exploration. Three different techniques will be used: address surface seismic noise problems with dense, high-resolution grids, image faults and fractures with a 9-component VSP and integrate all data both during processing and in interpretation, to bring it all together. Gravity will be used to constrain the interpretations. The quality of the scientific/technical design is logical, thoughtful and effective in achieving the project's objectives. The approach is focused, succinct, and clearly presented—reasonable and defendable. The approach to solving key technical barriers to achieving the project's objectives such as fielding high-resolution spacings and a 9-component VSP survey are likely to succeed. Scientific rigor employed in the approach depends on the experience and skill of the research team, which is top-notch. Results instilled a feeling of confidence in the team's capabilities, especially the hint of a reflection from a possible fracture shown on slide 8. The execution of the approach so far looks good as presented.

PI Response:

No response entered.

Reviewer 23412

Score: 4.0

Comment: The scientific and technical approach was accurate to provide a finished product of the resource structure.

PI Response:

No response entered.

Reviewer 23641

Score: 3.0

Comment: Scientific/technical approach is sound. Project is close to achieving objectives and is expected to achieve them with the no cost extension. It is unfortunate that more refined processing of the swath seismic was not available for this presentation.

PI Response:

Advanced processing needs such as reverse time migration identified during this project are, as the reviewer has noted, unfortunately beyond the scope of the project as currently structured. This does represent an area for future work.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23583

Score: 3.0

Comment: Project started Mar 2009 and the scope is 80% done. Scheduled end date has been extended through Jun 2013 assuming a one-year no cost extension is approved (presentation says 'requesting'), so the time used as of Apr 2012 is 73%. With 88% of the budget expended, the project is considerably over-spent with respect to (wrt) schedule (with new no cost ext.) and a little over-spent wrt scope. The project is waiting for DOE to approve funds to LBNL for Task 7. (Note: approval has been made; verbal communication from E. Majer). Project has made good progress and preliminary results look promising—clearly progress towards the projects technical goals has been made. The quality and the scientific reputation of the assembled technical team are very high. The quality and significance of the technical accomplishments and results are very good compared to the costs expended to meet project objectives. In addition, the productivity in work underway and future work and the value of the accomplishments compared to the costs is good because many of the tasks have been completed and the good results.

PI Response:

There is not a linear relationship between scope, time used, and budget. For example, permitting was a minor item in scope, but took approximately 6 months, and was relatively minor cost. There is almost an inverse relationship between the cost of processing and the time it takes. Rush processing costs more. We believe we are pretty much on budget, and with the exception of the extension needed for the LBNL VSP, on time.

Reviewer 23412

Score: 4.0

Comment: The project appears to be complete.

PI Response:

Nearly complete. We still have to acquire, process, and integrate the LBNL VSP into the overall interpretation.

Reviewer 23641

Score: 3.0

Comment: Significant results have been achieved. The requested no cost extension is expected to enable final results of swath seismic processing.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23583

Score: 3.0

Comment: As mentioned above, the technical plan for the R&D is good and the project is now back on schedule (including a one-year extension) with a couple variances (awaiting additional funding to LBNL for a multi offset VSP). Spending plans are a little “hot” and future plans are of very high quality and will be effective in meeting the project’s goals. The inclusion of appropriate and logically placed decision points that effect the future direction of the work were not discussed by the PI, but the PI has asked for a no costs extension. Coordination activities with collaborators and stakeholders looked very good with many different players and various tasks. Table on slide 3 really helped to make sense of the complexity of the project.

PI Response:

There were major go/no-go decision points at the end of each Phase. As the reviewer indicates, I probably should have emphasized these more in the presentation. The only remaining go/no-go decision point in the project is if the final interpretation results warrant moving on to technology transfer (presentation at major conferences and publication).

Reviewer 23412

Score: 3.0

Comment: The project was a subtask of Brady Hot Springs EGS. Then it became a separate project. Difficult to understand how the project was managed.

PI Response:

Actually, this project pre-dated the Brady's Hot Springs EGS project, and has always been separate. However, there is a lot of cross over between this project and the Brady's EGS project, and data, results and discussion have been shared widely between the two.

Reviewer 23641

Score: 3.0

Comment: Project management and coordination appears to have been conducted to a high standard. However, no cost extension is required to finish processing and yield final results.

PI Response:

Unfortunately, the funding of the LBNL VSP was outside the domain of our project, and was beyond our control. This separate funding of our project and the FFRDC effort was mandated by the FOA under which our project is conducted.

STRENGTHS

Reviewer 23583

Comment: This successful project, as yet, still in process, has achieved notable progress and impact toward advancing GTO's EGS mission and significantly reducing EGS hydraulic fracturing knowledge gaps, and improving the program's understanding of how to lower current EGS reservoir creation technology barriers. The implemented scientific/technical approach is good—well thought out, reasonably likely to succeed and has been/should be effective in achieving the project's objectives. The quality and the scientific reputation of the assembled technical team is top notch. The project's accomplishments in gathering high-quality seismic data are impressive and the preliminary results look very promising. The quality and significance of the technical accomplishments and results is very good. Various project achievements suggest that project management has been effectual in getting the work done and plans to move forward are reasonable, logical, and likely to succeed. Coordination activities with collaborators and stakeholders looked very good with many different players and various tasks.

PI Response:

No response entered.

Reviewer 23412

Comment: The strength of the project is that it survived stop and go progress from data acquisition, processing and interpretation.

PI Response:

No response entered.

Reviewer 23641

Comment: Encouraging data improvement from near offset VSP approach. Swath reflection seismic results still pending further interpretation; early results encouraging but to soon to tell with certainty.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23583

Comment: The project is considerably over-spent wrt the new schedule (with new no cost ext.) and a little over-spent wrt scope. This will require effective project management to handle.

PI Response:

Please see the response above to this reviewers comments in the ACCOMPLISHMENTS, RESULTS, AND PROGRESS section. Reiterating, we believe we are pretty much on budget.

Reviewer 23412

Comment: The weakness of the project was that it suffered the stream of funding required to complete the project in a reasonable time period.

PI Response:

The FOA mandated funding of LBNL's work by DOE headquarters has been challenging.

Reviewer 23641

Comment: Swath seismic acquisition interpretation has not been completed, so final results pending. Task 7 VSP not yet conducted due to lack of funding.

PI Response:

Swath seismic acquisition was actually completed by the time of the presentation. The reviewer is correct that interpretation is awaiting completion of the VSP. Overall, dealing with the funding issue has been a real learning experience.

IMPROVEMENTS

Reviewer 23583

Comment: The inclusion of appropriate and logically placed decision points that effect the future direction of the work would be helpful.

PI Response:

There were major go/no-go decision points at the end of each Phase. As the reviewer indicates, it would have been beneficial to have emphasized these more in the presentation. This will be done in the future. The only remaining go/no-go decision point in the project is if the final interpretation results warrant moving on to technology transfer (presentation at major conferences and publication).

Reviewer 23412

Comment: Fund these projects with enough up front funding to efficiently determine results.

PI Response:

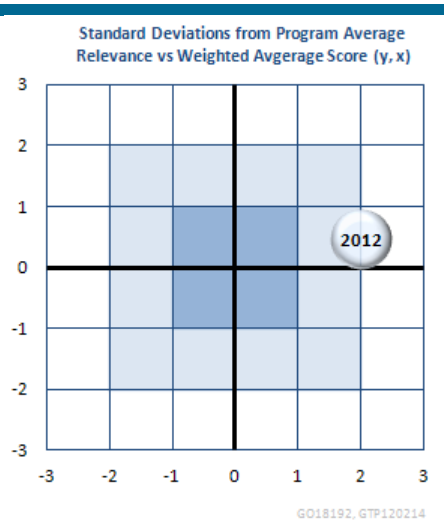
Agreed. This will be a major consideration for us to any future responses to FOA's.

Reviewer 23641

Comment: Additional consideration of the potential usefulness of these tools in less controlled, more exploratory situations. E.g., would swath seismic be an economic technique for unexplored areas?

PI Response:

One of the accomplishments of this project is a much better understanding of the technical effectiveness of both swath seismic and VSP. We believe the application of reconnaissance swath seismic could significantly reduce critical geological uncertainties in unexplored areas at a much lower cost than 3D seismic. Evaluating the economic usefulness of these approaches is much more difficult. Traditional cost/benefit analysis, which seems to be widely used in the geothermal arena, does not factor in value of information. Modern decision analysis based on Bayesian methods does allow assessment of value of information through conditional probabilities. Addressing the question of, for example, the economic benefit of applying swath seismic in unexplored areas, could be explored through the construction of a decision analysis model. That is a significant undertaking beyond the scope of our project, and frankly, beyond the skills of our team. We do feel we could contribute by providing expert technical assessments, but such an effort would need to be led by experts in decision analysis. It would also require input from experts from the geothermal industry to identify the critical uncertainties when prospecting in unexplored areas. I do think such an effort would lead to significant improvement in the success of geothermal development.



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18192
Project: The Use of Downhole Technologies to Characterize Fractures in EGS Reservoirs
Principal Investigator: Horne, Roland
Organization: Stanford University
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 4.0

Comment: Effectively demonstrated impact of fracture flow modleing on NPV calculations for Soultz fracture and flow data. More detailed discussion was required to completely agree with the asserion of success but good nonetheless.

PI Response:

Reviewer 23550

Score: 3.0

Comment: There is a clear need to improve the characterization of fractures and fracture connectivity in an EGS. The nanosensor component of this project is novel and very strong. The use of nanoparticles to sense and characterize experienced temperature and fracture apertures could potentially have very high impact for better determining fracture networks induced by EGS. Furthermore, the development of new technologies for determining the connectivity of fractures is much needed to better understand EGS. Consequently, the potential impacts of this project are strong. The actual current impact of the work performed is less clear. Potentially the highest impact of the work performed is the proof of concept demonstration of the use of nanosensors to characterize temperature and fracture aperture. Based on the results presented so far, the impact of the work on tracers and resistivity for quantifying fracture connectivity is less clear.

PI Response:

Reviewer 23505

Score: 3.0

Comment: This is a very relevant project. Both in potential as well as current impact. A positive aspect is the training of the next generation of geothermal scientists. New approaches to fluid path detection and the aspect of potential of temperature impacts as well as fracture determination.

PI Response:

Reviewer 23641

Score: 4.0

Comment: A relevant and potentially high impact attempt to develop three distinct reservoir engineering approaches (nanotech, ERT and interwell regression) for use in fractured EGS reservoir characterization and management.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 4.0

Comment: Well focussed research effectively tying hard. Won geothermal reservoir engineering fracture flow hypotheses to state of the art materials, actual reservoir rock, modeling and ERT work.

PI Response:

Reviewer 23550

Score: 3.0

Comment: This project is a bit unusual in its technical approach in that it is broken into three major tasks. Each of these tasks could probably be a standalone project, and I think that the team struggled to make adequate progress on all three fronts because of this. The technical approach associated with the nanosensors is strong and the most impressive part of the work. Nanosensors sense changes in temperature and where those changed occurred. This appears to be a unique concept and it represents a novel use of state changing nanosensors. These sensors also have the potential to provide information on fracture aperture and the distribution of these apertures based on what passed through the apertures. The technical approach associated with the second part of the project focused on tracers for obtaining fracture connectivity seems solid as presented. However, the technical approach to the third part of the project focused on developing resistivity measurements for determining information on fracture connectivity is less strong. I got the impression that the PI and team were not sure of the best way to pursue this research objective. For example, the resistivity modeling approach presents a solution to modeling a discrete fracture network using ITOUGH2. This is one approach, although this modeling capability could equally have been developed using existing academic freeware that would allow for inversions to be run and sensitivity analyses to be performed in order to determine whether the method could really provide information on the distribution of an electrically conductive tracer away from a borehole.

PI Response:

Reviewer 23505

Score: 3.0

Comment: Good scientific approach, well thought out objectives and tasks. The combination of nanotechnology, ERT and modeling to determine flow paths is very good. The systematic investigation of nano-material is very important and lends much welcome new ideas to the geothermal program. I like the "out of the box" approach.

PI Response:

Reviewer 23641

Score: 3.0

Comment: Sound scientific and technical approach to development of three distinct tasks, nanotech, ERT and interwell regression.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435

Score: 4.0

Comment: Excellent work in training geothermal researchers. The project seems to have met all of its goals and porposed rational extensions. Strongly recommend implementing field component but Stanford is not the outfit for field implementation, choose field partner carefully!

PI Response:

Reviewer 23550

Score: 2.0

Comment: The team has performed a good investigation of different nanoparticle shapes, with spherical particles shown to be most effective particularly when considering the effect of the surface charge on these particles. The team has also performed some experiments with dyes, which have benefits of not having to be recovered. The team has made good use of SEM imaging on cores to capture evidence of the effectiveness of their approach for using nanosensors to capture

fracture aperture. However, the claim that the team can determine information on the distribution of the sizes of the fractures is not well validated. The team has also made good progress in the development of pore scale modeling approaches to predict nanoparticles transport in the presence of a charged surface and overcome the limitations encountered in the physical experiments. With respect to the second part of project, the team has performed solid laboratory experiments aimed at measuring pressure, temperature and concentrations of tracers in order to provide information on fracture connectivity and implications for well flow rates during EGS. With this effort, the team is focused on determining CONNECTIVITY of the fracture network, not individual fractures. With respect to the third part of the project, the ERT measurement and modeling is not fully developed. The PI was quick to recognize that the term ERT is a misnomer in this project as there is no tomographic characterization of fractures involved. Despite this limitation, the use of a time-lapse signal proposed to determine tracer migration into fractures has some merit and has been employed in other areas of the earth sciences (e.g. near surface hydrogeological studies). The coupling of resistivity to TOUGH2 via substitution is a reasonable approach to the modeling of discrete fracture networks that provides the potential to model resistivity signals resulting from coupled flow and transport. The team recognizes that resolution of the discrete fracture networks is very unlikely to be feasible. They identify a positive step forward as being the development of the technique for focusing on determining connectivity of fractures. At present, this concept has not been demonstrated or proven, although some tools have been developed to move in this direction. There are ways to solve this inverse problem readily in order to better explore the objectives of this project in determining connectivity from ERT. From what was presented, it is not entirely clear how the resistivity measurements would be deployed and how the measurements would be analyzed. Finally, it is not clear how resistivity data would physically be acquired and what information from the ‘resistivity history’ would be used to determine the connectivity. Overall, the progress on the resistivity studies is strikingly limited compared to what has been made on the nanoparticles sensors research.

PI Response:

Reviewer 23505

Score: 3.0

Comment: Very high quality results that have eliminated as well as tested some hypothesis about nano-materials. Good progress towards the goals. Very productive in publishing and educating students.

PI Response:

Reviewer 23641

Score: 4.0

Comment: Interesting and potentially useful results from the three tasks. Good start in developing and testing nano-materials for application in EGS reservoirs, developing tools for application of ERT to EGS reservoirs, and developing more robust methods of inter-well modeling.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 4.0

Comment: The project seems to have met objectives on time and on budget. Other collaborators are notable and useful. Stanford materials collaboration very successful.

PI Response:

Reviewer 23550

Score: 3.0

Comment: From the limited information that I was provided, it seems that the team has been effective in project management and spending. No significant issues appear to exist. Furthermore, the team report on good collaborative arrangements with nearby institutions (primarily with respect to the nanosensors) that has helped to ensure the project success. I also noted the evidence of working with and effectively mentoring a student group and graduating students. Overall, the project management appears strong, except that the progress on the three tasks is far from equal.

PI Response:

Reviewer 23505

Score: 3.0

Comment: Very effective management with solid approach and integrating of tasks. Future plans are well thought out and there are opportunities to apply results to actual field tests.

PI Response:

Reviewer 23641

Score: 3.0

Comment: Good job in managing and coordinating this three-task project.

PI Response:

STRENGTHS

Reviewer 23435

Comment: Excellent ties between geothermal fracture flow reservoir engineering research, materials science, modeling and fracture flow research needs.

PI Response:

Reviewer 23550

Comment: Strengths and weaknesses have been addressed in the previous criteria.

PI Response:

Reviewer 23505

Comment: This is an innovative well thought out and exciting project. Looking forward to an integrated approach to several field sites at a geothermal test facility.

PI Response:

Reviewer 23641

Comment: Making progress on three fronts to develop reservoir engineering tools for EGS.

PI Response:

WEAKNESSES

Reviewer 23435

Comment: None

PI Response:

Reviewer 23550

Comment: Strengths and weaknesses have been addressed in the previous criteria.

PI Response:

Reviewer 23505

Comment: None

PI Response:

Reviewer 23641

Comment: Limited degree of integration of the three tasks so far.

PI Response:

IMPROVEMENTS

Reviewer 23435

Comment: Modeling and experimental results should be compared with previous Stanford core measurements. ERT work could be imporved by coupling with 3-d EM forward modeling codes and inversion for fracture flow modeling before field deployment.

PI Response:

Reviewer 23550

Comment: The team needs to work more on the resistivity modeling and demonstrating the viability of the method with respect to determining information on the fracture connectivity away from boreholes.

PI Response:

Reviewer 23505

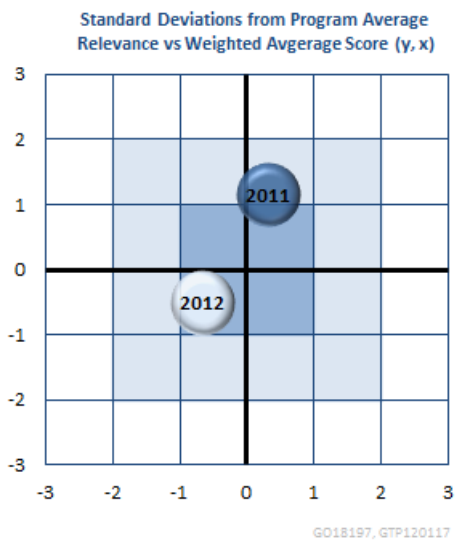
Comment: None

PI Response:

Reviewer 23641

Comment: None.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18197
Project: Monitoring and Modeling Fluid Flow in a Developing EGS Reservoir
Principal Investigator: Fehler, Michael
Organization: Massachusetts Institute of Technology
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 2.0

Comment: This modestly extends efforts to relocate eathquakes more accurately. The project attempts to leverage the unsurprising observation that injection seismicity magnitudes increase with depth. Will observations derived from wastewater injection be useful for stimulation, where pressures will be higher and intended to fracture?

PI Response:

Reviewer 23563

Score: 3.0

Comment: The overall relevance is providing ever more accurate and predictive models for flow, heat transfer and mechanical alteration of Enhanced GS reservoirs. Better models will guide development and economic optimization of major EGS projects. This project is focused on applying acoustic methods based on tomographic and interferometric methods to better locate micro earthquakes associated with fracture networks created from reservoir enhancement. New methods are applied to better locate seismic events in the 3-D subsurface giving trends and develop more accurate velocity models (P and S-wave) to characterize subsurface mechanical earth models which can lead to better strategies for future enhancements.

PI Response:

Reviewer 23425

Score: 3.0

Comment: Use seismic data to monitor low pressure stimulation in a Chevron field in Indonesia. Effort leverages on previous seismic efforts. EGS development requires producing useful reservoir models. Goal of project is to use high quality data to better understand stress changes and permeability development during the fracture growth stage of an EGS stimulation. Doesn't specifically develop a tool for industry but may provide basis for developing a useful tool meeting GTO's goals.

PI Response:

Reviewer 23550

Score: 3.0

Comment: This project is relevant to the Geothermal Program's mission as there is a clear need to develop more reliable reservoir models to improve performance of an EGS. The team seeks to improve fundamental understanding of evolution of seismicity in geothermal well fields. Specifically, they have identified some interesting questions pertaining to the seismicity of Fenton Hill reservoir based on results of injections only spaced relatively small difference apart. One key question they seek to answer is 'why does seismicity migrate downwards with increasing injections? Specifically, the team is investigating how well constrained the depths of seismic activity are, relation to injection depths, and relationship of these depths to wellbore fractures and geology. The project has merit as fundamental questions are being addressed using real world data. This is a challenging task that could make fundamental advancements in understanding of geothermal reservoirs.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 1.0

Comment: The use of Chevron's "hidden" data reduces the value and usefullness of this project to the geothermal community. The "why does seismicity propagate downward with injection?" question is inadequate for justifying this project, especially with no injection rate and volume data. Given the field's history and data, this question could easily be answered with an elementary stress field determination as shown in slide 16. The lack of data sharing makes it impossible to place in a scientific context. The proposed use of interferrometry could be useful but it will be a challenge given the relocation results shown here.

PI Response:

Reviewer 23563
Score: 3.0

Comment: A key element of the approach is to use Chevron's high-quality, long term data from the Salak geothermal field. Nearly 1200 events could be used near the injection region. This can yield well sampled trends which will aid mapping of stress distributions and fracture permeability. In addition velocity structures from the tomography and correlation to seismic events can aid construction of a 3-D mechanical earth model to guide future developments. Although probably beyond project scope, there is no discussion how all this data will eventually factor into a coupled flow, heat transport, stress model of the reservoirs. Also there is no mention (plan?) on any attempt to map the located

seismic events to an optimal set of fracture planes which could be used in 3-D models. I supose this may remain as part of Chevron's plan which will remain proprietary. Value will come from comparing seismic methods for event location performance - main method today is tomography - difference in travel times gives better locations. Chevron field exhibits down depth energy release - is this common and what is the mechanism?. This project could give some valuable insight.

PI Response:

Reviewer 23425

Score: 2.8

Comment: Microseismic events are monitored during high pressure and high flow rates (Fenton Hill) and also low pressure, low flow events. Want to improve the link between measurements made during stimulation and reservoir simulations. Will develop and test new methods for analysis of seismic data and new modeling approaches. More realistic models will include fracture permeability, how the stress field within the reservoir causes microearthquakes, and changes caused by seismicity. Approach while probably technically quite good seems a bit unfocused in the results it produces.

PI Response:

Reviewer 23550

Score: 3.0

Comment: The team is utilizing high quality data from Salak geothermal field in Indonesia acquired by Chevron. This is a strength of the project as the team is utilizing a unique, very rich dataset. The team is working with seismic tomography, an established technique for event determination. However, they have been experimenting with new methodologies for improving the imaging capabilities. One approach based on analyzing the temporal change in waveforms now appears unlikely to work, and this is not specific to the investigated geothermal system. The team is also developing new and improved tomographic inverse codes building from existing platforms at their disposal. Furthermore, they are also employing seismic interferometry and working on advancements to improve identification of location patterns with the technique. In summary, the team is adopting a robust scientific approach by improving the resolving power of existing seismic technologies for investigating geothermal reservoirs.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435

Score: 2.0

Comment: Some minimal seismic processing was done. It is impossible to tell exactly how much the tomography improved seismic characterization results (see slide 18).

PI Response:

Reviewer 23563

Score: 2.0

Comment: Event location using multiple methods has progressed yielding interesting interpretation questions related to more deeply bias events. There is evidence that the velocity model needs more refinement especially to account for anisotropy and its effects on the stress field. This is likely a key step for the rest of the project and may be a heavy effort. The score of two only reflects the fact that progress on certain goals is still at an intermediate stage.

PI Response:

Reviewer 23425

Score: 3.0

Comment: Refined sub-grid scale model of fracture permeability as a function of normal and shear displacements and incorporated this model into the fully coupled thermal-hydrologic-mechanical (THM) simulator FEHM. Incorporated Mohr-Coulomb model for shear displacement on a fault into the simulator to allow for MEQs in response to stress changes caused by the fluid injection. Performed seismic tomography using arrival times of microearthquakes from the Salak geothermal field to better evaluate seismicity and its relation to the fluid injections. Found that the seismicity accompanying the injection is located closer to the injection wellbore than indicated by the initial locations determined using conventional location methods. Zone of seismicity clearly extends downward from injection point. Developed and tested a method based on seismic interferometry that allows the estimation of the time of flight of seismic waves between the locations of two earthquakes. Project has resulted in improvements to understanding specific geothermal regimes, but it remains unclear how to incorporate these into a tool or methodology useful to industry.
PI Response:

Reviewer 23550

Score: 3.0

Comment: The team has demonstrated an improved understanding of the well field under study via seismic tomography (using Tomdd), along with P and S correlations. For example, the team has produced evidence that the seismicity follow a low velocity zone. The potential of the imaging approaches being developed has been demonstrated, and the pattern of seismicity at the well field is being well related to fractures. The seismic interferometry does show some progress but there are clearly significant challenges that must be overcome. The predicted locations of events show a significant bias, although the team appears to have some understanding of this affect. They are working on the premise that part of this problematic offset may be due to needing a better velocity model i.e. a 3D velocity model. The team has also made

progress on understanding focal mechanisms using layered velocity models, although they recognize a need for a 3D velocity model. Although the team presented this as a work in progress, some significant progress has clearly been made. The team has developed a conceptual mechanical model to explain the downward migration of seismicity associated with downward migration of shear zones. This interesting conceptual model will need to be validated with data.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 1.0

Comment: This project will run out of money before the "future work" and anything really useful will come from this work. The unfortunate reliance on Chevron and their data will ensure limited future success and data supporting results.

PI Response:

Reviewer 23563

Score: 3.0

Comment: No discernbabe problems.

PI Response:

Reviewer 23425

Score: 2.5

Comment: Project co-ordinates with other organizations including universities and power companies. To project's credit, it leverages developments in seismic tomography applied to geothermal energy systems and has borrowed methodology for focal mechanism determination. Evidently has a good track record of interfacing with Chevron. Unclear how results will be evaluated by stakeholders.

PI Response:

Reviewer 23550

Score: 4.0

Comment: This project seems to be well on track, most of the money is spent and the progress seems quite reasonable. The team has provided evidence of strong participating institutions, including international partners. Inevitably, the issues of proprietary data have limited dissemination efforts. The team cited evidence of more planned activities for conference presentations, etc. Finally, there is good evidence of the incorporation of high caliber students in the project, including student presentations and student involvement in the work e.g. best paper awards.

PI Response:

STRENGTHS

Reviewer 23435

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23563

Comment: Strong team.

PI Response:

Reviewer 23425

Comment: Excellent analysis of injection induced seismicity. Developed explanation of migration of seismicity. Evaluated different methods of MEQ location. Developing method of seismic interferometry. Work generally seems to be an excellent attempt at characterization of induced seismicity.

PI Response:

Reviewer 23550

Comment: The potential of the imaging approaches being developed has been demonstrated, and the pattern of seismicity at the well field is being well related to fractures. Other strengths are clearly noted in the response to previous sections.

PI Response:

WEAKNESSES

Reviewer 23435

Comment: This is clearly a "target of opportunity" that is behind the times. DOE has learned by now that such "industry cooperation" is usually not worth the investment. The presentation made reference to a wealth of chevron data that may support model development but no one will be able to verify and validate those data.

PI Response:

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23425

Comment: Most of the results involve seismicity characterization of a specific site which is important. However, it is not apparent how these results can be most effectively generalized and integrated into a model that can be applied by industry to support the development of an engineered geothermal system although the results obtained may well contribute to the basis for developing such an application.

PI Response:

Reviewer 23550

Comment: The seismic interferometry does show some progress but there are clearly significant challenges that must be overcome. The predicted locations of events show a significant bias, although the team appears to have some understanding of this affect.

PI Response:

IMPROVEMENTS

Reviewer 23435

Comment: Do not see many possibilities for improvement. DOE should reconsider involvement in this project.

PI Response:

Reviewer 23563

Comment: Would be nice if whole Chevron study could be public at some point.

PI Response:

Reviewer 23425

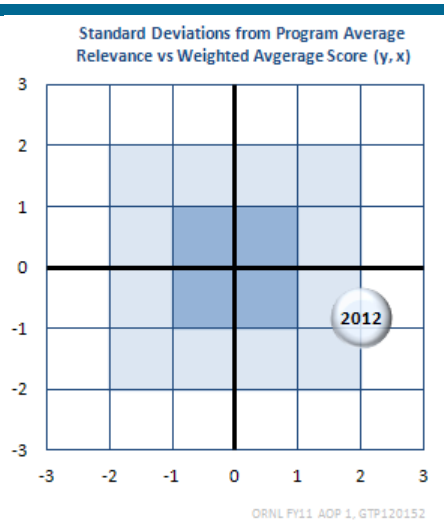
Comment: With the last 20% of support, should make every effort to generalize understanding gained during project and also work with Chevron to test whether the resulting model can be used to make EGS development at reservoir margins successful. In addition, publish papers that might be used as partial basis for a seismic interpretation tool or methodology.

PI Response:

Reviewer 23550

Comment: This project appears to be well on track and I saw no glaring needs for improvements.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: ORNL FY11 AOP 1
Project: Ultra High Resolution Cold Neutron Imaging of Fluid Flow and Fracture in EGS Environments
Principal Investigator: Bingham, Philip
Organization: Oak Ridge National Laboratory
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23435

Score: 1.0

Comment: The introduction discussion did not do a god job of placing the presented research in the context of previous similar DOE research and it offers no improvements. One could argue that this is a task shoe horned into ORNL HFIR capabilities. To his credit, he acknowledged that sandstone is not a representative geothermal rock type. A discussion of the results could be scaled up to relevant scales and different rock types (especially those containing clays and loosely bound, Van Der Wals bonded, water). Water is used with no temperature information, Water viscosity (and relative permeability) is relatively sensitive to temperature change.

PI Response:

Reviewer 23563

Score: 3.0

Comment: The purpose is to image flows in real fractured media (I presume rock samples from actual geothermal sites) under realistic conditions of temperature and pressure using neutrons from the High Flux Reactor at ORNL. This is an ambitious goal, but if successful, could have significant impact on fundamental understanding and assumptions relevant to describing flow in fractured media. As indicated these measurements could be undertaken under many conditions to characterize changes in flow properties and tracer transport when the rock is subjected to stress, hydraulically fractured and/or exposed to chemical alterations. Neutron radiography is not new, but this project offers in-situ investigations of fractured media which will likely produce new insights. Adding modeling effort to the project will enhance the impact.

PI Response:

Reviewer 23425

Score: 2.5

Comment: This project concerns using cold or relatively low energy neutrons to image tracer liquids in very small, pressurized rock cores that are presumably characteristic of the rocks comprising the fabric of a geothermal system. There

is no doubt that this is good basic research, such as is supported by the DOE BES program. Unfortunately, it is unclear how to upscale results on very small scale samples to scales characteristic of real geothermal systems. One possible way is to use the results obtained here as a means of validating computer simulations of stress and reactive transport influenced flows in such systems. Such computer programs can then be used in upscaled simulations with greater confidence that on the very small scale they produce a reasonable result, but the experimental results will not tell us if the upscaling is reasonable itself or if the simulations on a larger scale remain reasonable. The PI recognizes the need for upscaling as future work may involve cubic meter sized samples. Like the project presentation itself, the score of relevance to the broader geothermal program's mission and goals should only be interpreted as a "snapshot" or momentary measure of perceived relevance. It is recognized that future work could well rate a higher score.

PI Response:

Reviewer 23550

Score: 3.0

Comment: This project seeks to better understand EGS performance and to facilitate predictions on EGS implementation by performing experiments on cores in a laboratory setting. The team is specifically focused on time-lapse imaging of dissolution and precipitation processes associated with fluid flow in rocks representative of geothermal reservoirs. They argue that unique information of fluid flow and strain behavior in geothermal systems can be determined from such high resolution imaging experiments performed in a laboratory setting. The development of such high resolution imaging methods has potential to have significant impact in improving understanding of fluid flow in geothermal systems and could have high impact. Although experiments performed to date illustrate such potential, the full impact of the research will be realized only when measurements are performed on rock samples from geothermal systems and at the environmental conditions encountered in geothermal systems. To date, only simpler systems have been studied. However, the development of a high pressure, flow imaging chamber for the time-lapse experiments has made new imaging techniques available to address important geothermal questions related to fluid flow and strain behavior.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23435

Score: 1.0

Comment: The approach used is not valid for geothermal rocks and conditions.
PI Response:

Reviewer 23563

Score: 3.0

Comment: Use of neutron and x-rays to probe porous media flow is established - this work will add studies under realistic conditions of temperature and pressure. Strain measurements under conditions of flow, applied stress and fracture will detect small changes in spacings and record realistic effects not easy to observe otherwise. Advantages of technique - real time flows with tracers, resolution, throughput of data, use of contrast agents, size of samples (could achieve 1 m scale). Disadvantages - access (scheduling) at the HFTF. This project could easily benefit from the addition of a 3-D flow modeling effort. When asked, The PI said they are thinking about this. Overall, an interesting approach which could add much fundamental insight into dynamics of geothermal fractured media.

PI Response:

Reviewer 23425

Score: 3.0

Comment: X-ray imaging of rock cores has been performed previously. Based on the PI's comments, neutron imaging is preferable to x-ray imaging. Some of the results on 3/8" granite core are impressive. For what this method achieves with very small scale samples, it may well be that this is the best way to do it. That said, I have to wonder if a better method that would allow larger scale samples to be considered (e.g., meter scale or larger) might be a tomographic method based on induced changes in electrical resistivity resulting from flow in fractures and changes in saturation in fracture walls. In the current method, boric acid may be used as a tracer. I wonder if the pH changes that might be associated with this tracer might also interfere with reactive transport effects.

PI Response:

Reviewer 23550

Score: 3.0

Comment: The technical approach is based on high resolution neutron imaging making use of synchrotron imaging capabilities available at ORNL. In order to pursue the time-lapse imaging of fluid flow on rock cores, the team has worked hard to development a unique pressure chamber that facilitates neutron imaging under dynamic conditions. The approach is focused on determine the capabilities of such neutron imaging to address questions of relevance to EGS. The team has investigated the resolving capabilities of the different fluids, including fluids doped with boric acid. Coupled to this experimental work, the team is also pursuing modeling efforts to determine what kind of information might be expected from the measurements. Unfortunately, the link between the modeling and the imaging measurements was vague. I did not understand what quantitative information would be extracted from the imaging studies for validation against modeling simulations. The team has also developed an approach to examine strain imaging rather than H2O distribution and transport. This effort also includes a modeling effort for better predicting strain behavior and for comparison with the imaging. This is a particularly novel aspect of the technical approach being pursued.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23435

Score: 4.0

Comment: The objectives seem to have been met.

PI Response:

Reviewer 23563

Score: 3.0

Comment: Many tasks accomplished as preparation for more production like experiments. Pressure chamber for EGS done. Resolution measurements - current capability is ok, but will be extended using contrast agents such as B-10 doping of the fluids. Measurements and analyses to capture dynamic S of flow have been tested. Several prelim image acquisitions done to demonstrate the technique, such as water capillary imbibition into SS / analyses to project just water flow (vertical water front) / vol determinations, etc.
Contrast performance for enhanced resolution being tested for neutrons - 25 um desired and looks achievable. Observed crack formation and flow rate changes / Imaged granite (GT rock, 3/8/inch core). Attempting to image 6 inch samples with new pressure chamber, which is highly desirable. A modeling effort needs to be added - at least FEM modeling applied to CT-like images. VENUS - energy spectrum measurements with a field of view up to 1m x1m for large fracture samples may be possible, and would be very valuable if reasonable sample thickness could be reached. Overall, good preparations for production work, but big risk is compromised productivity in a multi-user user facility.

PI Response:

Reviewer 23425

Score: 2.5

Comment: Overall, I think the project has made adequate progress although the achievements may not be bargain priced. For what has been done, the quality is excellent. There is no reason why this work should not lead to some significant publications.

PI Response:

Reviewer 23550

Score: 3.0

Comment: The team has made good progress in understanding the limitations of the imaging technologies being developed e.g. the thorough investigation of the attenuation of signal and how it depends on dopes e.g. Boric acid. One limitation of the progress is that the team has so far restricted its work to sandstone samples for now, arguing that this rock type is sufficient for investigating the resolution capabilities of H2O based on contrast calculations between water and rock. Although the work suggests that neutron resolution is very high for H2O, the lingering question is whether the same contrasts and resolution will be obtained for rock types of more relevance to geothermal e.g. granite. The team recognizes this limitation and they did present some limited data to show that the contrasts should be sufficient to image fluid flow equally well. Despite this limitation, the team has performed some nice preliminary time-lapse neutron imaging experiments to illustrate the potential – in this case on capillary flow in sandstone. The difference imaging using the flow through chamber does nicely demonstrate how water distribution, thickness of water and affects of fractures on connectivity can be imaged. The combination of imaging high resolution breakthrough curves of the water front with using attenuation data to obtain the total volume of rock is promising. The recent experiments on rocks containing cracks to better represent EGS have nicely demonstrated flow rate changes due to the presence of the crack in a rock under capillary flow. It is notable that the team has also developed design layout for the VENUS instrument. The team appears to have made much less progress on the development of the modeling frameworks required to interpret these datasets being produced. Further effort is needed in this direction.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23435

Score: 1.0

Comment: I see no effort to integrate past DOE funded (NER and Stanford for example) core imaging and testing work into this effort. This lack of coordination will result in duplication of effort and a waste of DOE resources.
PI Response:

Reviewer 23563

Score: 3.0

Comment: Broad expertise project team - does it include modeling? No - they need to fill this gap.

PI Response:

Reviewer 23425

Score: 3.0

Comment: My best assessment is that "Good" is an appropriate descriptor for this category. One problem is competing for adequate beam time. The PI seems to have handled this challenge well and, to his credit, has adjusted his experimental approach to take into account recommendations by GTO. These are all positive characteristics of the management effort.

PI Response:

Reviewer 23550

Score: 3.0

Comment: The presented budget and project expenditures appear to be on track given the project maturity. Adjustments of the project plan due to delays in accessing beam time to use the high resolution method are reasonable. The team has decided that resolution of existing imaging methods is sufficient to focus on current capabilities of the imaging method rather than pursue initial objectives to improve resolution of the approach. This decision is quite reasonable given the promising high resolution datasets presented here.
The PI is pursuing opportunities for synergism with his DOE Career Award; this could certainly benefit progress on this project. Remaining future objectives are well defined and appear reasonable. The PI has also worked to develop collaborative partnerships to benefit the project e.g. with Ajo-Franklin at LBNL for assistance with neutron imaging. However, project management should be directed towards ensuring that the links between the modeling effort and the experimentation can be stronger.

PI Response:

STRENGTHS

Reviewer 23435

Comment: Obviously good equipment and experimental procedures.

PI Response:

Reviewer 23563

Comment: Strong experimental team and access to a world class facility.

PI Response:

Reviewer 23425

Comment: The method appears to provide very high resolution measurements of the distribution of water containing tracers created by flows induced in a rock core. The method can also distinguish some types of minerals in a rock core. Another strength is that this imaging can be done under in situ conditions of pressure. This work may potentially have significant value for validating our understanding of the role of stress, precipitation and dissolution of minerals on very small scales. This may be excellent basic research into the effects of stress- and chemically-induced changes in small scale flow system. Such results could be useful for validating computer simulations of these processes.

PI Response:

Reviewer 23550

Comment: [1] development of such high resolution imaging methods has potential to have significant impact in improving understanding of fluid flow in geothermal systems; [2] the development of a high pressure, flow imaging chamber for the time-lapse experiments has made new imaging techniques available to address important geothermal questions; [3] modeling effort for better predicting strain behavior and for comparison with the imaging is novel; [4] good progress in understanding the limitations of the imaging technologies being developed; [5] team has performed nice preliminary time-lapse neutron imaging experiments to illustrate the potential of the methods being developed for imaging fluid flow; the [6] team has also developed design layout for the VENUS instrument.

PI Response:

WEAKNESSES

Reviewer 23435

Comment: This project is totally out of DOE geothermal context. There has been no effort to develop work plans given past DOE work and results in this area.

PI Response:

Reviewer 23563

Comment: More of a modeling effort needed.

PI Response:

Reviewer 23425

Comment: There is some concern that this effort, while being of high quality, will have limited impact and relevance because of the very small scale of the sample being studied. A technique that allows for very much larger samples to be considered would seem preferable to this approach. Conditions of high pressure and stress can be simulated but temperature effects have not been considered to date. Furthermore, temperature gradients over 10s to 100s of meters can be important for reactive transport considerations. Nothing is indicated about taking into account the large-scale thermal gradients in scaled-down samplers. Because of the imaging method involved, this appears to be an exceedingly expensive experiment to perform.

PI Response:

Reviewer 23550

Comment: [1] full impact of the research has not yet been realized as it requires measurements performed on rock samples from geothermal systems and at the environmental conditions encountered in geothermal systems; [2] the link between the modeling and the imaging measurements is currently vague; [3] team has so far restricted its work to sandstone samples with limited relevance to geothermal applications; [4] relatively little progress on the development of the modeling frameworks required to interpret datasets has been made.

PI Response:

IMPROVEMENTS

Reviewer 23435

Comment: DOE geothermal should consider suspending support for this office of science creation.

PI Response:

Reviewer 23563

Comment: Add modeling - they are looking to do so.

PI Response:

Reviewer 23425

Comment: The PI might want to weigh the benefits of possibly considering a cheaper and lower resolution imaging method that would still allow him to consider much larger samples to at least partially address the issue of the exceedingly

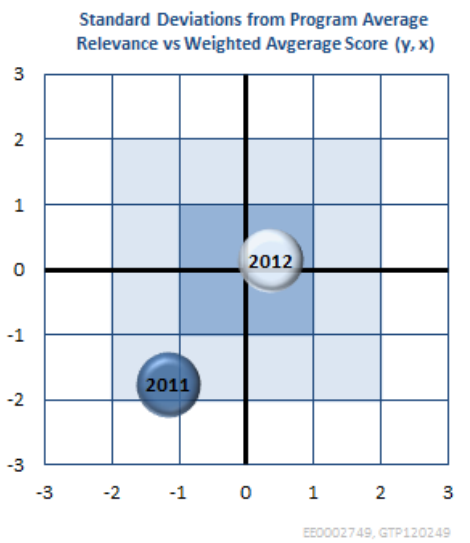
disparate scales between lab studies and a real geothermal system. He might also consider taking into account, as soon as possible, geothermal temperatures and gradients as well as the in situ pressure. I understand that he is already aware of most or all these things and that a subsequent effort may resolve many of the stated concerns.

PI Response:

Reviewer 23550

Comment: [1] the link between the modeling effort and the imaging measurements needs to be substantially strengthened; [2] team needs to focus its work on samples and environmental conditions more relevant to geothermal; [3] focused work on the development of appropriate modeling frameworks is needed; [4] future project management should be directed towards ensuring that the links between the modeling effort and the experimentation can be stronger.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002749
Project: Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-Exposed High-Velocity Rocks
Principal Investigator: Hardage, Bob
Organization: University of Texas at Austin
Panel: Seismicity, Fluid Imaging & Reservoir Fracture Characterization

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23471

Score: 3.0

Comment: This is a project to improve the quality of active source seismic imaging techniques across geothermal prospects, focusing on multicomponent analyses and extracting S- and well as P-wave information from traditional vertical-force vibrators. This is highly relevant to GTO goals in that S-wave imaging can offer better structural delineation of fluid-filled fractures than imaging only with P-waves, without necessarily requiring expensive multicomponent sources. In future presentations, however, it would help to have a more complete description of the state of the art in using vertical-force sources to acquire S-wave images, since this has been done before and it was at times difficult to ascertain which aspects of the data acquisition and (especially) processing undertaken in this study were truly new.

PI Response:

The comment “this has been done before” is incorrect. Although I made a PowerPoint (Slide #6) that emphasized how the S-waves we work with differ from the S-waves that are traditionally utilized with vertical-force sources, I still must not have communicated my point in an understandable manner. We work with S waves produced directly at the point where a vertical-force source applies its force vector to the Earth. We call these S modes direct-S waves. We find nothing in geophysical literature that indicates anyone has ever attempted to image geology with direct-S modes produced by vertical-force sources. There are numerous examples of people using direct-S modes produced by horizontal-force sources. The only S-wave modes produced by vertical-force sources that are widely used are converted-S modes produced at remote interfaces by P-to-SV energy conversion. These latter converted-S modes must be what reviewer 23471 is thinking of, but these modes are not the direct-S modes we are researching.

Reviewer 23505

Score: 3.0

Comment: The importance of improving the resolution of surface seismic and VSP in geothermal environment is very high. It is not clear at this point if this project will have a significant impact because it is not far enough along to answer that question. The proposed method to use vertical point sources to produce multi-component data has been investigated by others and used when it is successful. This approach can significantly lower costs of acquisition, but past studies have had limited success.

PI Response:

The statement “the proposed method has been investigated by others” is not correct. See comments above related to Reviewer 23471. If two reviewers missed my point, I failed to communicate properly.

Reviewer 23412

Score: 3.0

Comment: The relevance of this project is the interpretation of VSP surveys with a known granitic outcrop. Also data aquisition with vibra-seise techniques were investigated.

PI Response:

No response entered.

Reviewer 23641

Score: 4.0

Comment: Very relevant and potentially high impact research. Vertical source s-wave approach could be a major cost savings in acquiring s-wave data for geothermal imaging.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23471

Score: 3.0

Comment: Although it has been recognized for some time that vertical-motion vibrators also radiate horizontal “lobes” of S-wave energy, much of this S energy is trapped in low-velocity near-surface deposits or converted to surface waves and is not terribly useful in imaging deeper structure. When high-velocity materials are present at the surface – as is often (but certainly not always) the case in geothermal systems – then this is not as much a problem and the types of special processing being developed by this team can extract useful images from the direct S-wave energy. This improved S-wave imaging capability requires removal of backscattered noise produced by surface waves, and is also enabled by development of a cable-free 3-component receiver array for greater station coverage at lower cost.

PI Response:

No response entered.

Reviewer 23505

Score: 2.0

Comment: It was not clear from the presentation that the project may lead to progress for geothermal areas. This method may only be applicable to non-geothermal environments or in geologic types that are relatively homogenous and competent. Areas of future study would be a more systematic approach to examining the hypothesis put forward by doing limited field experiments and full waveform models/synthetic modeling. Also, if they could obtain more data sets that have already been collected by others (which there are many) and where there has been ground, may be of value. It also seemed that the difficulty of imaging in geothermal environments seemed to be a surprise to them. Many papers have been published to demonstrate this.

PI Response:

This reviewer must have missed the map I showed on which I specified that our seismic data come from two known geothermal areas: Soda Lake Field near Reno, Nevada, and the high geothermal-gradient area near Big Bend Park, Texas. A closing slide showed a map indicating the work would be extended to a third geothermal field (Wister Field, Imperial Valley, California). I did not think I expressed "surprise" about the poor seismic data quality at these geothermal sites. To the contrary, we expected poor data quality to be encountered at each site.

Reviewer 23412

Score: 4.0

Comment: The newer scientific approach to acquire and interpret processed data is straight forward and should be disseminated to the seismic geophysical community.

PI Response:

No response entered.

Reviewer 23641

Score: 4.0

Comment: Sound technical/scientific approach employing experience from petroleum seismic to geothermal settings.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23471

Score: 3.0

Comment: This project has faced serious delays due to temporary or permanent loss of three members of the six-person research team due to personal injury/illness or spousal illness, which put them about three months behind schedule. In spite of this, they seem to be back on track and progressing well. Progress to date has been good, with promising images

obtained from their test line demonstrating that vertical-force vibrators can produce good S-wave images akin to those obtained with horizontal-force sources. A PhD thesis is being written based on these results, which should be finished in December 2012, and an article is being prepared for The Leading Edge. Based upon this research, this team is also considering modifying vertical-force sources to enhance the efficiency with which they generate S-waves.

PI Response:

No response entered.

Reviewer 23505

Score: 2.0

Comment: Results presented are limited due to some to events beyond their control, but 70% has been spent. It was not clear from the results presented that much progress has been made. It was not also clear that if the results could be applied to geothermal environments or was being developed for oil field applications.

PI Response:

No response entered.

Reviewer 23412

Score: 4.0

Comment: Results of the out crop test will applied to Soda Lake.

PI Response:

No response entered.

Reviewer 23641

Score: 4.0

Comment: Encouraging demonstration of the potential value and cost reduction of acquiring s-wave data through vertical source. Preliminary results on Soda Lake example are encouraging but ultimate success at imaging below high velocity surface remains to be demonstrated with 30% of project yet to go.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23471

Score: 4.0

Comment: This is clearly a well-managed project, with the PI having long years of experience in seismic data acquisition and processing and project management. The team has established good collaborations with various geothermal energy companies, which provide software, data and processing assistance, and has clear plans to apply this technique to 3-component, 3-D seismic data acquired at Soda Lake NV and Wister CA.

PI Response:

No response entered.

Reviewer 23505

Score: 2.0

Comment: Some uncontrollable events seemed to have disrupted the project and there has been difficulty in making progress. Not sure what oil companies' involvement is contributing.

PI Response:

I listed a few "oil" companies on one slide out of courtesy for their support of a field test we did in which we compared direct-S modes produced by a variety of vertical-force sources. I made no mention of these specific companies in my presentation. To have picked up this minor inclusion of oil company support that was not addressed verbally, I conclude Reviewer 23505 is super sensitive to oil-company assistance in developing technology that can benefit geothermal exploitation. Many "oil" companies are of course also "geothermal" producers, so I do not understand the concern about oil company assistance with any part of our research.

Reviewer 23412

Score: 4.0

Comment: Project management had some unforeseen snags but did manage to complete a product.

PI Response:

No response entered.

Reviewer 23641

Score: 3.0

Comment: Overcame challenging staffing situation and kept the project moving forward.

PI Response:

No response entered.

STRENGTHS

Reviewer 23471

Comment: This is a strong project achieving innovations in the use of traditional vertical-force vibrator sources to generate both S- and P-wave images in selected geothermal prospects using a cableless 3-component receiver array and new processing techniques.

PI Response:

No response entered.

Reviewer 23505

Comment: None

PI Response:

No response entered.

Reviewer 23412

Comment: Applies proof of concept to data acquisition and interpretation.

PI Response:

No response entered.

Reviewer 23641

Comment: Interesting opportunity to reduce cost of s-wave seismic surveying in geothermal settings with simpler source configuration.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23471

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23505

Comment: Very worthy goals. It is not clear at this point if the hypothesis addressed will work in geothermal areas, and using single (vertical) component sources to extract horizontal data is valid. This may be an example of trying to evaluate a large project ($1.7M) with a four page write up and a 20 minute presentation. More detailed evaluation may prove that the hypothesis is very valid and useful.

PI Response:

No response entered.

Reviewer 23412

Comment: This project has no apparent weaknesses.

PI Response:

No response entered.

Reviewer 23641

Comment: Delays in project (managing difficult staffing challenges) make ultimate results of vertical source s-wave survey approach applied to Soda Lake dependent on further work.

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23471

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23505

Comment: None

PI Response:

No response entered.

Reviewer 23412

Comment: No improvements have been identified.

PI Response:

No response entered.

Reviewer 23641

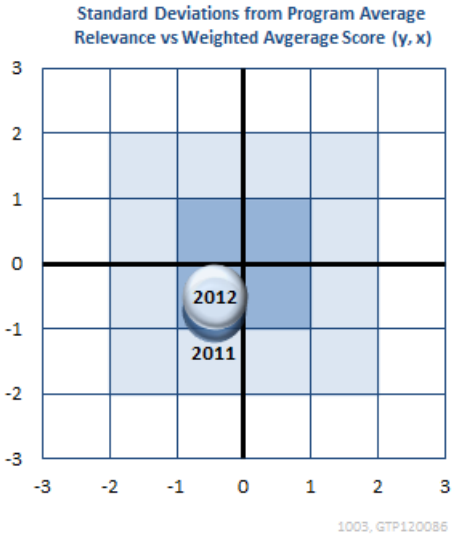
Comment: It would be interesting if the PI did some scoping quantification of the potential cost savings of using simpler source configurations (vertical source) compared with multiple x-y-z source to collect shear data.

PI Response:

No response entered.

SUPERCRITICAL CARBON DIOXIDE

Review: 2012 Geothermal Technologies Office Peer Review
ID: 1003
Project: Laboratory and Field Experimental Studies of CO2 as Heat Transmission Fluid in Enhanced Geothermal Systems (EGS)
Principal Investigator: Xu, Tianfu
Organization: Lawrence Berkeley National Laboratory
Panel: Supercritical Carbon Dioxide



RELEVANCE/IMPACT OF RESEARCH

Reviewer 23441

Score: 4.0

Comment: The project is of high relevance to DOE and its objectives are to report on the performance of CO2-based geothermal energy linking modeling, laboratory, and field studies to (1) assess the feasibility of converting an initial water-based system into a CO2-reservoir, (2) quantify aqueous chemical evolution and mineral alteration induced by mixtures of CO2 and water, (3) investigate development and operation of a CO2-based EGS for actual reservoir conditions that include presence of saline brine, and (4) explore the possibility of using CO2 as a chemical stimulation agent in conventional water-based EGS. The water footprint concerns are not an issue here and innovative aspects of using CO2 are that compared to water, CO2 could extract heat at 50% larger rates. [Possibly, the Geothermal facility could receive some credit for receiving the CO2, but this was not mentioned directly by the presenter]. Additionally, there is the prospect of finding sequestration of CO2 as an ancillary benefit. At least eight DOE geothermal program goals that could be addressed by this project are suggested.

PI Response:

Reviewer 23457

Score: 3.0

Comment: The project is mainly concerned with modeling studies (using LBNL TOUGHREACT code) of CO2 injection in to EGS reservoirs. The focus of these studies is on (1) demonstrating the superiority of CO2 as a heat transmission fluid, and (2) modeling chemical reactions between CO2, aqueous fluids, and rocks. Such studies together with field experiments are needed for deciding if CO2 should be used as a heat transmission fluid in EGS systems.

PI Response:

Reviewer 23509

Score: 3.0

Comment: Reservoir models for EGS are a critical area of need to enable lower cost production of geothermal resources. This project focused on modeling use of CO2 as a subsurface heat transfer fluid, which has potentially large benefits on overall plant efficiency. Project did not attempt to evaluate costs, which are far less clear for CO2 geothermal projects.

PI Response:

Reviewer 23465

Score: 1.0

Comment: The modeling work conducted by the PI has some merit and attempts to address knowledge gap. However, the project will have little impact on assessing the costs, performance, application and importance in geothermal energy development. This project should be refocused on another project site, other than the Ogachi site. It looks like it may be a very long time before the Japanese government is going to look at research activities that the public may perceive as a trigger to another earthquake. This Reviewer sees little advantage in completing this project unless the PI provides a clear direction as to where this project is going. This project while interesting from a modeling perspective, appeared inconsistent in direction and too many unknowns.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23441

Score: 4.0

Comment: The project approach will extend the well-established LBNL modeling capabilities building upon the work of Karsten Pruess. Measured concentrations of aqueous components at the 2006 Ogachi CO2 injection test measurements were reproduced by the LBNL numerical modeling; TOUGHREACT for fluid-rock interaction and reactive transport in a CO2-EGS system has been partially calibrated. Modeling of the five-spot reservoir with CO2-EGS operation conditions including the fracture domain and interactions with the rock matrix when there is a mixed two-phase CO2-water system was modeled. This included considerations for conditions in the reservoir and precipitation of carbonate minerals.

PI Response:

Reviewer 23457

Score: 3.0

Comment: The model parameters are based on laboratory experiments being carried out at LBNL, University of Utah, and PARC. To-date (September 2011), the model has been applied to investigate dissolved CO2 injection at Ogachi EGS site in Japan. Generic studies using a simple geometry (5 spot pattern) performed to-date show that CO2 is a viable heat transmission fluid. The relevance of these generic studies to real EGS systems with significant heterogeneity is not clear.

PI Response:

Reviewer 23509

Score: 2.0

Comment: Loss of planned field test validation at the Ogachi site seems to have derailed this project to some extent. Dr. Xu discussed modeling plans at Ogachi, Springerville (GreenFire), and Cranfied sites as replacements. These are vastly different reservoir types, especially at Cranfield, so the research plan seems disjointed and without a focus on advancing modeling for EGS. Even the modeling done to date implemented very simplistic and unrealistic assumptions in symmetry for a fractured EGS system. Analysis done since last year seems to have focused on mineral trapping, which is at best a side benefit and at worst a severe problem leading to reservoir plugging that would need to be avoided in a CO2-based geothermal project. The PI provided no discussion of these issues. No advances in TOUGHREACT were attempted to address reactivity with hot and wet scCO2.

PI Response:

Reviewer 23465

Score: 3.0

Comment: For the most part the technical approach taken by the PI was rational, logical and deployed in a reasoned sequential manner. The five-Point methodology employed is technically sound. The PI focused on developing a geothermal model by using known data from the Ogachi EGS site in Japan and the Soultz-sous-Foret EGS site in France. The project employed TOUGHREACT and MINC programs to determine preliminary results such as the establishment favorable CO2 mineral carbonation and favorable temperatures for mineral trapping between 160C to 190C. The five-Point methodology employed is technically sound.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23441

Score: 3.7

Comment: The project has expended less than $500K in funding and delivered significant accomplishments. Modeling of the five-spot reservoir with CO2-EGS operation conditions, have indicated that the fracture domain of the system is quickly filled with injected super-critical CO2. In contrast, the rock matrix remains in mixed two-phase CO2-water conditions, and precipitation of carbonate minerals continues for a long time. Geochemical modeling for two mineralogical compositions from Desert Peak and Soultz EGS field sites indicates that a rock with higher contents of Ca, Mg, and Fe (such as anorthite and chlorite), is more favorable for CO2 mineral carbonation in CO2-EGS reservoirs. The most favorable temperatures for the mineral trapping are between 160C and 190C. This is an important result. At the same time, the results appear to be of value to the program. However, there are concerns for this reviewer about the field task linkages in this project. This task used data from injection experiments at the Ogachi EGS site, Japan, and the project effort concentrates on modeling studies of aqueous chemical evolution and mineral alteration. In the future, possible sites include Springerville dome natural CO2 site (GreenFire), Cranfield site (BEG, Texas). The Japan site is now offline. It was in an earthquake zone was suspended from injection. The Springerville dome is a natural CO2 site (GreenFire) and the project efforts to develop wells with GreenFire appear to be in question.

PI Response:

Reviewer 23457

Score: 3.0

Comment: Project was started in February 2010. Funding for FY 2012 has not been received. Generic studies on CO2 as a heat transmission fluid, and the modeling of CO2 dissolved in brine at Ogachi have been completed. Future work (especially modeling of supercritical CO2 injection into EGS) will to a great extent depend upon the progress in field experiments.

PI Response:

Reviewer 23509

Score: 2.0

Comment: Although not a particularly large budget at something over $300K, tangible output from the funding received is very low. Three presentations at Stanford Workshops is all that has been produced. This points to a lack of clear technical direction discussed previously. Dr. Xu's presentation highlighted only very limited results that do not show any key technical advances or insights that would be of significant benefit to EGS projects considering using CO2 as a working fluid.

PI Response:

Reviewer 23465

Score: 1.0

Comment: The PI managed to complete a rather complex modeling analysis as proposed. It remains unclear what value, to what extent and to who will actually use the results of this modeling analysis. The PI did not provide enough information as to where this project is in relation to the schedule.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23441

Score: 3.5

Comment: The project focuses on numerical modeling hence, the issues of management to field deploy some EGS test system do not directly impact performance and budget. Overall there is strong management team linking with the field programs. The management has established a close working relationship with the University of Utah and the PARC colleagues who are conducting validating laboratory experiments.

PI Response:

Reviewer 23457

Score: 4.0

Comment: The researchers are to be commended for establishing working relationships with both US (University of Utah, PARC) and overseas (Ogachi, Japan) researchers. Such international collaboration is essential for scientific progress on complex projects. If DOE decides to fund this work in FY 2012 (and beyond), this project should be combined with the parallel project (T. Kneafsey, PI) at LBNL.

PI Response:

Reviewer 23509

Score: 2.0

Comment: PI stated during presentation that he was unsure of total budget, which never bodes well for a project. PI also seems to be confused about separation between this ARRA project and follow-on support that must be separate. Lack of significant technical accomplishments appears to be largely the result of management indecision about project direction once original plan proved impossible to carry out.

PI Response:

Reviewer 23465

Score: 1.0

Comment: The PI did not adequately address this criteria in the presentation or during the question and answer period. This project has spent $246K of FY10 and will spend $218K of FY11 that totals to $464K. It is unknown where this project is along the schedule, which apparently has been revised in June 2011. The PI indicated that this project has no end date. It is unknown where exactly what the spending plan is for FY12 or what the revised schedule looks like, and what exactly the final product(s) are going to be.

PI Response:

STRENGTHS

Reviewer 23441

Comment: The project is producing quantitative predictions that are being matched against field data. Key issues that are being addressed include: (1) establishing the effectiveness of CO2 as an energy carrier for extracting Geothermal heat; (2) establishing the role of hydraulic and thermal effects during CO2 circulation through the injection system and production boreholes; and (3) examining the major chemical interactions occurring among CO2, aqueous fluids, and rock minerals.

PI Response:

Reviewer 23457

Comment: The principal investigator (Xu) has been involved in modeling of aqueous chemical reactions in geothermal systems for a long time. The project is unique in attempting to combine modeling, laboratory, and field studies.

PI Response:

Reviewer 23509

Comment: Multiphase flow and reactive transport modeling is critical to any future geothermal project considering CO2 as a subsurface working fluid. Studies that exercise modeling tools and tailor their capabilities for CO2 EGS systems are badly needed.

PI Response:

Reviewer 23465

Comment: Close coordination with ARRA funded LBNL CO2-EGS project. The project has provided some useful modeling results from the integration of industry standard modeling programs, TOUGHREACT and MINC. The project met the initial phase of the stated technical goals and objectives. The project management team is highly qualified and capable.

PI Response:

WEAKNESSES

Reviewer 23441

Comment: The project needs to make a stronger case that the TOUGH model realistically simulates fractures as displayed in the graphical result slides. The reviewer has had direct reports work with the LBNL TOUGH model and there are other approaches within the TOUGH framework that may address fractures more realistically.

PI Response:

Reviewer 23457

Comment: Field data on supercritical CO2 injection into EGS systems may not become available any time soon.

PI Response:

Reviewer 23509

Comment: Project seems to have lost direction and focus due to loss of hoped for activities at the Ogachi site. PI's project presentation this year was a weak overview of accomplishments given an approximately $350K investment, which is borne out by a very small set of tangible project deliverables.

PI Response:

Reviewer 23465

Comment: It is unknown where exactly this project is going and what the funding is going to be used for. It is also unknown, if the project results will be of value to the geothermal industry. How much more modeling needs to take place? How many more technical papers are going to be published on this same subject?

PI Response:

IMPROVEMENTS

Reviewer 23441

Comment: Would encourage the team to actively continue to develop the TOUGH model systems and not assume that they will serve as an established platform for further work.

PI Response:

Reviewer 23457

Comment: Include more realistic configurations (rather than 5 spot pattern) in generic modeling studies. The project should be combined with the parallel project at LBNL. Also, the focus should be shifted to modeling laboratory experiments, and improving TOUGHREACT and TOUGH2 simulators. Little is to be gained from continuing with generic 5-spot computations.

PI Response:

Reviewer 23509

Comment: Project is at the end of its ARRA funding so no course corrections are possible.

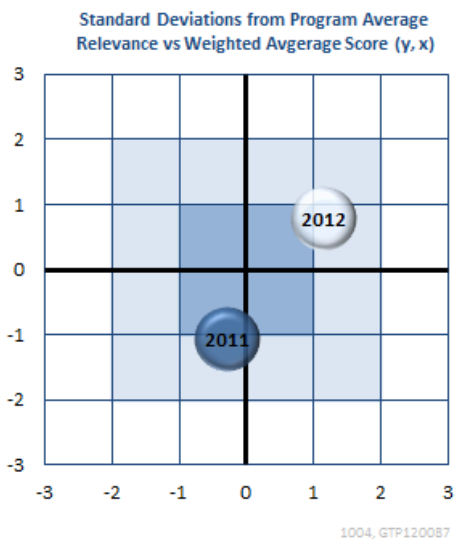
PI Response:

Reviewer 23465

Comment: The PI needs to specify clearly how this project is going to accomplish two ideas that, on the surface appear incompatible, namely the sequestration of CO2 and using CO2 as a heat transmission fluid for power production. The title of the PI's presentation is: Laboratory Field Studies of CO2 as a Heat Transmission Fluid in EGS, but no discussion was

provided in the materials or presentation on how the heat transfer properties of CO2 or a how the CO2 would be obtained, favorable geologic site location parameters, injection rates and locations, possible complications, etc.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: 1004
Project: Enhanced Geothermal Systems (EGS) with CO2 as Heat Transmission Fluid
Principal Investigator: Kneafsey, Tim
Organization: Lawrence Berkeley National Laboratory
Panel: Supercritical Carbon Dioxide

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23441

Score: 4.0

Comment: Enhanced Geothermal Systems (EGS) with CO2 as Heat Transmission Fluid combines geothermal energy production with geologic carbon sequestration of CO2. The project is of high relevance to DOE it continues earlier work that had been funded internally by the former LBNL Director (now Secretary of Energy). Success in this approach could make geothermal practical in regions where local sources of water are minimal allow energy production in reservoirs that would otherwise not be useable. The overall objective of this research is to explore the feasibility of operating with CO2 as the heat carrier and extend LBNL's well-established modeling efforts. The project proposed to test predictions about the heat transfer and flow properties of CO2; examine stripping water from a permeable medium by continuous circulation of dry CO2; look at optimization and scale-up of all aspects of stimulation, development, and operation of EGS with CO2; and identify favorable as well as unfavorable geologic conditions for a field testing.

PI Response:

No comment

Reviewer 23457

Score: 4.0

Comment: Objectives of this project include (1) exploring the use of CO2 as a heat transmission fluid in EGS systems (2) performing laboratory experiments to test predictions of theoretical models, and (3) investigation of techniques for water removal by circulation of anhydrous CO2. Successful completion of this work should help in the evaluation of CO2 as a heat transmission fluid instead of water in EGS systems.

PI Response:

No comment

Reviewer 23509

Score: 4.0

Comment: Project provides a good mix of experiment and modeling studies that address use of CO2 as a heat transfer fluid. Modeling studies done this year highlighted an issue around reservoir plugging due to salt precipitation as CO2 floods the fracture network. Experimental system developed is well-poised for future work supporting the GTO.

PI Response:

No comment

Reviewer 23465

Score: 3.0

Comment: The modeling work conducted by the PI has merit and attempts to address a knowledge gap of the feasibility of operating an enhanced geothermal system with CO2 as heat transmission fluid. This project investigates the possibility of combining geothermal energy production with geologic carbon sequestration. In theory, this may be accomplished by locating a hot geothermal zone with minimal water presence. Consideration should be given to The Geysers or areas within proximity of The Geysers. If this concept can be accepted by the public and regulating authorities, it may be a game changer. This however, will be highly unlikely. The PI is right, obtaining environmental clearance from regulatory agencies, will take years.

PI Response:

No comment

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23441

Score: 3.7

Comment: Key issues currently being addressed include the precipitation of salt in the reservoir resulting in clogging, and laboratory investigations of heat transfer using CO2 at elevated temperature and pressure. Numerous strategies are being investigated to examine their effects on reservoir clogging and this is linked to laboratory tests designed to specifically provide physical properties for the simulations platforms. The salinity of the native reservoir brine is very important. While CO2-rock interactions are not expected to be significant, evaporating water from the brine with anhydrous CO2 is likely to cause plugging of fractures. Our simulations have only considered one precipitation model, and additional simulations and laboratory work are warranted to examine this process. This process will also occur in geologic carbon sequestration, and work in this area may provide understanding for EGSCO2 and vise-versa. The laboratory component focuses on physical aspects of multiphase fluid flow and heat transfer of brine-CO2 mixtures, and is closely coordinated with an AOP-funded project on “Laboratory and Field Experimental Studies of CO2 as Heat Transmission Fluid in Enhanced Geothermal Systems (EGS).”
The LBNL TOUGH2/ECO2N simulator is being used to design and analyze laboratory experiments, and will be further enhanced to accommodate elevated temperatures and the full range of brine-CO2 mixtures of interest. The TOUGHREACT simulator is being used to model reactive chemical transport processes induced by CO2, and will likewise be enhanced for the range of thermodynamic conditions relevant for EGS with CO2. Observations of carbonation reactions in natural analogue systems will be used to guide and constrain model development, and to aid in model calibration.

PI Response:

No comment

Reviewer 23457

Score: 4.0

Comment: A combination of laboratory experiments and modeling studies is being used to address several issues including (1) salt precipitation and formation clogging as a result of CO2 injection, and (2) laboratory investigation of heat transfer by CO2 injection. In addition, work is being carried out to improve simulation tools (TOUGH, TOUGH/REACT).

PI Response:

No comment

Reviewer 23509

Score: 4.0

Comment: Experimental and modeling approaches are sound and have provided some key insights into use of CO2 as a heat transfer fluid. Excellent record of presentations and publications reflects that.

PI Response:

No comment

Reviewer 23465

Score: 4.0

Comment: The technical approach taken by the PI was rational, logical and deployed in a reasoned sequential manner. The PI focused on developing a geothermal model by using known data from the Ogachi EGS site in Japan and other known sources. The PI employed a modeling simulator TOUGH2/ECON. Project tasks were prioritized. The PI identified two key issues: 1) salt precipitation that will result in fracture clogging, and 2) need to understand the heat transfer properties and characteristics of CO2.

PI Response:

No comment

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23441

Score: 3.5

Comment: The project builds upon earlier technical accomplishments including the design and assembly of a laboratory test system capable of applying more than 30 MPa fluid into a test vessel that could be heated to 200C to examine heat extraction from a hot porous medium by means of dry CO2 and extending the simulation capabilities for multiphase flow of brine-CO2 mixtures to these physical conditions. In addition to continuing refinements of the laboratory and modeling work, the project has developed technical objectives and hypotheses, and site selection criteria for a first field test of EGS with CO2; designed and assembled laboratory flow and heat extraction tests for water-saturated porous medium by means of dry CO2 at different temperature, pressure, and flow conditions. These studies were linked to simulation capabilities for multiphase flow of brine-CO2 mixtures for the entire range of conditions of interest to EGS with CO2; and this was extended to modeling studies of rock-fluid chemical interactions in laboratory flow experiments and field-scale systems. In addition to previous modeling of field test data from the Ogachi field test, we performed numerical modeling of laboratory experiments of water-rock-CO2 interaction from laboratory experiments conducted by investigators at the conditions of the Ogachi geothermal field.

PI Response:

No comment

Reviewer 23457

Score: 3.0

Comment: 1. Assembled a laboratory apparatus to perform heat transfer experiments using dry CO2. Carried out experiments, and relevant modeling studies.
2. Extended TOUGH simulation capabilities for multiphase CO2-water flow.
3. Performed modeling studies of rock fluid chemical interactions for the field experiment at Ogachi.
4. Formulated site selection criteria for field test of CO2 EGS.

Laboratory experiments on water-CO2 have yet to be undertaken. Also additional work (lab and simulation) is needed to examine precipitation and clogging.

PI Response:

Although we have performed a test on the water-CO2 system, it was not well presented in the materials and more tests are desired. We agree with the reviewer's comment that additional lab and simulation work is needed to examine precipitation and clogging.

Reviewer 23509

Score: 4.0

Comment: Although Dr. Kneafsey only recently took over the project as PI, the transition appears to have been seamless. Milestones have been achieved despite loss of the Ogachi site and the project has produced a considerable number of publications and presentations covering both the modeling and experimental aspects.

PI Response:

No comment

Reviewer 23465

Score: 4.0

Comment: The PI completed various technical tasks on time and within budget. Some of these tasks were complex and required significant analysis as proposed.

PI Response:

No comment

PROJECT MANAGEMENT/COORDINATION

Reviewer 23441

Score: 3.0

Comment: It is not unusual for projects to grow to a point where the skill set of the original pioneers on the project are not the most appropriate for moving the work to the next stage. Refinements and revisions of the model should be an ongoing effort, however, the project focuses on linking experimental, field, and numerical modeling. Hence, the issues of management to field deploy some EGS test system were clearly not the area of strength. This becomes clear when the project concludes that; "finding a technically and politically ideal site for EGSCO2 may be challenging. Permitting an EGSCO2 site may take a few years and require an iterative approach including the feedback and buy-in from local, state, and federal regulators." The project needs to "spread its wings" and bring in team members with a different skill set who will be facilitate the work in these areas.

PI Response:

We agree with the reviewer. In the presentation I suggested perhaps working with the Greenfire project as it is perhaps the most realistic CO2-EGS project at the time. That being said, it may not be the best project to consider, and some CO2 sequestration pilot sites (such as Cranfield) should be considered as well to conserve resources. Additional skill sets will be needed both for siting a test, and performing a test.

Reviewer 23457

Score: 3.0

Comment: Although there have been some delays due to unavailability of data and other commitments, the project is proceeding in a logical fashion.

PI Response:

No comment

Reviewer 23509

Score: 4.0

Comment: Not much to comment on here. Project was well run and accomplished the key objectives.

PI Response:

No comment

Reviewer 23465

Score: 3.0

Comment: This project was well administered in terms of technical, scheduling, staff allocation and financial resource allocation. The PI provided appropriate and adequately placed decision points. The PI worked well with collaborating partners at UCB.

PI Response:

No comment

STRENGTHS

Reviewer 23441

Comment: The project is well grounded technically and the validation against field studies is very important to the possible success of using CO2 as an energy carrier. The simulation development, reporting and publication record are strong.

PI Response:

No comment

Reviewer 23457

Comment: Combination of model development, laboratory experiments, and simulation of both laboratory and field experiments is unique to this project. Because of the unavailability of field data, focus should be on characterizing relevant phenomena in the lab.

PI Response:

No comment

Reviewer 23509

Comment: Project addressed several critical areas of R&D for the GTO and made significant advances in understanding benefits and technical issues associated with use of CO2 as a heat transfer fluid in EGS.

PI Response:

No comment

Reviewer 23465

Comment: Close coordination and no overlap with the DOEGP funded LLNL Laboratory Field Studies of CO2 as a Heat Transmission Fluid in EGS project. The project has provided some useful modeling results from the integration of industry standard modeling programs, TOUGH2/ECON. The project met all milestones and completed all tasks on time and within budget. The project management team is highly qualified and capable.

PI Response:

No comment

WEAKNESSES

Reviewer 23441

Comment: The project needs more help on the linkage to the field work. This really is not optional. To this reviewer, this approach will either live or die as a successful demo based on expanding the team and bringing in personnel who will focus on the field work. This reviewer really would like to see success here. Hence, the bluntness of the critique.

PI Response:

We appreciate the comment (and its bluntness) and agree with it.

Reviewer 23457

Comment: Unavailability of field data on CO2 EGS will make it difficult to fully test and calibrate the modeling software.

PI Response:

We agree. This comment relates well to the above comment, which we are in agreement with.

Reviewer 23509

Comment: PI highlighted modeling result that brine dryout during the CO2 charge is predicted to cause plugging due to halite precipitation. Recommendation was to do more detailed work but a relatively cheap and simple fix is to just inject waste water or other brown water source at lower salinity before beginning the CO2 flood. Hence, it would be valuable in any follow-on work to identify other higher value research objectives.

PI Response:

We agree and are planning to perform these simulations this summer.

Reviewer 23465

Comment: It is unknown where exactly this project is going to lead given the unlikely possibility of public acceptance. The PI did not provide any discussion on possible project sites. Little discussion was provided on CO2 heat transfer properties or a how the CO2 would be obtained, favorable geologic site location parameters, injection rates and locations, possible complications, etc. How many more technical papers are going to be published?

PI Response:

Excellent comment, relating well to earlier comments on fieldwork. The reviewer's disappointment mirror's the PI's. Answering these practical questions will be critical to the success of CO2-EGS. As I stated in the presentation, they are not trivial questions and answering them will be time and labor intensive, and require bringing people with different skill sets into the project.

IMPROVEMENTS

Reviewer 23441

Comment: The project needs to “spread its wings” and bring in team members with a different skill set who will be facilitate the work in the field deployment of CO2 EGS.

PI Response:

We agree.

Reviewer 23457

Comment: Include more realistic EGS geometries in numerical simulations. Carry out heat transfer experiments using rocks characteristic of EGS systems. This project should be combined with parallel effort at LBNL (PI: T. Xu).

PI Response:

We agree.

Reviewer 23509

Comment: ARRA funding is spent so improvement suggestions are not implementable at this point.

PI Response:

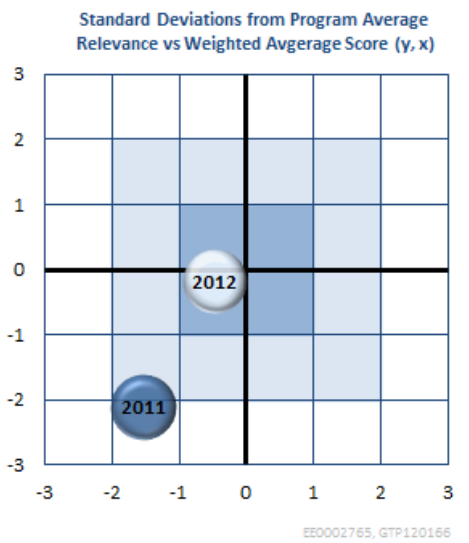
No response entered.

Reviewer 23465

Comment: The PI needs specify clearly how this project is going to accomplish two ideas that appear to be incompatible, namely sequestration of CO2 and using CO2 as a heat transmission fluid for power production.

PI Response:

I apologize for not addressing that in the presentation. We have published a couple of papers that address this based on fluids loss at geothermal fields. While losing water in a reservoir (~sequestering the water) is different from sequestering CO2, very large quantities of water can be lost leading to the conclusion that comparable quantities of CO2 can be sequestered as well. This unknown can be estimated to a certain extent using numerical simulations and available field data, however field testing will likely show different results because of different properties of CO2 (e.g. interfacial tension, viscosity, density).



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002765
Project: Experiment-Based Model for the Chemical Interactions between Geothermal Rocks, Supercritical Carbon Dioxide and Water
Principal Investigator: Petro, Miroslav
Organization: PARC (Palo Alto Research Center)
Panel: Supercritical Carbon Dioxide

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23441

Score: 2.5

Comment: This is a well-funded project that has costed over $2 MM. The main technical objectives of the project are to report on thermodynamics of rock-water-scCO2 interactions; and kinetics of rock-water-CO2 reactions. All of this effort will lead to better data that may be used by geothermal reservoir models and power generation cycles. Physical property measurements were not specifically discussed and this is a serious lack that needs to be addressed. What specific thermodynamic data is being generated, whether it is novel or confirming literature values, etc. needs to be explained in detail. It is the determination of this reviewer that the scoring for this effort should not be higher until it transitions from discussions and pictures of flow cells (which clearly do not account for project expenditures).

PI Response:

The impact of this project will depend not only on how relevant but also how conclusive are the results, therefore most of the effort so far was devoted to making sure that system generates accurate data, rather than addressing relevant issues. However, in agreement with the reviewer's suggestion, we are turning the project towards novel situation and interpretation of both thermodunamics and kinetics aspects of the complex mineral-water-CO2 interactions.

Reviewer 23457

Score: 4.0

Comment: Objectives of the project are to obtain thermodynamic and kinetic data on CO2-water chemical interactions with rocks. These data are needed for the modeling of CO2 EGS systems, and to evaluate the use of CO2 as a heat transmission fluid instead of water.

PI Response:

No response entered.

Reviewer 23509

Score: 1.0

Comment: The core problem with this project is the "build it and they will come" approach being pursued. The research project has been underway for over 2 years and has focused on constructing a high-pressure flow-through system instead of addressing scientific questions. This incredibly expensive flow-through system has been constructed but neither the presentation materials or the project summary described the rationale or more importantly the scientific basis or program plan for the mineral systems being studied. Critical factors such as gaps/discrepancies in the thermodynamic database, importance/relevance to EGS systems, solid solution issues, precipitation kinetics, transition effects to a water-wet scCO2 system, and a myriad of other critical scientific questions are not being addressed in a logical and coherent research plan. As a result, this project has virtually no chance of having a long-term impact on GTO objectives.

PI Response:

The "build followed by use" approach is being pursued as proposed and awarded. We agree that one of the critical factors is to address gaps/discrepancies in the thermodynamic database. Actually, we are addressing those issues with the following progress: 1) we have consulted with a key mineral thermodynamics expert at LBNL (Dr. John Apps) in interpreting our results, 2) we are also looking at issues such as solid solution in feldspars when interpreting the mineral dissolution experiments, and 3) the outcomes are being summarized in a new publication focused explicitly on the gaps and discrepancies in the thermodynamic model (to be presented at the GRC meeting later in the year).

Reviewer 23465

Score: 4.0

Comment: The experimental research conducted attempts to address a significant knowledge gap in the understanding the thermodynamics of rock-water-C02 interactions, and the kinetics of rock-water-CO2 reactions. This research, when completed, will provide a much needed understanding rock-water-CO2 interactions and kinetics, which are often misunderstood. The impacts of this research should help address the identification and location of existing or creation of EGS well injection sites. By knowing what types of diverse mineral formations exist in the subsurface, it will be easier to assess where best to inject CO2 and determine interactions for sequestration.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23441

Score: 2.5

Comment: Both in the presented and written materials, the scientific and technical approach were lacking in details. Construction of equipment is not a technical approach. While there were criticisms form other reviewers about the PARC effort revisiting well-known chemistry, there still seems to be good reason to support this work. However, the science must be more rigorous. Gathering specific thermodynamic, liquid-liquid equilibrium; and kinetics is not trivial and having the ability to interrogate a system when there are concerns about other possible reactions or dissolved electrolytes (the presence of salt for example) seems of value. The program must do better here.

PI Response:

Constructing the equipment was just a necessary step to create a tool that enables us to gain deeper understanding of the thermodynamics and kinetics, and we have started to dive into the science of complex interactions and intend to go deeper in the final phase of the project. In this respect, we have consulted with a key mineral thermodynamics expert (Dr. John Apps at LBNL) in interpreting our results, also looking at issues such as solid solution in feldspars when interpreting the mineral dissolution experiments, and summarizing the outcomes in a new publication focused on the gaps and discrepancies in the thermodynamic model (to be presented at the GRC meeting later in the year).

Reviewer 23457

Score: 3.0

Comment: Batch and flow through experiments will be performed to generate thermodynamic and kinetic data on CO2-water interactions with rocks.

PI Response:

No response entered.

Reviewer 23509

Score: 1.0

Comment: The PIs presentation and project summary show a technical approach focused on constructing an experimental apparatus first and then using it to collect data. This is backwards from a well-conceived research plan. First, the flow-through reactor system being constructed is not a first of kind or unique instrument that would justify such an approach. Various types of flow-through equipment are widely available and have been used for rock-water studies for decades. Instead, a clear discussion of the data gaps and fundamental scientific questions being addressed is needed and then an explanation of the experimental equipment needed or developed to fill those data gaps. "Discoveries" that vacuum degassing solutions is necessary when conducting solubility experiments does not instill confidence in this reviewer regarding soundness of the research approach being pursued.

PI Response:

Our plan hasn't changed and was to construct the multichannel batch reactor first, followed by generating initial data on mineral solubility, and then to upgrade the system with a flow-through channel, in order to address complex thermodynamics and kinetics of the mineral-fluid interactions in a one year-long final phase. We have built the batch reactor and generated a sufficient volume and diversity of data to update the pre-existing model (in progress at LBNL), with PARC currently finishing validation of the complete batch & flow-through system and getting ready for the final data generation focused on both thermodynamics and kinetics. Various types of reactor cells for similar studies were available but none could perform the multi-ion on-line analysis required for this program to succeed.

Reviewer 23465

Score: 4.0

Comment: The technical approach taken by the PI was rational, logical and deployed in a reasoned sequential manner. The PI was very clear in describing project objectives: 1) thermodynamics of rock-water-C02 interactions, and, 2) kinetics

of rock-water-CO2 reactions. Project tasks were properly prioritized. The PI employed the appropriate technical staff, procedures, methodologies, instrumentation, and equipment.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23441

Score: 2.5

Comment: The presentation could have done more to quantitative the current review matrix. This is a large and well-funded effort that hopes to generate sufficient data for the new supercritical CO2-EGS model (from late 2012 till mid 2013). Key accomplishments include the construction of a batch system for rock solubility (completed in 2011); and the generation of initial data (early 2012); and the upgrade into a flow-through system (mid 2012). The project builds upon earlier technical accomplishments and has been upgrading the system by adding a circulation channel to existing five batch reactors. PARC is now performing additional mineral characterization (BET, SEM, XRD) with the objective of using the mineral solubility data generated to model geothermal rock-fluid interactions. They now have started another data generation work task, targeting both thermodynamic and kinetic aspects of the rock-fluid interactions. Thus far they have generated sufficient volume of the solubility results to serve as an input for initial modeling for a variety of mineral samples; a variety of water-CO2 fluids; and different T/P conditions. PARC believes that for some systems the trends in known mineral responses to specific fluids and conditions now are confirmed. Where there are discrepancies in absolute solubilities, these seem to be explained by an effect of fluid/mineral impurities.
PI Response:

No response entered.

Reviewer 23457

Score: 3.0

Comment: Solubility data has been obtained for various minerals using various CO2/H2O fluids under several pressures and temperatures. Modeling work has been initiated to compare measurements with literature. Work is proceeding on upgrading the batch setup to a flow through circulation system.

PI Response:

No response entered.

Reviewer 23509

Score: 1.0

Comment: Although the project experienced a startup delay, it is impossible for this reviewer to rationalize expenditure of over $2M for rock-water-CO2 studies with no tangible output over a 2 year period other than a single presentation done just weeks before the program review. The presentation materials provided no insight either as the PI highlighted no

solubility products, rate constants, pH dependence, or other relevant data that would suggest progress towards improved data sets for geochemical modeling. The "discovery" that residual CO2 in air would impact measured solubility of calcite and dolomite is not notable except for the fact the PI believed it was significant enough to highlight in the presentation.

PI Response:

Building and validation of a multi-channel well synchronized equipment, the first of its kind, is not a trivial matter and requires a significant engineering effort. That needs to be supplemented and eventually replaced by the effort of researchers performing the experiments and turning the data into models. We believe that knowledge and capability created can justify such a significant effort.

Reviewer 23465

Score: 3.0

Comment: The PI completed a number of technical tasks on time and within budget. Some of these tasks were complex and required significant analysis. The PI provided start and end dates. The project is on schedule with 53.7% of the $4.0 million total budget has been spent. It is unknown what percentage of $3.0 million DOEGP funds have been spent to date.

PI Response:

The DOE portion corresponds to 75% of the spent amount, the 25% is covered by PARC and includes the LBNL's portion of the cost share.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23441

Score: 2.5

Comment: The management needs to link the team with a strong thermodynamicist who is skilled at reviewing and developing thermodynamic; physical property; and kinetic data.

PI Response:

We have consulted with Dr. John Apps, who has a wealth of experience in fluid-rock interactions and the thermodynamics and kinetics of mineral precipitation and dissolution reactions, to assist us in the interpretation of the experimental results. We will continue to interact with Dr. Apps and other geochemists at LBNL.

Reviewer 23457

Score: 3.0

Comment: The project has experienced some delays because of "novation". The remainder of the project work (flow through experiments) are expected to proceed on schedule.

PI Response:

No response entered.

Reviewer 23509

Score: 1.0

Comment: Lack of technical output, an upside down R&D plan, and unclear scientific objectives fall squarely on the PM to both recognize and correct. Similar issues were highlighted at the review of this project last year but there was no evidence of course corrections being implemented by the PM. The PI did not indicate where and how collaborations with LBNL were taking place. It seems to be a one-way effort with data generated by the PI eventually transferred to LBNL for modeling. The PI would be strongly advised to take advantage of expertise at LBNL and elsewhere to shore up his experimental methods and plan before proceeding further with costly experiments of uncertain value and impact to the GTO.

PI Response:

The collaboration with PARC and LBNL is not a "one-way effort", but a dynamic interaction with the modeling of initial data providing guidance in further experimenting. Among examples, we have identified issues with composition of the assumed anorthite sample that affected its dissolution behavior, we have quantified the effect of residual CO2 on solubility of some minerals, and jointly addressed the effect of kinetics on measured thermodynamic data.

Reviewer 23465

Score: 4.0

Comment: This project was well administered in terms of technical, scheduling, staff allocation and financial resource allocation. The PI provided appropriate and adequately placed decision points in the schedule. The PI has worked well with collaborating partners at LBNL, SPX, Parr, ISCO, UCB and LBNL Molecular Foundry.

PI Response:

No response entered.

STRENGTHS

Reviewer 23441

Comment: The project eliminated the initial delay in project progress by making the system more easily capable of upgrades, thus speeding up the remaining tasks.

PI Response:

No response entered.

Reviewer 23457

Comment: Laboratory experiments to obtain fundamental thermodynamic and kinetic data needed to assess the use of CO2 in EGS systems.

PI Response:

No response entered.

Reviewer 23509

Comment: There are certainly key gaps and scientific questions to be addressed with respect to CO2 and water interactions with key minerals. I just do not see this project succeeding in addressing these questions.

PI Response:

No response entered.

Reviewer 23465

Comment: The technically solid approach taken by the PI in addressing a significant knowledge gap. Technical credentials of project team and collaborators. Coordinated collaboration with other research organizations. The project has met all milestones and completed all tasks on time and within budget.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23441

Comment: The management needs to link the team with a strong thermodynamicist who is skilled at reviewing and developing thermodynamic; physical property; and kinetic data. The publication record is weak and needs to be significantly improved. Journal articles are required.

PI Response:

As mentioned in our response to other reviewer comments, we are consulting with one and looking for other experts in fluid-rock interactions and the thermodynamics and kinetics of mineral precipitation and dissolution reactions, to assist us in the interpretation of the experimental results. We published a description of our system and preliminary data at the Stanford Geothermal Workshop "System and methodology for rapid evaluation of geothermal rock-fluid interactions associated with CO2-EGS", had another paper on the experimental capability at the TechConnect conference in June, and have a paper devoted to dissolution data and modeling issues accepted for presentation at the upcoming Geothermal Resources Council meeting entitled "The solubility and kinetics of minerals under CO2-EGS geothermal conditions: Comparison of experimental and modeling results." As our work progresses, we will publish our findings as journal articles as well.

Reviewer 23457

Comment: It is not clear if the experiments will be performed on rocks(e.g. granite) hosting the EGS systems.

PI Response:

We are focussing on characterizing mineral-fluid systems before progressing to rock-fluid systems, which are inherently more complex and difficult to model without fully understanding behavior of their components.

Reviewer 23509

Comment: See previous comments.

PI Response:

No response entered.

Reviewer 23465

Comment: The PI did not provide any discussion on possible project sites. What is the next phase? Will it be more lab work resulting more technical papers? Are there a plans for larger scale experiments? Or will the results of this project be used in a real setting?

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23441

Comment: The management needs to link the team with a strong thermodynamicist who is skilled at reviewing and developing thermodynamic; physical property; and kinetic data. The publication record is weak and needs to be significantly improved. Journal articles are required.

PI Response:

See previous response above.

Reviewer 23457

Comment: Include at least a few rock samples from EGS sites. High priority should be assigned to establishing error bars on measurements.

PI Response:

The last phase includes using rock samples. Measurement errors will be quantified and reported.

Reviewer 23509

Comment: Consult with LBNL or other outside experts and pick a mineral system that is: 1) critical for modeling likely EGS projects using CO2, 2) has key data gaps or scientific questions associated with its thermodynamics and/or kinetics, 3) formulate an experimental plan to close those gaps, 4) collect and analyze the data (hopefully without additional hardware expense) and publish the results in a quality scientific journal. If the PI can get that far by the next review, and have some funds left to repeat the process on another system, then there is a chance of some lasting benefit developed out of this project.

PI Response:

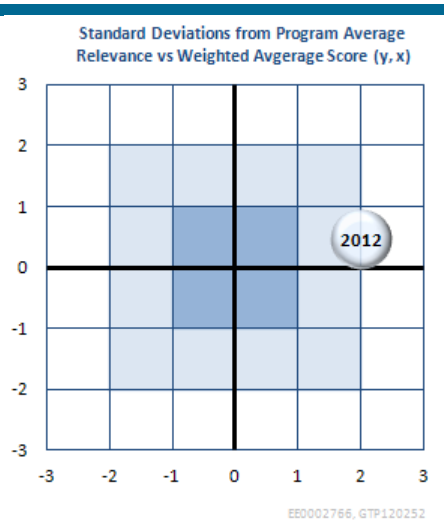
The suite of minerals that were chosen for analysis were selected with the input of scientists from LBNL to constitute the main rock-forming minerals that are expected to occur in EGS reservoirs.

Reviewer 23465

Comment: The next step should be proving that the lab test measurements can be useful in a real geothermal field.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002766
Project: Development of Chemical Model to Predict the Interactions between Supercritical CO2 and Fluid, Rocks in EGS Reservoirs
Principal Investigator: Mcpherson, Brian
Organization: University of Utah
Panel: Supercritical Carbon Dioxide

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23441

Score: 3.7

Comment: The objective of this effort is to improve thermodynamic databases to include wider temperature and pressure ranges than those currently available in existing simulators for application to geothermal reservoirs; determine applicable chemical reactions between water, rock, and scCO2 through thermodynamics analyses; estimate respective kinetic rates of chemical reactions; and evaluate water/brine displacement by scCO2, water recharge, geochemical reaction processes and effects on EGS reservoirs by lab- and field-scale numerical simulations; and investigate scCO2 risk and uses as an acidization agent in EGS reservoirs.

PI Response:

Reviewer 23457

Score: 4.0

Comment: Objectives of the program are to (1) improve existing thermodynamic databases for water-Co2-rock reactions, (2) perform laboratory experiments to investigate reactions of supercritical CO2 with water-saturated granite, and (3) perform laboratory and field scale simulations for water/brine displacement and energy recovery by the injection of supercritical CO2. This work should aid in deciding whether CO2 as a heat transmission fluid is a viable alternative to water. There appears to be a fair bit of overlap between this project and the work being performed at LBNL(especially TOUGH modeling) and PARC (Improvement of thermodynamic databases).

PI Response:

Reviewer 23509

Score: 3.0

Comment: Project is conducting a mix of experimental and modeling efforts that are directly tied to evaluating technical performance of using CO2 as a working fluid in a fractured granitic rock system. Hence, it is on target for a demonstration project being proposed by GreenFire Energy.

PI Response:

Reviewer 23465

Score: 3.0

Comment: The experimental research conducted attempts to address a significant knowledge gap in the following areas: 1) Expanding the current thermodynamic data which is limited in temperatures and pressures for EGS reservoirs; 2) Establishing kinetic rate constants of mineral reactions; 3) Determining chemical interaction of scCO2 and rocks at high temperatures and pressures in EGS; 4) Investigate the effects of scCO2 as a working fluid and acidization agent. The abovementioned research will contribute to the understanding, planning and development of EGS. It is premature to provide a cost estimate on EGS development. What is known is that research in these areas will have a beneficial impact on accelerating EGS development. The deployment of methods and models utilized for chemical reactions, kinetics and coupling of EGS with geologic CO2 sequestration needs to be well established before attempting to determine if CO2 can be used as working fluid. This activity is still in its nascent stage but it is the most significant. The impacts of this research should help address the identification and location of existing or creation of EGS well injection sites.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23441

Score: 3.7

Comment: Both in the experimental approach investigating hydrothermal fluid-rock (with 5 experiments completed) and the geochemical equilibrium modeling using the PFLOTRAN; TOUGHREACT; ECO2H module / TOUGH2 simulators the focus will be on supporting GreenFire's St. Johns Dome project. The project is trying to complete six major technical tasks to improve high temperature-pressure thermodynamic databases; determine applicable chemical reactions; evaluate the reactivity of minerals in aqueous and CO2-rich fluids; modify existing simulators and develop predictions using them, including studies relevant to field conditions; and investigate mineral precipitation in surface facilities (as opposed to studies of precipitation in the reservoirs).

PI Response:

Reviewer 23457

Score: 3.0

Comment: Technical approach consists of a number of steps:
1. Improve existing thermodynamic databases, and implement the same in PFLOTRAN and TOUGHREACT codes.

2. Perform laboratory experiments to study chemical reactions in granite+vein minerals + water +scCO2.
3. Perform 2-D and 3-D numerical simulations to model geochemical processes, and heat recovery.

Items 1 and 3 have significant overlap with LBNL and PARC projects.

PI Response:

Reviewer 23509

Score: 2.0

Comment: Experiments with granites are being conducted but the fundamental goals for these tests is poorly described. The materials provided by the PI do not establish the connection between the thermodynamic database work that was done early and the experiments being conducted. Assuming the principal purpose is to validate the geochemical model, there are several issues. Granites are complex multi-mineralic rocks and the autoclave experiments will produce a time-evolving fluid chemistry representative of differential reaction rates and surface areas for the individual minerals in the granite. Differential rates of reaction between mineral components, over time, will result in mass transfer constraints imposed by the slower dissolving phases. This is presently not simulated in geochemical models (all the components of the mixture are exposed to the solution phase at all times). Moreover, very few experiments have been run and seem to be planned. With 1/2 of the planned experiments completed according to the project summary, justification is needed that so few tests in a complicated parameter space (P,T, rock-water ratio, ionic strength, grain size) can adequately validate their model.

PI Response:

Reviewer 23465

Score: 4.0

Comment: The technical approach is rational, logical and was deployed in a reasoned sequential manner. The PI was clear in describing project purposes: 1) provide tools to advance knowledge of interaction of scCO2 and rocks in EGS, and, 2) feasibility of scCO2 as a working fluid in EGS. Project tasks were properly prioritized. The PI employed the appropriate technical staff, procedures, methodologies, instrumentation, and equipment.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23441

Score: 3.7

Comment: The presentation highlighted a nice description of the details about the specific experiments that had been performed as for example for the equal part K-feldspar, plagioclase, quartz system. That included a phase diagram and alluded to XRD and SEM data indicating that illite formation was seen in all experiments; and that smectite formation in response to scCO2 injection; there were considerations for the stability of illite vs. smectite at varying hydrothermal conditions. Linked to this were well developed modeling efforts that were linked to the experimental data. The project has a good presentation record.

PI Response:

Reviewer 23457

Score: 3.0

Comment: 1. Completed analysis of 3 experiments on water+granite+scCO2. Analysis shows the formation of illite/smectite, but not carbonate predicted by modeling.
2. Implemented improved thermodynamic databases in PFLOTRAN and TOUGHREACT.
3. 2-D/3-D simulations performed to simulate energy extraction.

Laboratory experiments (item 1) show the formation of smectite - an expansive clay; this has the potential of being a "show stopper".

PI Response:

Reviewer 23509

Score: 2.0

Comment: The presentation materials indicated that results would be presented from the first 3 granite tests but no results were actually shown. Modeling work has been performed and the use of two independent codes is admirable. However, at this point in the project, a comparison of model predictions in the batch system (as in slide 12) is far less interesting than an analysis of how well the code predictions matched the experimental data. Very disappointing this was not addressed in the presentation. The simulations of the reservoir injections in 2-D and 3-D are fine but are out place since no evidence was provided on how well the underlying geochemical model was doing relative to the batch experiments. This reviewer is concerned about the level of tangible progress on this project. Setting up, running, and analyzing a small number of autoclave tests with granite samples and publishing the results along with the modeling comparison is not much to ask in 2 years of effort. Several modeling presentations/proceedings have been done but no peer reviewed publications.

PI Response:

Reviewer 23465

Score: 3.0

Comment: The PI completed a number of technical tasks on time and within budget. A number of these tasks were very complex and required significant analysis. The PI provided start date of April 1, 2012 and an end date of March 31, 2013. The project is on schedule with 32% of the $3.86 million total budget has been spent. 38% of the $3.0 million DOEGP funds have been spent to date.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23441

Score: 3.0

Comment: The project is already considering the technical issues in an exemplary manner. It is not clear as to how much depth some of the task elements may receive since the required funds to carry through on the detailed effort may not be sufficient. The project is linked to GreenFire's St. Johns Dome project. The GreenFire demonstration is not working out well and is not on track to deliver the DOE Geothermal CO2 program useful data. This is a critical weakness.

PI Response:

Reviewer 23457

Score: 3.0

Comment: As of the report date, about 32% of the total project were spent. This may indicate that the project is somewhat behind planned schedule. Future plans include completion of laboratory experiments, modeling work to include the effects of scCO2 injection on reservoir rocks, and possible validation of model results with field data. The project will benefit from better co-ordination with parallel work being performed at LBNL and PARC.

PI Response:

Reviewer 23509

Score: 3.0

Comment: Project is well connected with key players in the geochemical modeling community. However, project is clearly behind schedule, mainly on the experimental efforts. PM should place additional emphasis on accelerating those activities.

PI Response:

Reviewer 23465

Score: 3.0

Comment: This project appears to be well administered in terms of technical, scheduling, staff allocation and financial resource allocation. The PI provided appropriate and adequately placed decision points in the schedule. There has been some minor slippage in regard to the schedule. The PI has worked well with collaborating partners with INEL, University of Wyoming, LANL and subcontractors AltaRock and Greenfire. However, the work with both Greenfire may not materialize.

PI Response:

STRENGTHS

Reviewer 23441

Comment: The project is a well-integrated effort.

PI Response:

Reviewer 23457

Comment: Combined laboratory work and modeling studies to characterize the effect of scCO2 injection in granitic rocks. Experiments on water + granite +CO2 system are unique to this project. Formation of smectite has the potential to be a show stopper.

PI Response:

Reviewer 23509

Comment: Project is intending to conduct key experiments to validate a geochemical model of direct importance for a CO2 EGS demonstration project. Multiple models are being evaluated and tested.

PI Response:

Reviewer 23465

Comment: The technically solid approach taken by the PI in addressing a significant knowledge gap. Technical credentials of project team and collaborators. Coordinated collaboration with other research organizations. The project has met all milestones and completed all tasks on time and within budget.

PI Response:

WEAKNESSES

Reviewer 23441

Comment: The project is linked to GreenFire's St. Johns Dome project. The GreenFire demonstration is not working out well and is not on track to deliver the CO2 program useful data. This is a critical weakness.

PI Response:

Reviewer 23457

Comment: Field data may not become available in time for model validation.

PI Response:

Reviewer 23509

Comment: Experiments do not seem to be very well planned to complete a largely unstated objective in model validation. Quantitative metrics on what constitutes "validation" are also missing. Experiments are behind schedule and tangible project output pretty meager after 2 years.

PI Response:

Reviewer 23465

Comment: This project will not be completed, if it will use any data from the stalled Greenfire project at St. John's Dome. Is the PI performing due diligence and looking for another project site that will provide geological data? What is the next phase?

PI Response:

IMPROVEMENTS

Reviewer 23441

Comment: The project has a good presentation record and this needs to move forward to the peer-review Journals.

PI Response:

Reviewer 23457

Comment: Use realistic EGS geometries for 3D simulation work. Modeling work should be better co-ordinated with LBNL and PARC. Higher priority should be laboratory experiments, especially in light of the formation of smectite in experiments performed to-date.

PI Response:

Reviewer 23509

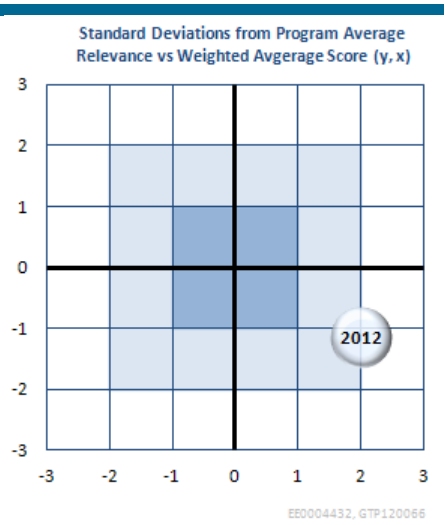
Comment: Reassess experimental plan and make corrections to adequately address key model validation goal. Reconsider expansion into vein mineral experiments given limited time and resources remaining. Publish a peer-reviewed paper on the experiments and model validation results. Consider reducing redundant modeling activities, again given time and budget limitations and need for additional experiments and less significant impact of code comparison results (GTO is starting up a comprehensive code comparison effort).

PI Response:

Reviewer 23465

Comment: Has the PI reviewed the results of the WESTCARB Phase I and II project? If not, why not?

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0004432
Project: Single-Well Low Temperature CO2-Based Engineered Geothermal System
Principal Investigator: Eastman, Alan
Organization: GreenFire Energy
Panel: Supercritical Carbon Dioxide

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23441

Score: 2.0

Comment: The project the GreenFire group reported on has a clear mission as well as a site specific goal relevant to DOE Geothermal. These goals would have a high impact if they are met and they are goals well worth pursuing. However, this reviewer needs to clearly convey that the presentation has raised serious doubts about the current program meeting the goals. The project does not appear to be on track to achieve the proposed project goals. The project mission is to show that supercritical CO2 is a workable carrier fluid for geothermal power that it can effectively be deployed for use by a single well in a "huff and puff" demonstration. In itself, that would be an important demonstration. Additionally, a claim is made that the use of supercritical CO2 could provide electricity at costs that would meet the target goals for the DOE Geothermal program, but there were no supporting materials for this, and given the current expenditures, not sufficient funds have been spent to address the energy cycle in a meaningful way. The lower ranking comes from a serious concern that none of the project goals will be met. Hence, the lower rating is not for the relevance of the goals, but for the ineffectiveness at conveying that the program had reached or is on track to meet any meaningful results.

PI Response:

Reviewer 23457

Score: 3.0

Comment: The goal of this project is to demonstrate the feasibility of using CO2 as the heat transfer fluid in EGS. In recent years, there has been considerable in the possible of CO2 as a heat transfer fluid in EGS. The proposed project is designed to study heat transfer from reservoir rocks to CO2.

PI Response:

Reviewer 23465

Score: 2.0

Comment: There are times when hard decisions have to be made in favor of protecting naturally occurring geological formations and the shear uneconomical reality of some research projects verses the needs of society, and this one of them. Why do this in an area that does not have the adequate geological data? This Reviewer sees little advantage in completing this project. This project as presented is noteworthy but it's project scope is too ambitious and there are too many unknowns for the amount of time remaining. The PI has not been able to obtain the required permits for continuing this project. What we do know is that the State of Arizona will continue to hold up this project and will not act on this issue until public hearings are scheduled and the public is convinced that the exploration of the St. John's field will not cause seismic activity. This will result in millions of dollars spent to discover that DOE needs to spend more dollars. Why not spend those dollars in a proven location where geological conditions are well characterized? It is inconceivable that by even by 2020 that this project will lead to the demonstration of 5 MW reservoir and lowering LCOE to 6 cents/kWh by 2030. WESTCARB Phase II results indicates that there exists a deep saline formation in the northern part of the state but that formation is too far from the St. John's formation. It is in the existing saline formation where the Choya Power Plant located where this project should be tested.

PI Response:

Reviewer 23463

Score: 2.0

Comment: The main objectives of the project are to demonstrate the feasibility of using supercritical CO2 as the heat carrier in an EGS system. The use of CO2 as a heat exchange fluid is an important area and may be very relevant especially if ways can be found by which the CO2 can be captured from fossil fuel plants. Therefore, the objectives of the project are highly relevant and their achievement would have a significant impact. However, there is doubt if the execution of the proposed work would be adequate to demonstrate the feasibility of using supercritical CO2 as the heat carrier in an EGS system. This is expanded under the next heading.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23441

Score: 2.0

Comment: The well will be neither deep enough nor large enough to determine drilling and fracturing costs for this "huff and puff" service at the challenging low temperature of 150C. Since the well will not be in the proper zone (i.e. now the CO2 geothermal heat production zone is 6,500m rather than 10,000m) the formation will be cooler (90C rather than 150C) and performance and actual costs will be a matter of conjecture. If the project goals cannot be met, showing a "green light" for going ahead seems to provide little assurance that project results will provide the assurance to the investment community that they should support commercial "huff and puff" CO2 facilities. If this reviewer is right in believing that the value of results obtained are not likely to persuade commercial investors to look further into this approach, the project seems of limited value. GreenFire believes that it will "still [be] possible to test thermal properties of formation," however this again is not persuasive to this reviewer -- while the well is into the basement crystalline formation, the actual properties both fracturing and thermal of that formation 4km further down may well prove in reality

to be different from projections. The project effort on using Metal-Organic Heat Carrier (MOHC) during tests builds on work by PNNL that may be good, but this is a distraction. This reviewer is keenly interested in power cycles. The tough engineering problem is going to be to deploy a workable energy recovery cycle that can use CO2 at a continuously non-steady state rate as demanded by "huff and puff." The downgrading of this program element to a mere mention is not reassuring. The project claims that it has filed seven provisional patents, but there is no basis for determining whether these are really significant.

PI Response:

Reviewer 23457

Score: 2.0

Comment: The scientific and technical approach consists of the following steps:
1. Design, install and operate a 5-station seismic network to monitor natural and induced seismicity.
2. Site and drill a 6500-ft core hole. Fracture the formation if the natural permeability is low. The temperature at 6500 ft is estimated to be ~90 C.
3. Perform a huff and puff experiment. Use the experimental data to investigate heat transfer characteristics.
4. Operate a small power generation apparatus.

The project will not address certain key aspects of EGS - such as reservoir creation and flow of CO2 between injection and production wells.
It is not clear what kind of power generation apparatus can be operated at these low temperatures, and production/injection in a huff and puff mode.

PI Response:

Reviewer 23465

Score: 2.0

Comment: For the most part the technical approach taken by the PI was rational, logical and deployed in a reasoned sequential manner. The PI took a risk with the State of Arizona regarding the permit. The project employed the right procedures, methods, equipment and contracted experienced engineering firms, environmental consultants and lobbying consultants.

PI Response:

Reviewer 23463

Score: 1.0

Comment: It is proposed to drill a 6500'-slim hole (4" diameter) and perform stimulation huff-and-puff tests. While it is acknowledged that the choice of the method reflects the limitations of the project budget, it is not clear if the method will be successful.

The risks are as follows:
(a) the slimhole is too small to pump fluids at the rate required to stimulate the fractures
(b) Since the area of the slimhole would be only a quarter of a typical production well, it will provide too much resistance against high-speed CO2 flows and wil severely limit production.

While the project is important, it is needed to explore options to help it achieve its objectives.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23441

Score: 2.5

Comment: The project expenditures thus far have been low. Hence, a higher scoring is given here than may be warranted if the project stays on the present course that will not address the project goals in a meaningful way. Permitting is tough. No question. However, permitting activity and securing a CO2 supply appear to be the major accomplishments reported. There was no discussion of the proposed "huff and puff" recovery cycle that permits this reviewer to evaluate whether it is likely to lead to a viable commercial system. The distraction of bringing in the likely to be exceptionally expensive nanoparticles and moving away from discussing the "huff and puff" challenges creates a new and very real economic challenge to project viability and claims for meeting the target goals for LCOE either in 2030 or beyond that date.

PI Response:

Reviewer 23457

Score: 2.0

Comment: The project is behind schedule due to permitting difficulties. To-date, a site has been identified for the well. A 5-station seismic network has been designed, installed, and started to operate.

PI Response:

Reviewer 23465

Score: 1.0

Comment: The project is 25% completed and is behind schedule although a variance was approved. The PI mentioned that 15 years of modeling has taken place. With all this time and effort in modeling of the formation, no permit has been issued. This indicates that there must be a serious public perception or environmental problem with the proposed drilling.

PI Response:

Reviewer 23463

Score: 1.0

Comment: Not much has been achieved since the start . This is mainly because the project failed to receive the site permit. It is even more worrying that there is no clear path towards obtaining such permit.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23441

Score: 2.5

Comment: Not clear that the management is proving a path to the stated project goal of demonstrating CO2 as a carrier fluid for "huff and puff." The management needs to develop a more aggressive time frame; needs to stay on task – specifically, energy recovery at temperatures and pressures of relevance using a non-steady state flow of CO2.

PI Response:

Reviewer 23457

Score: 2.0

Comment: Project manager holds a weekly call with all the participants. Failure to anticipate permitting difficulties has delayed the project.

PI Response:

Reviewer 23465

Score: 1.0

Comment: Here the PI and project team fell short. They should have known that obtaining approval for continuing this project was not automatic. The PI and project team are well qualified to conduct the indicted work. The PI has retained the appropriate staff and contracted out with experienced subcontractors. The project is being deployed in coordination with partners, and permitting agencies. The project adheres to DOE policy and objectives. The spending plan appears acceptable in relation to project schedule.

PI Response:

Reviewer 23463

Score: 1.0

Comment: It is difficult to judge the quality of the management because it is not clear whether an alternative way could be found to obtain injection permit. The project seems to have stopped on its tracks because of failure to receive this permit. No contingency plan has been presented as a way around it.

PI Response:

STRENGTHS

Reviewer 23441

Comment: The project seems on track with permitting.

PI Response:

Reviewer 23457

Comment: Attempt to study aspects of CO2 as a heat carrier fluid in EGS.

PI Response:

Reviewer 23465

Comment: The project meets the DOEGP's mission and goals. The project met the stated technical goals and objectives for Phase 1. The project management team is qualified and capable of administering DOE and match share funds in a prudent and acceptable manner.

PI Response:

Reviewer 23463

Comment: The main strength of the project is that it was going to be the first demo for CO2 as an heat exchange fluid.

PI Response:

WEAKNESSES

Reviewer 23441

Comment: The project the GreenFire group reported on has a clear mission as well as a site specific goal relevant to DOE Geothermal and it is a goal with a high impact. The goal is well worth pursuing, but this reviewer needs to clearly convey that the presentation has raised serious doubts about the current program meeting the goals. The use of supercritical CO2 by GreenFire could provide electricity at lower costs, but these are reported to be in the 2030 time frame. There surely could be a more aggressive time frame since 18 years is simply too long a development window to expect continued funding to establish the success of this approach.

PI Response:

Reviewer 23457

Comment: A single slimhole and low temperature (90 C) will make it difficult, if not impossible, to generalize the results to a "real" EGS system.

PI Response:

Reviewer 23465

Comment: Inability to obtain permit from State of Arizona. This may have been expected by the PI but he took a risk in thinking the permit would be granted without going through an adequate environmental review. The lack of geological (seismic and core) formation data. The project is too complex to accomplish with the remaining time and funding allocation. The likelihood of project completing Phase II is uncertain. During Phase II development, the cost of transporting liquefied CO2 from an unknown source is going to be extremely expensive. How many truck loads will be necessary to conduct testing? The building of a 400 mile pipeline from the Coronado Station to pump CO2 into the formation for heat extraction is economically inconceivable. Even if drilling confirms enough temperature exists in the formation, geologic or connate water may be present. It may or may not be pressurized. How much water is unknown?

PI Response:

Reviewer 23463

Comment: The inability to obtain an injection permit seems to have stopped the project. It is not clear what is to be done about it.

PI Response:

IMPROVEMENTS

Reviewer 23441

Comment: Focus on "huff and puff."

PI Response:

Reviewer 23457

Comment: Serious consideration should be given to relocating the project in a different area with high temperatures at shallow depths (5000 ft or less). Also, it is important to have at least two wells (i.e. a production and an injection well).

PI Response:

Reviewer 23465

Comment: The PI did not convince the Arizona permitting authorities of the differences between the St. John's project and the results of the WESTCARB funded project sponsored by DOE, the Arizona Public Service, Company, Salt River Project, Tucson Electric Power, Arizona Electric Power Cooperative, Peabody Energy, EPRI, LLNL, LBNL, and the California Energy Commission, and how it would relate to this particular project. Reduce the scope of the project. First, focus should be placed on obtaining the proper permits before going forward. If the Arizona authorities have not granted a permit by now, it must because they must have some serious concerns about this project. Second, if a permit is approved, concentrate on establishing baseline resource geology. Employ use of gravity, magnetotelluric surveys, ground vibration, advanced spaceborne thermal emission and reflection radiometer, and interferometric synthetic aperture radar seismic measurements. Third, drill where the baseline data has indicated the highest probability for success.

PI Response:

Reviewer 23463

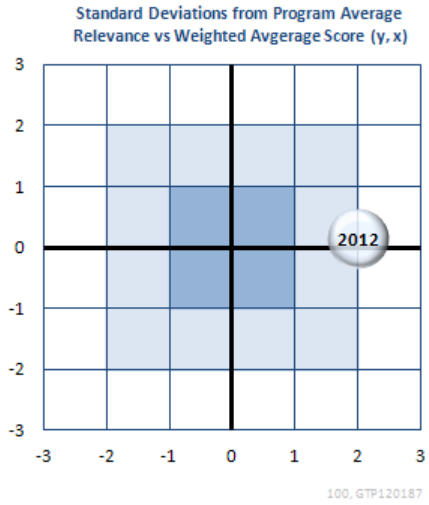
Comment: The improvements are obvious but require a larger budget:

(a) Drill a proper production well.

(b) Drill a deeper well.

PI Response:

SYSTEMS ANALYSIS, RESOURCE ASSESSMENT, DATA SYSTEM DEVELOPMENT AND POPULATION, EDUCATION



Review: 2012 Geothermal Technologies Office Peer Review
ID: 100
Project: Geothermal Systems Engineering and Analysis
Principal Investigator: Lowry, Tom
Organization: Sandia National Laboratories
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23444

Score: 3.0

Comment: Understanding the behavior, evolution and dynamics of geologic systems are filled with uncertainty. As a geologic and engineered system, geothermal energy is also filled with uncertainties from the natural to the manufactured system. This research attempts to quantify the large uncertainties associated with geothermal energy, beginning with the physical system through engineering to predicting future costs and regulatory framework. Interdependencies in various uncertainties are ascertained and their influence evaluated. As such, priorities for uncertainty reduction can be developed with the ultimate objective of reducing costs. Providing a probabilistic risk assessment may reduce market barriers to geothermal technology developments and more widespread use and fill a knowledge gap related to uncertainties (and risk) the system in its entirety.

PI Response:

No comment needed.

Reviewer 23600

Score: 3.5

Comment: Project addresses uncertainties and risks in the main facets of the GT production system. It tackles the GTO broad goals of understanding GT systems and what will ultimately drive geothermal power use expansion. Project has created a tool that allows for thinking probabilistically, which is a must when dealing with numerous unknowns noted in the review.

PI Response:

No comment needed.

Reviewer 23532

Score: 4.0

Comment: This modeling project is of the utmost importance to DOE for modeling economics of geothermal operations. The project appears to have made substantial progress and is nearing completion as originally planned. As noted in the overall comments at the end of the review, this project should be continued and could be quite useful for parametric studies of reservoir and power plant coupled operation.

PI Response:

Parametric studies are a natual extension of uncertainty analysis and have been discussed as a future piece of this work.

Reviewer 23601

Score: 2.3

Comment: The project's goal is to provide a way to quantify the uncertainty in Geothermal energy performance and cost. The tool being developed can produce probability curves of LCOE based on the approach of associating individual probability curves to both system and component costs and reservoir thermal performance. This does have value to the GTO and Geothermal energy community but on a second order level compared to simply improving the LCOE base line estimates in terms of better data, improved reservoir modeling and performance understanding, and many technology improvements efforts needed to reduce the cost of Geothermal energy. A somewhat less accurate but still valuable approach to quantifying Geothermal LCOE uncertainty could be achieved by attaching probability functions to the cost and other variables in GETEM and using @RISK or other programs to develop an LCOE probability distribution. The greater value in this Project might be in improved cost, well drilling and reservoir performance models used and imbedded in this project.

PI Response:

Using @RISK with GETEM has been done in the past and is limited by the fact that the uncertain variables (i.e., the variables that @RISK is perturbing) are treated independently. As an example, one is allowed to perturb the mass flow rate using @RISK but the effect of changing the mass flow rate on the reservoir performance and pressure changes through the reservoir are not accounted for; they are separate, independent inputs. While these separate inputs can also be perturbed, the there is no way of filtering the scenario's to exclude those that are physically impossible to achieve (e.g. high mass flow rate with low pressure loss through the reservoir). GT-Mod accounts for these types of dynamics by modeling the physical performance as an integrated system of systems.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23444

Score: 2.0

Comment: A computational system-dynamics modeling approach is used to capture interdependencies and feedbacks in the system. Here the system is clumped into two subtasks, systems modeling and reservoir performance modeling. Reservoir modeling uses the standard TOUGH2. Key inputs involve pipes,wells, power plant and reservoir. Because much uncertainly for geothermal systems occurs in the geologic conditions and performance of the reservoir, there appears to be a rather simplistic view of the reservoir in the modeling approach that has the potential to dramatically impact the productivity and longevity of the reservoir - and ultimately the calculated uncertainty. For this study, a homogeneous rock is assumed, the system does not appear to be dynamic, no fluid compositions are included nor fluid-

mineral reactions that may occur in the reservoir or pipes that change the system dynamics. Using a conductive heat transport model may be ok for EGS but not for hydrothermal convective reservoirs - that choice is curious. The heterogeneous, dynamic state of the reservoir appears to be missing but may have a large impact on calculated uncertainties for risk. As is the case in any modeling study, the outcome is only as good as the input and assumptions. Because the economic model is driven by the geology, it appears to lack rigor. Uncertainties are then propagated. It is unclear to me how reservoir uncertainly is propagated in light of the simplistic reservoir model developed. GETEM is used for cost analyses - this appears to be the industry standard.

PI Response:

I agree with most of the points in this response but would add that this is a work in progress. The reviewer is correct in stating that no chemistry is included, which was a decision made early on in this project to be a dynamic that would be added later as the model is matured and developed. I do take issue that we are using a "rather simplistic view" in modeling the reservoir. The TOUGH2 models are highly complex and account for a full range of reservoir characteristics. The homogeneous example used for the review was just that, an example. We are currently integrating heterogeneous fracture patterns in our TOUGH2 modeling and those results will be included into GT-Mod during the next phase of development. I would also argue that GT-Mod is the ONLY tool of its type that IS accounting for the heterogeneous, dynamic state of the reservoir. Reservoir uncertainty is propagated to GETEM through the dynamic performance of the reservoir over time.

Reviewer 23600

Score: 3.5

Comment: Well-thought out approach, which is necessary to meet the project's goals. Listed general unknowns up-front and approach was focused on creating the simulation tool. Used a broad range of geologic and operational conditions in the simulation, which is commended. It was not stated why the stochastic simulations needed to be intimately linked to the economic model. There was no outside collaboration on this effort, which should be done. The oil and gas industry has addressed theses modeling issues and should be consulted.

PI Response:

The stochastic simulations are used to propogate the geologic uncertainty to the economic calculations through the variability in reservoir performance over time. The suggestion of leveraging oil and gas modeling work is a good one.

Reviewer 23532

Score: 4.0

Comment: This model development offers what I believe to be a unique methodology for evaluating the value of geothermal systems. Additional value could be added to the project in order to modify the code slightly to allow interaction of the reservoir model and operational parameters of the electrical generation system. The model could then be used to optimize field operation coupled with power plant operation. See additional discussion at "Strengths."

PI Response:

Agreed.

Reviewer 23601

Score: 3.0

Comment: The computer modeling utilized appears state of the art and is an excellent approach to the project objective. Utilizing TOUGH2 to model the reservoir performance and coupling that with Powersim to dynamically link the interactions resulting from scenario changes and uncertainties in individual variables, and connecting that to GETEM for LCOE analysis is a very powerful approach. The is also real value in improved cost and reservoir performance models used and imbedded in this project. The final model and software might benefit through more interaction with people at NREL, INL, and on the GTO LCOE Team. Seeking information and vetting from industry might also have be beneficial. It appears the development of this model and software system were done in near isolation at SNL.

PI Response:

Agreed.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23444

Score: 3.0

Comment: Modeling approaches have been developed and tested, and are now ready to be used for analyses. Models have been developed relating uncertainty propagation to risk to suggest a drawdown mode for EGS that best reduces risk. Additional modeling components have been completed and beta tested. Additional analyses will be forthcoming. The data analyses tool appears to be largely complete for EGS technologies. Preliminary analyses have been completed. Project is near completion. The end product of this research is not well defined - is it to be a modeling program? Results follow milestones.

PI Response:

The current "end result" is to have a model that DOE, industriy, and other analysts can use and exploit, but our hope is that it remains a work in progress as there are still limitations and added functionalities that need to be addressed.

Reviewer 23600

Score: 3.2

Comment: Solid progress towards goals, showing simulation versus analytic solutions is good for the thermal performance. It is unclear how to interpret the table on page 17 as no conclusions are drawn from it. The project needs to show what drives the lessening of risk and uncertainty. Before going into component level assessments with the model, assessing the main drives of risk would be of benefit to tailor the next approach. If the link to the economic model is challenging, re-thinking the linkage to a more manageable method should be considered.

PI Response:

The table on page 17 simply shows the work task progress for completing this project and has nothing to do with results and/or any analysis. We agree that a thorough demonstration of the model's capabilities are needed and are working on that as part of the FY12 final report.

Reviewer 23532

Score: 4.0

Comment: The project has prepared several papers and talks. The project appears to be on schedule. The technical targets appear to have been met and appear to be of high quality and usefulness.

PI Response:

No comment.

Reviewer 23601

Score: 3.0

Comment: The project is accomplishing what it set out to do in an efficient and timely way with an excellent approach. Until the model is made available and vetted by comparing results with GETEM, other models, and industry's perspective, it is difficult to judge how accurate it is.

PI Response:

No comment.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23444

Score: 4.0

Comment: Project met milestones after rescoping and is now near completion. The project is on time and budget. No partners were funded as part of the original projects. However, coordination with interested parties is taking place and will likely lead to future interactions.
PI Response:

No comment.

Reviewer 23600

Score: 3.0

Comment: Future plans – It would be better to first give results/drivers before embarking on hydrothermal/porous media/low temperature and component work. It is important to consult with appropriate experts within the oil and gas industry on modeling systems like those done here. I would suggest linking the work here to that being done by the project: “Estimation and Analysis of Life Cycle Costs of Baseline EGS”, Uday Turaga, ADI Analytics LLC as some of this overlaps with your effort.

PI Response:

Agreed and all good suggestions.

Reviewer 23532

Score: 4.0

Comment: The project has been well managed as evidenced by the timely completion of work, appearance that it will be completed on time and the completion of several pares and talks.

PI Response:

No comment.

Reviewer 23601

Score: 3.0

Comment: The project is being completed in a timely manner. Better Project management would have included more interaction with NREL, INL, and industry during the Project execution for vetting purposes.

PI Response:

Our intent is to interact more strongly with INL and NREL in FY13.

STRENGTHS

Reviewer 23444

Comment: Provides an integrated modeling tool for connecting potential uncertainties in development of an EGS reservoir with risk associated with economic factors. Quantification of risk may provide investment incentives and inform decision makers.

PI Response:

No comment.

Reviewer 23600

Comment: Well-thought out approach, which is necessary to meet the project's goals. Listed general unknowns up-front and approach was focused on creating the simulation tool. Used a broad range of geologic and operational conditions in the simulation, which is commended. Solid progress towards goals, showing simulation versus analytic solutions is good for the thermal performance.

PI Response:

No comment.

Reviewer 23532

Comment: This is the most interesting presentation that I listened to. The project as presented appears to offer an important tool for the analysis of geothermal systems and I strongly recommend that it continue to be funded in order to include the following effort. The project provides a framework for modeling the coupling between the operation of the geothermal reservoir and the power plant, particularly in the case of a binary plant. Coupling of the reservoir and the power production cycle offers the ability to optimize project operation for greatest economic gain, reservoir performance, power plant efficiency or some combination of factors. I suggest that a team comprising Lowry, Greg Mines and a geothermal reservoir engineer should be established to explore this application.

PI Response:

Nice comment and teaming up with Greg Mines and a reservoir engineer would be great.

Reviewer 23601

Comment: The computer modeling utilized appears state of the art and is an excellent approach to the project objective. Utilizing TOUGH2 to model the reservoir performance and coupling that with Powersim to dynamically link the interactions resulting from scenario changes and uncertainties in individual variables, and connecting that to GETEM for LCOE analysis is a very powerful approach. There is also real value in improved cost and reservoir performance models used and imbedded in this project. The project is accomplishing what it set out to do in an efficient and timely way with an excellent approach.

PI Response:

No comment.

WEAKNESSES

Reviewer 23444

Comment: The simplistic geologic and thermal model used for reservoir simulation may provide an unrealistic view of uncertainties. Quantification of risk can be done but it is questionable what the values actually mean. Case studies should help validate this approach.

PI Response:

Again, I have issue with the statement that we are using a "simplistic geologic and thermal model". We are in fact, using the most complex geologic and thermal models of any tool of this type, which is the product of the TOUGH2 modeling we are doing.

Reviewer 23600

Comment: The project did not show what drives the lessening of risk and uncertainty nor economic results. Before going into component level assessments with the model, assessing the main drives of risk would be of benefit to tailor the next approach.

PI Response:

Agreed. The intent is to highlight these drivers as part of the FY12 final report.

Reviewer 23532

Comment: No apparent weaknesses.

PI Response:

No comment.

Reviewer 23601

Comment: The tool being developed can produce probability curves of LCOE based on the approach of associating individual probability curves to both system and component costs and reservoir thermal performance. This does have value to the GTO and Geothermal energy community but on a second order level compared to simply improving the LCOE base line estimates in terms of better data, improved reservoir modeling and performance understanding, and many technology improvements efforts needed to reduce the cost of Geothermal energy.

PI Response:

No comment.

IMPROVEMENTS

Reviewer 23444

Comment: Using more realistic geologic input data for heterogeneous systems would more closely model 'reality' and inform potential risk associated with geology for use in modeling studies. How will the final product be made available? A plan should be developed for code distribution and validation.

PI Response:

One of the issues we've run into is finding realistic geologic input data for heterogeneous systems. There is very little quantified data available that describes fracture patterns, apertures, etc. I completely agree with the idea of developing a plan for code distribution and validation. Good idea.

Reviewer 23600

Comment: Distribution of economic results would enhance this project. We had seen some results of thermal drawdown solutions but it is recommended to go beyond that. The intimate link from the simulation model to the economic model will become burdensome. It is recommended to de-link these and take summarized results from the simulations and use them in the economic model. It is recommended that discussing this with oil and gas companies would be of benefit as they have already addressed this issue. It needs to be remembered that this tool will give general results, not precise results. It is recommended that cost data of the project ““Estimation and Analysis of Life Cycle Costs of Baseline EGS”, Uday Turaga, ADI Analytics LLC be considered for use in the project. It would be better to first give results/drivers

before embarking on hydrothermal/porous media/low temperature and component work. It is important to consult with appropriate experts within the oil and gas industry on modeling systems like those done here.

Questions:

1. Your project has emphasized Uncertainty Quantification and Risk Assessment, which is commendable. You have shown how the thermal drawdown solution method influences risk. Can you comment on how all this manifests into economic uncertainty? There were no economic results shown. Can you give us some results? What are the main drivers of the range of economic results besides the Thermal Drawdown Solution?

2. What are the major knowledge gaps/uncertainties in the systems you reviewed and how can these be addressed?

3. What are the key uncertainties and bottlenecks that you have found?

4. Now that you are a long way into this project, reflecting back, would you do anything differently?

5. Do you have enough resources to get this done on time?

6. Have you considered de-coupling the reservoir/plant simulations to the economic simulations? Have you consulted with experts in the O/G industry to understand what they have done in similar situations?

7. Have you tied your cost data ranges to those used in the following project: "Estimation and Analysis of Life Cycle Costs of Baseline EGS" to ensure consistency?

8. Your thermal model, has it been "history matched" to real data to ensure it meets those conditions? Do you have "real" data from demo projects?

PI Response:

Numbers refer to questions above.
1. Economic results were shown on slide 16 as a function of the reservoir performance model and mass flow rate. While admittedly simplistic, the results show that for systems that are stressed (e.g. at the 50 kg/s mass flow rate), the difference in thermal performance over time can be seen. In addition, the spread of the LCOE increases as the reservoir reaches its performance limits.

2. The biggest knowledge gap in my opinion is in predicting how a reservoir will perform and how it will be enhanced through stimulation. Most of the data for this is anecdotal and won't really be understood until we start drilling holes in the ground and doing focused field studies.

3. For key uncertainties, see the answer to #2. From a numerical modeling point of view, the key bottlenecks are in our ability to include high-fidelity reservoir modeling in probabilistic economic performance analysis.

4. The main thing I would do differently is to develop the model in a coding language that can be more easily distributed (the Powersim environment requires a software license to use). This would also allow for easier integration with other tools like GETEM.

5. We have enough resources to reach our FY12 targets, but will need more funding if we are to continue expanding and developing the model.

6. We have considered decoupling the economics from the physical performance and at one level, that is the way the model works. It first simulates the entire physical performance over time (thermal drawdown, pressure losses, pumping requirements, etc.) and then sends that to the economic model. It's set-up to do this automatically.

7. No we have not but grounding the model is a key task that is on our to-do list.

8. The issue we have regarding modeling EGS is that there are no field data to match. However, we have tested and verified the model against various analytical solutions as well as some more complex modeling exercises that have been published in the past (e.g. Sanyal and Butler).

Reviewer 23532

Comment: I believe that the project should be continued and expanded to include parametric studies coupling reservoir management and power plant operation. The model appears to be in place, or perhaps might need minor alterations to include this type of activity. If the model could then be made public it would be of great benefit to the industry, particularly the smaller operators of binary plants.

PI Response:

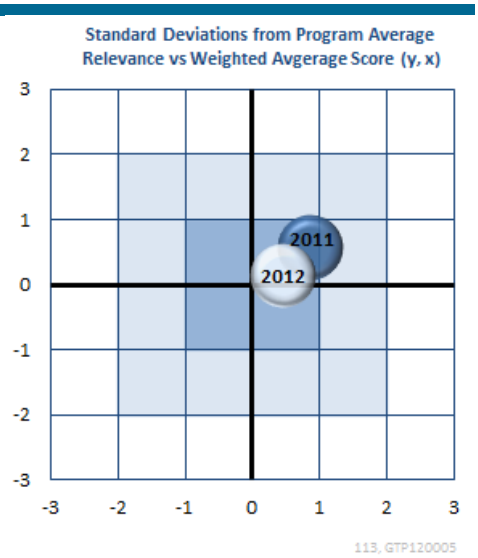
Agreed.

Reviewer 23601

Comment: The final model and software might benefit through more interaction with people at NREL, INL, and on the GTO LCOE Team. Seeking information and vetting from industry might also have be beneficial.

PI Response:

Agreed.



Review: 2012 Geothermal Technologies Office Peer Review
ID: 113
Project: Life Cycle Analysis of Geothermal Systems
Principal Investigator: Wang, Michael
Organization: Argonne National Laboratory
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23444

Score: 4.0

Comment: Quantification of the life cycle energy and emission impacts of geothermal power generation is an important component for decision-making when considering options for renewable energy. Such information should begin with an analysis of cost and environmental impacts of power plant development and continue through to the sustained use of geothermal energy, from source to sink. Reducing green house gas (GHG) emissions is an underlying driver for development of renewable energy. However, it is difficult to compare GHG emissions from geothermal power with other renewable energy types due to paucity of data for CO2 and life cycle analysis. Existing data is sparse and none follows the complete cycle to quantify CO2 emissions from geothermal energy. Therefore, data from this analysis is critical to assessing the costs and benefits of geothermal energy as compared with other renewable options. New data for energy consumption and emissions includes LCA of scCO2 EGS power generation, a new option for energy production with little data that analyzes impacts. Obtaining life cycle criteria pollutant emissions for geothermal power provides a baseline for how green is green. This study permits direct comparison of GHG emissions from geothermal energy plant building through electricity generation to disposal so that it can be compared to other conventional and renewable power resources. As such, this study addresses a significant knowledge gap and provides necessary data for decision making with a focus on environmental impacts. Such data, primarily focused on GHG, will contribute to a broad knowledge base of information for communication to the stakeholders and public.

PI Response:

Thank you!

Reviewer 23600

Score: 3.0

Comment: Project's objectives do meet the GTO goals in assessing life-cycle emissions impact of GT power technologies versus non-GT processes. Clearly laid out the challenges associated with the lack of concrete data. Modified its approach in 2011 to include industry input, which is critical to enhancing overall results. This work will have an impact on comparing GT plants to other types relative to GHG emissions.

PI Response:

Argonne will continue to work with industry and state and federal agencies to acquire critical data for completing our analysis. Range information on GHG emissions from geothermal facilities is important and the pending availability of

new and more complete data will help meet our objective of comparing emissions from a variety of power generation technologies.

Reviewer 23411

Score: 3.0

Comment: The DOE GTO embarked on an effort to quantify life cycle energy and emissions associated with geothermal power generation and this effort appears to adequately support this effort. I was at a disadvantage because I have not followed this work since its inception but it appears that at Argonne has done a solid job in this important assessment activity. The presented information provides an objective assessment of the CO2 burden across the power production spectrum and should be included in DOE discussions with policy makers. Additionally, the work demonstrates that CO2 EGS is viable from an energy perspective and could result in significant GHG reductions. While the CO2 EGS work is interesting, one must ask what the current relevance is to the GTO, since EGS is largely notional with no commercially viable systems currently operational (i.e., perhaps EGS should be figured out first before DOE moves to CO2 EGS). If the CO2 work is to be continued, perhaps a mechanism to include the environmental impacts and associated costs of water withdrawal could be included in the analyses (not sure how this would be done, however).

PI Response:

GTO has directed Argonne to conduct LCA for EGS, as well as other geothermal power technologies including hydrothermal binary and hydrothemal flash, especially in comparison to other power generating technoloiges. Though hydrothermal binary and EGS as currently operated or conceived have in principle no GHG emissions, hydrothermal flash incurs these emissions during operation. Since the hydrothermal flash (and dry steam) represents 85% of all current US geothermal electricity generation, GHG emissions from such facilities are a relevant and significant component of their environmental performance. Evaluation of EGS with supercritical CO2 was done in this year by Argonne based on the direction by GTO. Argonne's results for supercritical CO2 show that EGS combined with conventional fossil fuel power plants could be an effective way of managing CO2 emissions from fossil fuel power plants.

Reviewer 23601

Score: 2.5

Comment: A key driver for Geothermal energy use is the reduction in GHG emissions compared with fossil energy sources. Thus it is important to try to quantify this advantage by doing LCAs on Geothermal energy options and to compare them with those of fossil energy while also including the LCAs of other low GHG emission energy technologies. That is what this project is doing. Having said that, it is quite clear that Geothermal is a low GHG emission technology. The work done in this area by this project substantiates this. It is not clear to me how much if any more LCA work on Geothermal is warranted.

There is interest in the potential use of CO2 as the motive fluid in EGS technology. It could be economical if the CO2 needed was being produced from a fossil based power plant that needed to sequester it based on state or federal policy. This combination of technologies has the interesting synergy of including some simultaneous CO2 sequestration. It is useful to understand the LCA of this energy production approach. However, a simple material balance shows that unless there is significant CO2 sequestration within the geothermal reservoir, the potential amount of carbon sequestration is small per MW of geothermal power and there would need to be an immense amount of geothermal power involved for any significant sized fossil plant. It is not expected that CO2 based geothermal plants will have enough carbon sequestration to make this approach practical.

PI Response:

The reviewer correctly notes that GHG emissions from geothermal plants, zero for binary systems and finite for flash, are considerably lower than those from fossil power plants. GHG emissions from flash plants could be considerable in certain contexts relative to some other renewable power generating technologies. One of our objects, which is not quite completed, is to quantify the relative GHG performance among all power generation technologies on a consistent LCA basis. Looking into future, additional LCA efforts could cover new geothermal technology scenarios to be developed by GTO and its analytic team, gather more reliable CO2 data of existing GT operations from various sources, and address uncertainty and variation in GT LCAs.

We agree that the consumption of CO2 from fossil power plants for use and sequestion in geothermal fields is a opportunistic case, resulting mainly in CO2 management of fossil power plants with some supplement power generation from geothermal plants. Our primary interest here is to establish the GHG performance of using supercritical CO2 derived from fossil plants as the geofluid in EGS facilities, as it is purported to offer operational performance advantages over saline geofluids.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23444

Score: 4.0

Comment: The approach is appropriate. Most data was obtained by conducting a survey and review of existing literature, while some measured data was made available from primary sources. If data was missing, surrogates for missing data were developed. Some data was of variable and questionable quality such that data needs to be assessed for quality (i.e. measured vs. calculated). System boundaries for determining environmental impacts are well constrained and comprehensive. Various well-developed, industry standard modeling approaches were used for calculation of environmental impacts. All data needs to be normalized for better comparison. Assumptions inherent need to be clearly stated in the approach/modeling. New, higher quality data will be forthcoming soon and can be incorporated into the existing analyses. These data should significantly improve estimates of emissions from geothermal power plants.

PI Response:

Our LCA approach, as developed in the GREET model, follows generic LCA approaches and protocols by addressing system boundary, dealing with co-product issues, and technology advancement over time. LCA is data intensive. Through GREET, we make our approach/methodologies transparent. Wherever possile, we build alternative methods to address crtical LCA issues in GREET. GREET is available to any party from its website and its data is completely open. In this way, we intend to increase transparancy of methodologies and data in GREET LCA so others can test alternative methodologies and use their own data.

Reviewer 23600

Score: 3.0

Comment: Straightforward approach. Created system boundaries around comparative projects to ensure consistency. Used literature, industry and GT experts for inputs and scenarios. Need to assess the ranges associated with each type of power producer to place results in context. A method to do this type of work needs to be created.

PI Response:

The need to assess range information has and continues to be one of the objectives for FY13.The two areas of most importance are: 1) GHG emissions from geothermal power plants and, 2) life cycle burdens for geothermal power plant exploration activities.The approach for the former has been developed employing data from industry and state and federal agencies. For the latter, a method has been developed employing industry information, albeit limited, to estimate geothermal resource exploration life cycle burdens. The GREET model is designed to conduct stochastic simulations. Efforts will be made in FY13 to develop range estimates for key factors affecting GT GHG emissions and other power generation systems.

Reviewer 23411

Score: 3.0

Comment: As noted previously, I have not followed this work from the beginning so I am at a bit of a disadvantage. However, the performance of life cycle analyses is not new to Argonne and the approach applied to this effort appears to be robust. They have exercised internal resources, used available data and reached out to others in the community to develop and understanding of life cycle energy and emissions for geothermal power production. While the CO2 EGS work may be required for policy purposes, it provides little value in terms of geothermal energy over the next couple decades; if similar efforts continue beyond this project care must be exercise to ensure the work remains relevant to the goals of the GTO.

PI Response:

The LCA efforts of Argonne are intended to address environmental effects of geothermal technologies in comparison with other power generation technologies. While EGS may be a long-term technology, it is a critical technology under evaluation by GTO. For this reason, Argonne has been evaluting GHG effects of EGS, among other geothermal technologies.

Reviewer 23601

Score: 3.0

Comment: This project is accumulating GHG data from published information on Geothermal energy systems around the world. This is a great place to start. It is also comparing the data and how it is being obtained to better judge its quality. It is recognizing and properly taking into account the fact that California data, especially starting from here forward, is of better quality and will rely more heavily on it. This is an excellent approach. It would also be very worthwhile for this project to utilize the GTO LCOE effort and GETEM model, plus existing GREET data to estimate GHG emissions and energy use for several different Hydrothermal and projected EGS operations based on a few different resources (temperatures and depths). These results could be compared with the data the project has found to try to better validate both the data and the GETEM results. The project plans on estimating GHG emission and energy use during exploration. These results would be interesting but would assuredly have a minor contribution to the overall LCA and may not be worth the effort and cost. The project is doing a very good job on disseminating its results including making them directly available in GREET.

PI Response:

The GHG emissions of most significance arise from the operation of hydrothermal flash plants. Argonne's LCA efforts address GHG effects, while LCOE and GETEM efforts address cost issues. The LCOE and GETEM effects provide

critical inputs in terms of geotehrmal technology specification and productivityto the LCA efforts. Argonne has closely collaborated with INL and NREL to get critical inputs from those two efforts. As for the relative magnitude of exploration's contribution to geothermal powers LCA, this requires a more detailed assessment. Based on our preliminary estimates, exploration's contribution ranges between 5 and 25 percent of GT GHG emissions (which are very low relative to fossil power plant GHG emissions), depending on the magnitude of plant power output.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23444

Score: 4.0

Comment: Data for GHG emissions from US and global geothermal power plants have been collected where such data exists (not a large number of power plants collect these relevant data). Analysis suggests that most GHG emission data for US geothermal power plants derives almost exclusively from a single source, the state of CA. The quality of these data have been evaluated and potential sources of problems identified. Using these aggregate data a range of GHG emissions has been developed and suggests that US emissions are lower than global emissions. Additional estimates for the amount of GHGs produced by drilling extra wells has been included in the data analyses. With this data, comparisons of GHG emissions for consumption and usage of geothermal technologies are made with various renewable energy options including use of scCO2. In addition to renewable energy, coal and biomass were included for analysis and comparison (after last year's review). With the potential for scCO2, these data are essential for technology evaluation. Appropriate and valuable comparisons were made of various energy types - although some non-standard references were used in the diagrams making it difficult to understand the graphics. Overall, geothermal energy has lower GHG emissions than fossil fuels and these are primarily from plant construction. More importantly, gaps and data limitations have been identified. To date, these data provide one of the first benchmarks for making LCA comparisons of GHG emission for a large swatch of the energy sectors.

PI Response:

Thanks for the comment. The constuction activies of hydrothermal binary power plants and wells are the only source of GHG emissions for those plants and as such are at least an order of magnitude less than the overall emissions (construction and operation) of fossil power plants. For hydrothermal flash and dry steam plants, the operational GHG emissions can be considerable due to the geofluids exposure to the atmosphere during plant operation. Reliable estimates of those GHG emissions are currently being developed by Argonne for this project.

Reviewer 23600

Score: 3.0

Comment: GHG emissions (g/KWh) were presented for 19 types of power plants. Also, CO2 emissions per KWh from GT production were given. In both cases, the data is old and needs to be updated (acknowledged). CARB will supply much more useful data. Efforts need to be pursued to get industry on board with supplying more data to make this assessment more current, meaningful and complete. Ranges of emissions should be used to enhance understanding of values given. Page 8 needs more text to explain the importance and usefulness.

PI Response:

Data is a major challenge for GT LCAs in particular and LCAs in general. Argonne continues to pursue newer, additional data in order to generate reliable LCA results. Argonne will continue to update its GHG emissions analysis for geothermal power plants using data from state and federal government sources. The data contained in those sources were and are supplied by the industry. Further, from these sources range information will be derived for GHG emissions from geothermal power plants.

Reviewer 23411

Score: 3.0

Comment: It appears that the project has progressed as planned and that targets and goals have been met. The review of work performed over the last year has certainly progressed as planned and it is assumed that previous year's tasks have also.

PI Response:

Thanks for the comment.

Reviewer 23601

Score: 3.2

Comment: The project has accomplished a great deal in a timely manner. The results produced are very good and very useful.

PI Response:

Thanks for the comment.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23444

Score: 4.0

Comment: Project is making significant progress on time and as planned. It is unclear if decision points were placed in the timeline but such data analyses likely did not require a go/no go option.

PI Response:

This analysis project is in place to help GTO make go/no go decisions for its R&D projects.

Reviewer 23600

Score: 3.0

Comment: Coordination and collaboration are sound. Future plans to use CARB data are good. Need to push industry to give more time-related data on emissions and get them on board with this work.

PI Response:

For reasons of proprietary considerations, industry has been retiscent to provide GHG emissions data or well field exploration information. Argonne will continue to pursue industry data sources. Besides, new data avaialbe from CARB and other sources in the near future will help improve LCA result reliability.

Reviewer 23411

Score: 3.0

Comment: This is very difficult to assess but this appears to be a well planned and coordinated project.

PI Response:

Thank you!

Reviewer 23601

Score: 3.5

Comment: Based on the quantity, quality and timeliness of the results of this Project it appears to be well managed.

PI Response:

Thank you!

STRENGTHS

Reviewer 23444

Comment: Proper evaluation of the disparate types of renewable energy technologies necessitates that GHG be known for the complete life cycle of these technologies. Developing this quantitative data is paramount to data-driven decision making concerning reduction of GHG emissions. This study develops an important baseline for understanding the environmental and economic impacts of geothermal energy within the constraints of the existing data and could provide suggestions for future data acquisition. The approach and data evaluation was comprehensive and the data will be of interest to a large sector of stakeholders as well as the public. Well-presented and clear presentation focusing on relevant and important points.

PI Response:

Thank you!

Reviewer 23600

Comment: The project has had solid coordination and collaboration to keep it on track. The project laid out the goals and impact on the GTO goals, which is good. They clearly laid out the challenges associated with the lack of concrete data

and modified its approach in 2011 to include industry input, which is critical to enhancing overall results. I liked the summary of all the technical accomplishments, given in the 4 page summary report.

PI Response:

Thank you!

Reviewer 23411

Comment: The strength of this project is founded on Argonne's established approach to addressing life cycle energy costs leveraging on experience from other projects. In addition, it appears the Argonne team has been thorough in the use of available data and the identification of required assumptions.

PI Response:

Thank you!

Reviewer 23601

Comment: The key driver for Geothermal energy use is the reduction in GHG emissions compared with fossil energy sources. Thus it is important to try to quantify this advantage by doing LCAs on Geothermal energy options and to compare them with those of fossil energy while also including the LCAs of other low GHG emission energy technologies. This project is accumulating GHG data from published information on Geothermal energy systems around the world. This is a great place to start. It is also comparing the data and how it is being obtained to better judge its quality. It is recognizing and properly taking into account the fact that California data, especially starting from here forward, is of better quality and will rely more heavily on it. This is an excellent approach.

PI Response:

Thank you!

WEAKNESSES

Reviewer 23444

Comment: Perhaps the largest weakness of the work is the lack of robust data on GHG for inclusion into the project's analysis and conclusions. However, this is an industry weakness and not a weakness of the proposal. The PIs are addressing this issue as best they can within the existing framework.

PI Response:

Thank you! Argonne will continue to pursue industry for data sharing.

Reviewer 23600

Comment: The data's age is the largest weakness. This has been acknowledged but needs to be strongly pursued. The results shown in the chart imply a degree of certainty that is likely not there. So, emission ranges should be shown on the charts, which would place the current results in the proper context.

PI Response:

If the reviewer is referring to the chart on Slide 7, those results are indeed midpoints of various power generation technologies. In the future, Argonne will consider to present ranges of reuslts.
If the reviewer is referring to the chart on slide 8, the global results are a decade old but likely still quite representative. The CA data are new, but have uncertainty. The newest CA data to be released in the fall of 2012 will have a much higher quality. Argonne will attempt to develop range estimates with the new data.

Reviewer 23411

Comment: I remain skeptical of the need for CO2 EGS assessments for any applications in the next few decades. If the CO2 analyses are to be performed, is there a manner in which the "saved costs" of reduced water withdrawal and use could be assessed?

PI Response:

GTO asked Argonne to address LCA GHG results of supercrical CO2 EGS in FY12. While the technology path certainly has technical challenges, LCA results show that it can be supplement to fossil fuel power plants for CO2 management. Other issues such as potential water benefits could be examined by other GTO projects.

Reviewer 23601

Comment: The work already done in this LCA area by this project substantiates that Geothermal energy is very attractive from a GHG emissions perspective. It is not clear how much more, if any, LCA work on Geothermal is warranted. It would be very worthwhile for this project to utilize the GTO LCOE effort and GETEM model, plus existing GREET data to estimate GHG emissions and energy use for several different Hydrothermal and projected EGS operations based on a few different resources (temperatures and depths). These results could be compared with the data the project has found to try to better validate both the data and the GETEM results. The project plans on estimating GHG emission and energy use during exploration. These results would be interesting but would assuredly have a minor contribution to the overall LCA and may not be worth the effort and cost. There is no mention of interactions with industry. Having industry involved to help vet the information being generated would be very helpful.

PI Response:

This study has taken advantage of results from GTO-funded GETEM and LCOE efforts. Their contributions have been and will continue to be clearly acknowledged in LCA publications. Additional LCA efforts in the future may address new GT secenarios to be developed by GTO and its analytic team, improve data quality of GT LCAs, and develop range estimates for LCA results.

IMPROVEMENTS

Reviewer 23444

Comment: Improvements to the project will come from additional, higher quality data as stated by the PIs. Dissemination of study results should be made as widely available as possible such as publication in peer-reviewed journals, in addition to DoE reports and buried in GREET. Consider developing webpages with key results, i.e. graphs of comparison, for

easier access by the public to relevant data. Perhaps the PIs could develop a list of key measurable GHG components that could serve as suggestions to geothermal industry so that in the future, this data would become available.

PI Response:

Peer reviewed publications are being prepared to document LCA results. Available websites at Argonne will be explored for presenting analysis results of GTO-funded projects.

Reviewer 23600

Comment: Need to assess the ranges associated with each type of power producer to place results in context. A method to do this type of work needs to be created. Efforts need to be pursued to get industry on board with supplying more data to make this assessment more current, meaningful and complete. Page 8 needs more text to explain the importance and usefulness.

Questions:

1. The GHG emissions noted on Slide 7 chart: are there different kinds of GHG emissions for each type of facility or have they all been equilibrated to CO2? What is the vintage of the data used in this chart? Do the size and vintage of plants impact this study?

2. Are there ranges associated with the GHG emissions and should these be noted on the slide?

3. What causes the GHG variance noted on slide 8? The data used is old. What is your estimation of the chart using newer data? Can you explain the chart? Why are US data showing fewer emissions? How many GT plants are used in this chart? Should there be an uncertainty bandwidth applied to this chart?

4. What is the impact of more exploration wells on emissions?

5. Has the industry been more forthcoming with the needed information for your project?

6. If you were to do this project over, knowing what you know now, what would you do?

7. What are your largest uncertainties and how have you addressed them?

8. What new technologies are coming forward and how will they impact your study?

9. How do you plan to keep this study up to date?

PI Response:

1. All GHGs cited in slide 7 represent a combined CO2e for N2O, CH4 and CO2 with their 100-year global warming potentials. However, in almost all cases CO2 emissions represent 95% or more of CO2e emissions.

2. Yes. Ranges can be provided in the future.

3.

i) The functionality shown on slide 8 simply depicts that some facilites have more dissolved CO2 (and some CH4) than others. And in some cases can be quite substantial.

ii) Newer data for the global plot are unlikely to appear any different. Newer data for the CA plots might be quite different due to: 1) consistency in data reporting between plants, 2) reporting only measured emissions data rather than using one size fits all emissions factors, and 3) more reliable values for annual plant electricity output.

iii) The US data (actually CA data) are actually a mixed bag of measured emissions and the use of one-size-fits-all emissions factors. The latter might low ball emissoins from facilities. Further, which data points represent measured data are unknown. Hence, the CA plot must be considered at best provisional.

iv) The CARB data provides 13 somewhat aggregated GHG emissions values, which represents output from 32 plants or sites, where there might be more than one generator per "plant."

v) Data provided to CARB does not include variation per reportee. The variation seen in the figure, whether for the global or CA plots, presumably represents typical emissions for the plants and sites of any given reportee.

4. More exploration would increase plant cycle GHG emissions and energy consumption. Preliminary estimates suggest it could range between 5 to 25 percent of GT GHG emissions (which, however, are very low in absolute values).

5. No. for proprietary reasons regarding exploration, useful information from industry is sparse.

6. Very little. With few exceptions, LCA data gathering will be based primarily on searches of databases and literature and the use of models. For proprietary considerations, industry is generally reluctant to provide LCA information, unless conducted as an industry group or under non-disclosure agreements.

7. Our largest uncertainties are associated with GHG emissions from operating GT flash and dry steam plants. To reduce them, we are awaiting new CARB data, which requires reporting of measured data only.

8. We have examined supercrical CO2 as a heat transfer fluid. There may other technologies under GTO R&D that we will examine in FY13.

9. Because the data derived from this study is to be included in GREET, we will update the information in GREET as it becomes available.

Reviewer 23411

Comment: See weaknesses.

PI Response:

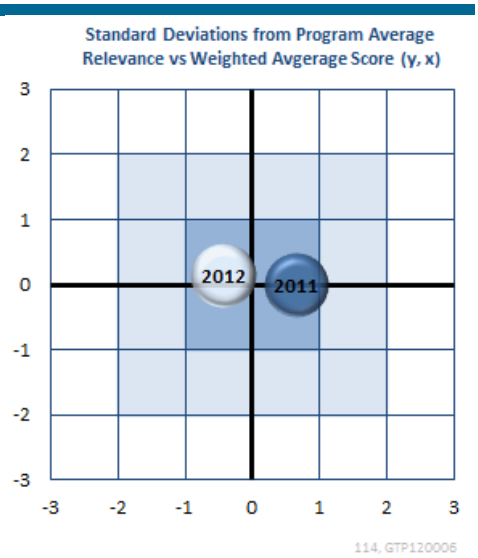
See above responses.

Reviewer 23601

Comment: The project plans on estimating GHG emission and energy use during exploration. These results would be interesting but would assuredly have a minor contribution to the overall LCA and may not be worth the effort and cost. Having industry involved to help vet the information being generated would be very helpful.

PI Response:

We agree that exploration will have minor contribution. However, quantitative analysis is needed so that others would understand the contribution from exploration.



Review: 2012 Geothermal Technologies Office Peer Review
ID: 114
Project: Water Resource and Water Quality Assessment of Geothermal Systems
Principal Investigator: Wang, Michael
Organization: Argonne National Laboratory
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23444

Score: 4.0

Comment: Geothermal energy relies on water-rich fluids. "Water" quantity and quality affect the potential for resource development, recharge and sustained extraction, therefore assessing the life cycle requirements of water provides important data for markets, performance, development and application of geothermal energy. This project estimates water quantities for geothermal technologies to allow for a comparison with other renewable technologies. In addition, these data serve as a baseline for targeting areas of potential development. This study fills that knowledge gap and provides data to overcome potential market barrier for deployment of geothermal energy. It is highly relevant to the program's mission. One such area of focus is geopressured-geothermal systems that occur in large regions of the US. Because groundwater is essentially a non-renewable resource, understanding its use, loss, and quality is a first step in making geothermal energy sustainable.

PI Response:

No comment.

Reviewer 23600

Score: 3.2

Comment: Project’s objectives do meet the GTO goals by improving the understanding of water uses/demands/quality of various GT technologies. Water use will become more challenged due to multiple demands from population, industry, agriculture and recreation. The more these issues can be quantified (with ranges), the better, especially when comparing these results to other power generation methods. This is well laid out.

PI Response:

No comment.

Reviewer 23411

Score: 3.0

Comment: An assessment of water quantity and quality issues related to geothermal energy production I a vital effort for the program. It seems that Argonne is doing a good job in this arena. With regard to water quantity, this work only accounts for the withdrawal of fresh water (which makes geothermal flash such a small water consumer). While I understand that a common comparison metric is required this can be confusing and can lead to conclusions not intended by Argonne's work - a deeper look into the long-term effects of water withdrawal (beyond pressure decline) may be worth a consideration. An understanding of EGS water use is important to the GTO and Argonne should be careful that any assessments of EGS water use be qualified with an understanding of the systems being evaluated and any assumptions that enter into this quantification - I am doubtful that sufficient data exists for green-field EGS locations to provide a defendable quantification of water use related to the yet to be develop heat resource in the US.

PI Response:

Water quantity issues have been addressed based on well established and widely accepted methods. The most common metrics for quantifying water for electric power producting are "water withdrawals" and "water consumption". Water withdrawls quantify any water that is withdrawn from a surface or ground water source and used for any reason at the power plant even if the water is returned to the source where it can be reused by another user. Water consumption is the metric used by this work to compare different power technologies, and it only includes water that is withdrawn but not returned in a usable form. A once-through cooling tower is an example of a process that would withdraw a large quanity of water but only consume a small quantity of water. While both water withdrawls and water consumption are important metrics, water consumption is a more direct measure of impact on the availability of water resources.

Water consumption can be further differentiated according to the type or quality of water consumed using so-called green, blue, and grey waters, in which green water denotes rainwater, blue water accounts for fresh surface and ground water, and grey water represents water that is of low quality or otherwise degrated such as municipal wastewater. Additionally, geothermal production also relies upon geofluid which is quantified separately. Given the implications of geofluid consumption and the potential for geothermal to use grey water sources such as produced water or reclaimed water for makeup, Argonne will continue to work to increase the specificity of the water quantity analysis by water type.

The reviewer has a valid point that any EGS results must be qualified with the fact that these systems are still under development and that the results include a high degree of uncertainty. Although data is limited, there is sufficient data to make reasonable and defensible quantifications of the potential water consumption from EGS systems.

Reviewer 23601

Score: 3.3

Comment: Water availability constraints could impact the expansion of Geothermal energy and/or the expansion of Geothermal energy could cause water shortages in certain areas of the country, especially in the west which is ripe for Geothermal energy but low on water supply. It is important to study the potential for this issue in the use of Geothermal energy. Thus this project is very relevant to the Geothermal energy industry and DOE. It is important to compare the water intensity of Geothermal energy to other possible energy systems since water availability will likely be an issue for many energy systems in certain regions of the country. This project is doing that.

PI Response:

Separate efforts at Argonne and other national labs are addressing regional water supply and demand issues including many sectors. The data obtained from these efforts will be used to better understand the potential stress that GT projects may have on regional water supply and demand.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23444

Score: 2.0

Comment: Life cycle assessment involves an inventory of existing literature for data, acquisition of measurements from primary sources and development of appropriate surrogates where data is missing. Clear boundaries for the LCA exist. Water requirements for the system include volume data, existing water demands and needs. The focus is on EGS but data should be compiled for traditional geothermal resources. Data was aggregated for comparison and analyses using industry standard modeling programs. The regional water resource assessment focuses on demand and availability - using predictions for projecting future demands based on energy growth. In comparing various energy sectors, water consumption appears to be water loss which is different than the quantity of water used. To evaluate water quantity, one would need to include all water used in the plant. To equate water quantity with water loss negates the actual water needed for use by the various energy technologies. Perhaps these are not intended to be equivalent and if not, then please clarify. No metrics have been included for evaluating water quality nor is there a clear definition for the intended meaning of water quality.

PI Response:

There appears to be some missunderstanding by the reviewer here. This is admittedly due to a communication oversight on our part, but it is not suprising given the complexity of the issues surrounding water and the limited number of slides and time to present a large body of work. In the near future, our technical report will present this issue in a thourough way. The term "water quantity" was used generally to describe all of the work related to quantifying water or geofluid flows and consumption for geothermal plants. The most important final metric is "water consumption", which includes any water that is consumed either in the construction or operations (make up water and/or cooling water) of a geothermal plant. These values are compared to water consumption for other competing technologies. We also quantified "geofluid loss" which was quantified separately and only included in water consumption calculations if that geofluid loss was made-up with fresh or other surface water sources. The term "water quality" was also used generally to describe all of the work related to the chemical constituents found in geofluid and water that may impact plant or reservoir performance or the environment through an accidental release.

Reviewer 23600

Score: 3.4

Comment: The approach was straightforward and used multiple sources. I really liked the SMART objectives, which laid out the milestones. I would encourage interfacing with GT industry companies on actual water uses and the oil and gas industry regarding fracture stimulation treatments and the re-use of water. Looking into non-potable sources would also be of benefit. This has been a big area for oil and gas companies relative to fracture treatment stimulations.

PI Response:

We have a long history of working with the oil and gas industry and are very familiar with their fracture processes and efforts to recycle flowback water. However, there are also important differences between stimulation of EGS wells and hydraulic fracturing of a natural gas well. A close examination of these differences will be included in our final report. We are also attempting to quantify the availability of non-potable water sources in our water resource assessment task. Initial

efforts in examining the availability of produced water from oil and gas activities as a potential non-potable water source are summarized in our report ANL/EVS/R-11/10.

Reviewer 23411

Score: 3.0

Comment: I have not followed the work associated with the project but the approach related to the quantification of water use appears robust and appropriate. As a result of last year's Peer Review, the PI incorporated efforts to expand their study to include recent EGS work. However, transparency beyond what is available in the Peer Review is needed to understand how assessments are determined for geothermal technologies that either poorly or not at all represented in the market place (i.e. EGS). The work associated with water quality confuses me. What was presented was an aggregation of water quality information, but this tends to be a site/resource specific issue and I am unclear to what end this work is being performed. While the purpose may be clear to the DOE, greater clarity of the water quality work is needed for me.

PI Response:

Our methodology for assessing EGS is described in ANL/ESD/10-5 and ANL/EVS/R-10/5 and relies upon input from experts from industry and the national laboratories, modeled results from the Geothermal Electricity Technology Evaluation Model (GETEM), and available data.

As described in our response to Reviewer 23444, the term "water quality" was used broadly to describe our efforts on several topics related to composition and chemistry of geofluid and water. Previous work (FY10) under this task label included agregating (development of Argonne Geothermal Geochemical Dataset) and analyzing geochemical data for current and potential geothermal sites, evaluating potential risks related to the release of geofluid, operational considerations related to geofluid composition including scaling and corrosion, and evaluation of the potential for mineral extraction. The current work under this task includes updating the Argonne Geothermal Geochemical Dataset (AGGD) to make it more user friendly and available for the National Geothermal Data System (NGDS), a closer examination of EGS stimulation practices, evaluation of EGS stimulation fluid compositions, analysis of water quality parameters affecting stimulation (with regards to the use of non-fresh water sources for stimulation), and an update of our anlysis of non-condensible gas concentrations in geofluids based correcting data in the AGGD for air contamination.

Reviewer 23601

Score: 2.7

Comment: The project has recognized that the limited data it had found and used last year is not sufficient and reliable. It is good that it is now seeking better data directly from existing geothermal plants. However, the limited data used to date lays into question the results to date. The earlier project approach that only looked at Geothermal energy water use with respect to regional water constraints was clearly lacking. It is good that the project will now look at a region's total water demand and constraints and on a more granular (smaller regions) basis. In summary, the project is now taking much better approaches to meet its objectives. There is no evidence that industry has been approached and involved in this effort. Having them involved may have improved the approach that was originally taken and could improve the quality of the Project moving forward.

PI Response:

Industry has been approached numerous times over the course of this project. Industry has been involved in developing or verifying our assumptions for the material inventory for the drilling and pipeline development stages of both the life cycle

and water analyses. We have been unsuccessful in our attempts to engage industry on verifying operational assumptions with the exception of our geopressured scenarios. However, state and federal agencies have been extremely helpful in providing data and documentation relevant to existing hydrothermal projects and planned EGS projects.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23444

Score: 2.0

Comment: Data analysis have identified the processes responsible for the majority of water consumption (loss) for hydrothermal and EGS plants. These data allow processes to be targeted for saving water. A comparison is made amongst various traditional and renewable energy technologies for water loss /KWh of lifetime energy output. Results of these analyses provide a valuable comparison for assessing the overall potential for geothermal energy development. A more valuable and perhaps relevant comparison should include water required for use of the technology, in addition to that lost to the surrounding. Data results equate water loss from coal energy with nuclear energy, both are equivalent in this analyses but not in actual water usage. Results need to be clarified for actual meaning of the terms in cf. water consumption, water intensity, water quantity, water quality, water loss. In an arid environment, it is hard to understand the conclusion that produced geofluids is a bigger issue than freshwater use. Is this groundwater or surface water, potable water? Geothermal is low in water usage/consumption but in areas of high usage, water is not readily available. There seems to be an inconsistent use of the terms water quantity, consumption, loss and use which clouds the actual results. Technical results also include a regional water resource assessment for likely growth sectors. Progress seems appropriate. Water quality assessment is ongoing - and not well understood as presented.

PI Response:

See response to Reviewer 23444 under scientific/technical approach for clarification on water consumption comparison.

The statement about geofluid production being more important than freshwater consumption applies only to geopressured systems. In these systems high pressures prevent the return of the geofluid to the formation creating a large waste stream that can be costly to dispose of (very similar to produced water from an oil and gas field). These same systems however consume very little water for construction or operations (<0.01 gal/kWh) so it is unlikely to be much of a limitation.

See response to Reviewer 23411 under scientific/technical approach for clarification on water quality assessment.

Reviewer 23600

Score: 3.4

Comment: Solid findings/results for water quantity analysis. Good ranges, keep using them. Need to note what the ranges represent (P90 – P10?). Work is ongoing in quality assessment and regional water demands. Looking into ways to make GT more water quality tolerant would be good. Results from GT growth scenarios shows water intensity of EGS will be an important parameter in its deployment. Working with industry on the quality tolerance of various power generation methods might show a real benefit to EGS if it is more quality tolerant.

PI Response:

No comment.

Reviewer 23411

Score: 2.0

Comment: Given the importance of this project, it is imperative that the results are communicated in a manner that is clear and unambiguous. Of particular concern is water use relative to EGS. This is at best an immature technology and results related to EGS must be couched with the appropriate caveats. In addition it is unclear to me to what the specific motivation is behind the water quality work. Is it to provide an aggregated assessment of geothermal waters? Is this what the DOE program is looking for? Argonne and the GTO should work together to assure that the quality work is addressing the need of the program.

PI Response:

See response to Reviewer 23411 under scientific/technical approach for clarification on water quality assessment. The work has evolved from an aggregated assessment of geothermal waters to address a number of issues associated with water and geofluid composition and chemistry. Argonne will continue to work with GTO to assure that the work is addressing the needs of the program.

Reviewer 23601

Score: 1.8

Comment: Since the data used thus far in this Project on Geothermal energy water intensity has been limited and not validated, it puts in doubt the results to date. The project is basically starting from scratch. The Project has thus far only included Geothermal energy water demands in its study of regional water constraints. The Geothermal water usage data is in doubt. The Project will also now use much smaller regions for this part of the effort. Thus the Project efforts in this area are really starting from scratch as well. The project has gathered data on Geothermal water quality issues but there is more to be done and it it is unclear what its use will be.

PI Response:

The project is not starting from scratch. The first few years of work were based on design assumptions, input from industry and other experts, and limited data - particularly for EGS, which provided valuable baseline data and analysis on water consumption for the full life cycle of geothermal plants. It also identified areas of limited data or high uncertainty. The current work builds upon that effort through the availability of more data as industry has progressed on EGS development. The work seeks to provide a more in depth and detailed analysis of the life cycle stages that have limited data to improve the overall estimates and reduce uncertainty.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23444

Score: 3.0

Comment: Progress appears to be largely on schedule and within budget. No decision points are apparent, but this is a life-cycle analyses such that they are largely unnecessary.

PI Response:

This is an analysis-focused project to provide results to help GTO in its go/no go decisions of R&D programs.

Reviewer 23600

Score: 3.4

Comment: The use of SMART objectives must be complemented. More teams should use this method. Several future plans, all tied to the core focus objectives have been given. They need to get with the oil and gas industry on re-use of produced waters, especially after stimulation. Also, will all the work get done?

PI Response:

See response to Reviewer 23600 under scientific/technical approach on engagement with oil and gas industry.

Reviewer 23411

Score: 3.0

Comment: The project is well managed and well coordinated between the Argonne researchers and outside subject matter experts.

PI Response:

No comment.

Reviewer 23601

Score: 2.0

Comment: The Project is basically starting over to get better data on Geothermal energy water intensity and to use smaller regions and total water use to look at the impact of water constraints on Geothermal energy. There is limited time to accomplish all this by September of 2012. This does not appear to be a well managed project.

PI Response:

See response to Reviewer 23601 under accomplishments, results, and progress.

STRENGTHS

Reviewer 23444

Comment: Understanding the water usage for geothermal power is essential for developing and maintaining this industry. Environmental impacts should include water usage and the resulting impact on water quality. These data are necessary for making appropriate comparisons with other energy technologies in order to assess the overall impact and viability of geothermal energy. This potentially results in an expansion of geothermal energy.

PI Response:

No comment.

Reviewer 23600

Comment: Good layout of the objectives and how this ties to the GTO goals. The approach was straightforward and used multiple sources. I really liked the SMART objectives, which laid out the milestones. Solid findings/results for water quantity analysis. Good ranges, keep using them. Looking into ways to make GT more water quality tolerant would be good.

PI Response:

No comment.

Reviewer 23411

Comment: Argonne possesses the base capabilities to do this work has appears to have reached out to other organizations to bolster this important work.

PI Response:

No comment.

Reviewer 23601

Comment: Water availability constraints could impact the expansion of Geothermal energy and/or the expansion of Geothermal energy could cause water shortages in certain areas of the country, especially in the West which is ripe for Geothermal energy but low on water supply. It is important to study the potential for this issue in the use of Geothermal energy. Thus this project is relevant to the Geothermal energy industry and DOE. The potential impact of Geothermal energy on water quality is also important to study and understand.

The Project will now take a much more rigorous approach to obtain better Geothermal energy water intensity data and will look at total water use in smaller more granular regions relative to water constraints on Geothermal energy expansion.

PI Response:

No comment.

WEAKNESSES

Reviewer 23444

Comment: Clearly separating water consumption and water loss from water intensity or water use or water needs is important to accurately communicate the objectives as well as results of this research. Evaluating the overall water usage/requirements may be as valuable as quantification of water loss, especially for environmental impact. There is not a clear definition nor metric for assessing water quality. What is quality and how is it measured? Simply stating that higher concentration of contaminants were observed is inadequate to evaluate quality. What is a contaminant? Elevated TDS

does not equate with risk to drinking water, quality may or may not be tied to TDS. Expertise in water chemistry seems to be needed in this study. The presentation skipped around and I found it difficult to follow which likely detracted from the overall results.

PI Response:

Expanding the analysis from water consumption to include water withdrawals and perhaps to differentiate types of withdrawals as they pertain to potential environmental impact is an excellent point.

It is evident that sufficient time was not allotted to adequately address what we mean by "water quantity" and "water quality". As previously addressed in our response to Reviewer 23444 under scientific/technical approach, these terms were used broadly. The "water quality" portion of the work has evolved from an overall assessment of composition and concentration of geofluids to the examination of particular chemical components that may provide benefits or challenges to geothermal electricity production. For example, although TDS is not equated with a risk to drinking water, geofluids that are supersaturated with silica can cause significant scaling in geothermal plants without pretreatment of the geofluid. The emphasis of our "water quality" work has been on the chemical composition of the geofluid.

Reviewer 23600

Comment: The more the project can work with GT industry and oil and gas operators and service providers to look into tailored ways to make GT EGS more flexible relative to water quality, the better will be these results.

PI Response:

We agree.

Reviewer 23411

Comment: The water use scenarios need better clarification. For example why flash and geopressured systems are considered to use so little water - this is not intuitive to the reader. Similar sentiments with respect to how EGS assessments are made (see previous comments). Also unclear where the water quality work is going.

PI Response:

The questions asked here are addressed in detail in our FY10 and FY11 final reports. This peer review was focused only upon work between May 2011 and May 2012 and so the details of the previous work were excluded from the presentation and supporting documentation.

Reviewer 23601

Comment: The project has recognized that the limited data it had found and used last year is not sufficient and reliable. It is good that it is now seeking better data directly from existing geothermal plants. However, the limited data used to date lays into question the results to date. The earlier project approach that only looked at Geothermal energy water use with respect to regional water constraints was clearly lacking. The project will now look at a region's total water demand and constraints and on a more granular (smaller regions) basis. It does not appear that industry has been directly involved with this effort. Their knowledge would be very beneficial to this project.

PI Response:

The previous work established a baseline from which the current work build upon. Industry has been involved in the development and verification of assumptions although greater industry involvement particularly in obtaining operations stage data would greatly enhance the work.

IMPROVEMENTS

Reviewer 23444

Comment: Clearly define the goals of water quality and quantity and use the terms appropriately. Develop criteria for assessing water quality. Consider consulting with an expert in water chemistry to more accurately evaluate water quality.

PI Response:

We agree.

Reviewer 23600

Comment: Type or Paste Text Here

I would encourage interfacing with GT industry companies on actual water uses and the oil and gas industry regarding fracture stimulation treatments and the re-use of water. Looking into non-potable sources would also be of benefit. This has been a big area for oil and gas companies relative to fracture treatment stimulations. Working with industry on the quality tolerance of various power generation methods might show a real benefit to EGS if it is more quality tolerant.

Questions:

1.b Data Aggregation: Have you been able to gather EGS water data from the demo plants that are being done in the US? If so, what have been the results? If not, why not?

2. What are some of the barriers to siting GT plants, from a water quality perspective? If water is available but not the right quality, what can be done to make it the right kind of water? Reverse osmosis?

3. Do make-up requirements or production/injection rates vary with time for the kinds of GT plants reviewed? Are some plants more efficient than others?

4. Regional water demands versus supply – where is there a large gap (supply > demand) such that GT can be used?

5. Have you contacted the Oil and Gas industry on how they are re-using frac water?

6. What are you seeing relative to the overlap of regional water resources, water power demand, and geothermal optimal reservoir conditions?

7. What are your largest uncertainties associated with this work and how are you overcoming them or quantifying them?

8. Is water quality a function of locale of the EGS reservoir, such that every site's quality issues are going to be unique?

9. Are the new issues you have raised being addressed within the GTO umbrella of projects?

PI Response:

1) Yes we have now found some data from a few of the EGS demo projects and it will be incorporated into our updated LCA results.

2) This is not something we have looked at in any detail but it is an intriguing question. We are currently looking at potential water quality requirements/limitation on stimulation fluids.

3) Yes. This is something that we are currently investigating with more production/injection data from more more plants. There are definitely differences between plants, but it is not always clear why.

4) This is something we hope to answer with our updated water resource assessment.

5) We have worked on a number of projects related to water use in shale gas development and are quite familiar with the practices being used in the oil and gas industry.

6) This is a complex question to answer in this format and will be addressed in our final report, but in general areas with the best geothermal resources tend to also be areas with limited water availability.

7) When analyzing a technology that is still in the early development stages, there is always significant uncertainty. To address this we have attempted to use ranges as much as possible in order to capture at least some of the uncertainty.

8) While there are some regional similarities, every geothermal field is different. That being said there are certain water quality parameters that are important for all goethermal systems and analyzing those has been more of the focus of our water quality work.

9) GTO is certainly aware of the issues that we have raised through this work.

Reviewer 23411

Comment: While I am certain that DOE has held internal reviews of the Argonne work, it may be advisable to have a workshop, or something similar to communicate the work that is being pursued in this project. This a very important work and should be scrutinized.

PI Response:

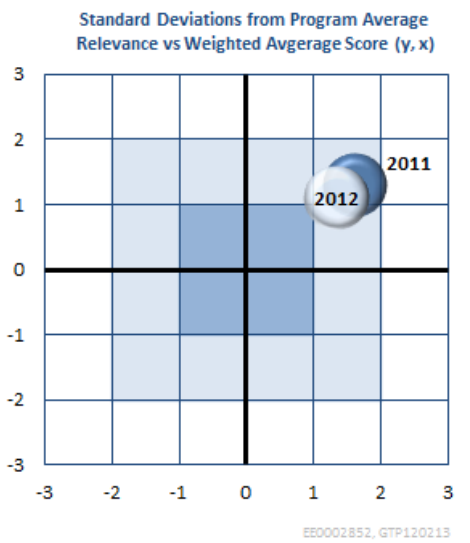
This is an excellent idea, and something we will pursue upon completion of our current tasks.

Reviewer 23601

Comment: The Project will now take a much more rigorous approach to obtain better Geothermal energy water intensity data and will look at total water use in smaller more granular regions relative to water constraints on Geothermal energy expansion. These are vital improvements. It would be appropriate for this project to also use GETEM as way to look at potential water use by Hydrothermal and EGS systems. It is true that water loss is a GETEM input, but by varying that input over the range that people in the industry have experienced or expect, could provide another perspective on water intensity.

PI Response:

GETEM was used to model each of our reference scenarios. While GETEM did provide useful information on fresh water consumption for hydrothermal flash scenarios, it did not provide the consumption data needed for the binary and EGS scenarios. Parameters generated from the GETEM model runs were used to develop the water consumption estimates. GETEM has been and remains a very useful tool to our ongoing analysis.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002852
Project: Heat Flow Database Expansion for NGDS Data Development, Collection and Maintenance
Principal Investigator: Blackwell, David
Organization: Southern Methodist University
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23437

Score: 4.0

Comment: The knowledge retained by the project participants is of immense value for the geothermal community at large. With this project that expansive knowledge base of geothermal information is being interpreted, consolidated and correlated, and made available through a single capability. It will be a resource available to facilitate any number of geothermal R&D activities. It will contribute significantly to the NGDS objective of providing an information base that will help drive down risks associated with geothermal development.

PI Response:

No response entered.

Reviewer 23638

Score: 4.0

Comment: Heat flow and temperature gradient data are two of the primary exploration tools used for geothermal exploration in the Basin and Range province. This data base will provide access to data hosted by the seven institutions participating in this project, in a uniform manner. The data are being reviewed using a statistical analysis tool developed by Siemens to identify repeated data, and to highlight outlier points that might reflect a true thermal anomaly or reflect poor data quality. The ability to query and display thermal data over a selected geographic area will assist in identifying prospective geothermal sites as well as to highlight areas where limited or no thermal data are available (as captured within this database). One limitation of the project is that the quality control scan is limited to data hosted within this system, and will not be extended to other thermal data that might be hosted within other nodes of the NGDS. An important aspect of the project is that it is accessing all of the thermal data that are contained within the publications of the Geothermal Resources Council. In developing metadata and key word search terms, an ontology of similar terms was developed to facilitate data searches. Another important aspect of this project has been the linking of related data sets; for example, scout ticket data and well log data associated with a well with temperature log data are all cross referenced.

PI Response:

No response entered.

Reviewer 23640

Score: 4.0

Comment: This project aims to provide to substantial data resources via a node on the NGDS, and is highly relevant to the geothermal industry need for data acceptability and distribution. The spatial capabilities are key to how this project aims to have significant impact in the geothermal space. The deduplication efforts on this project are crucial and will result in a more relevant data set for use across the NGDS. The development of consistent standards for data structure and metadata is a strong step towards making the discovery of distributed data resources a success for the larger NGDS.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23437

Score: 4.0

Comment: In general the SMU/Siemens team appears to be following a solid system development process. They have an extremely competent team comprising world-renowned domain experts and impressive information system development experts. The team composition, combined with an appropriately rigorous development methodology, ensures the ability to accomplish project objectives. This is borne out in the impressive results presented to date. As a result the project has a high likelihood of a successful roll out of the information system at project completion.

PI Response:

No response entered.

Reviewer 23638

Score: 3.0

Comment: Most of the effort to date on this project has focused on data retrieval, collection, and development and QA. Siemens has developed a data analytics tool for heat flow and temperature gradient well data to evaluate data quality and identify possible outlier points using an automated process, which greatly speeds up data evaluation and assignment of a quality ranking. Only data that is part of the project consortium will be evaluated using this software. Data from over 2000 heat flow sites and 5000 temperature well sites and related data will go into the database. The data types will have automatic linking and will be cataloged by attribute. Open sourced software developed under this project will facilitate searches, and data can be displayed using map views with screenings of temperatures and depth intervals. The user will be able click on a well to get more detailed information, and can download associated data, such as temperature depth curves. The data analytics tool is for data quality assessment only, and is not designed to assist in the interpretation of temperature depth data. A large number of documents (including the publications of the GRC) have been scanned, and automated extraction tools are being used (employing full text search and key word ontologies) to identify and extract thermal data and associated information from these records.

PI Response:

The analysis does include extraction of information from scanned documents both for linking purposes and to make numerical geothermal measurements from scouting tickets available; it is not feasible to reliably extract thermal information from arbitrarily formatted research papers such as in the GRC proceedings. Related data have been manually extracted from GRC and other publications, up to this point, and entered into the SMU Geothermal Lab Heat Flow and the UND Global Heat Flow databases that are being merged in this project. Future support of efforts such as this are suggested funding opportunities for the DOE.

The number of heat flow sites from BHT data are closer to 15,000 than the stated 5000 above.

Note also that while many open source libraries are used, the code written by Siemens is currently not available under an open source license. See also response to reviewer 23638 below.

Reviewer 23640

Score: 4.0

Comment: The rigid Agile development method is solid for this project and a clear indication of the likely success. The data integration efforts including the linking of heat flow dB's with supporting detail are another indication that the development team is collaborating well with SME's on this effort.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23437

Score: 4.0

Comment: This project appears to be well on track toward meeting all of its objectives. There is high confidence that the end result will be a valuable information resource for the geothermal community. Significant progress has been made on this project toward the acquisition, aggregation, correlation and management of data from a variety of sources and in a variety of forms. The work to assess and improve the quality of the information resource appears to be proceeding well.

PI Response:

No response entered.

Reviewer 23638

Score: 4.0

Comment: The project is on schedule and within budget. The data analytics software developed by Siemens has been tested using the SMU heat flow database as a test case. Each member of the project has initiated data entry into the system using a set of mutually agreed upon data templates that contain metadata terms that will be used to catalog the entries in a systematic fashion. Remaining work includes integration of this node into the NGDS. One aspect of the

project that perhaps should be expanded is the use of the data analytics software to evaluate thermal data generated by the existing DOE EGS and IET projects - these data will be submitted to the NGDS system via the OpenEI portal, and at present, there are no plans to evaluate any data outside of the SMU data node using the Siemens software package. In visiting the SMU geothermal web page, it does not appear that the new data system is available yet for public viewing.

PI Response:

That is correct; the system is not yet available for public viewing, as it is actively undergoing development and testing. The SMU Geothermal Laboratory has maintained a website at http://smu.edu/geothermal for many years where the public can pull information on many of SMU's projects. Additionally, this webpage contains information on our conferences and other items not part of the NGDS project. The software being developed by Siemens for the SMU node of the NGDS resides on a separate (virtual) server and will provide access to a much larger quantity of data from SMU as well as data from the other consortium members. When available, the address will be https://geothermal.smu.edu. Links to the 'other' webpage will be prominently displayed for users who are curious and/or misdirected. SMU will be updating our legacy webpage in the next couple of weeks to notify users that the SMU Node of the NGDS is under construction and will be available in early 2013 at https://geothermal.smu.edu.

Regarding the application of data quality to other data in OpenEI, please see respones to reviewer 23638

Reviewer 23640

Score: 4.0

Comment: The project is on schedule and is progressing strongly from Phase 2 to phase 3.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23437

Score: 4.0

Comment: There is no reason to believe this project is being run using anything other than best practices. Work is on time and on budget; technical progress is consistent with the plans; milestones are being met; change is being incorporated appropriately; manpower needs are managed; collaboration and coordination, internally and externally to the project, are being handled well.

PI Response:

No response entered.

Reviewer 23638

Score: 4.0

Comment: The project has a well organized structure that appears to integrate the activities of each of the participating organizations. The work flow includes sprint processes, consisting of biweekly SMU database development meetings with Siemens followed by a demonstration of developments from previous week's meetings. The project also has general meeting groups, working group meetings, and meetings to address NGDS interaction. There are also regularly scheduled activities to comply with DOE reporting and ARRA financial reporting requirements. A geothermal workshop was conducted at SMU earlier this year (attended by representatives of all but two of the project groups) to identify key research needs and facilitate future coordination efforts.

PI Response:

No response entered.

Reviewer 23640

Score: 4.0

Comment: Project development sprint reporting tied to the Agile development effort, keyword discussions and financial meetings are regular and iterative, supporting the successful development of this solution.

PI Response:

No response entered.

STRENGTHS

Reviewer 23437

Comment: Rigorous system development methodology. Domain and system development expertise on the team. Solid architecture and technology foundation. Well-understood system requirements. Emphasis on highest possible data quality. Partnership representing academia, industry, government.

PI Response:

No response entered.

Reviewer 23638

Comment: The main strengths of this project is its focus on developing a comprehensive database for heat flow data in the US. This information will serve as an important resource of existing and future geothermal exploration projects, as thermal data is a key component in identifying potential geothermal systems, especially hidden systems that have no surface features. Siemens has developed a data analytics tool that has been used to automate extraction of thermal data from unstructured formats (such as scanned publications) and evaluate and rank the quality of thermal data. The system also provides a mechanism for linking related data (such as well log data and drilling notes) with heat flow and downhole temperature measurements. A comprehensive set of data submittal templates, metadata terms, and a key word ontology have been developed by the project team to facilitate cataloging and searching of the data.

PI Response:

The ability for Siemens to extract data from files has made a tremendous difference in the amount of data we can convert from scanned documents to usable data. They have scanned 1000s of publications for text and keyword searches, yet much of the extraction tool work has been on items like the SMU field notes, temperature-depth data, BEG Scout tickets, etc, most of these have previously not been available to the public.

Reviewer 23640

Comment: Robust data/digital de-duplication effort. The highly effective use case development for this project is a clear strength and another indicator of its likely success.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23437

Comment: No significant weaknesses.

PI Response:

No response entered.

Reviewer 23638

Comment: There are a few concerns that have been identified with the current project. These include:

1) While the data analytics tools are being used to evaluate and rank thermal data within the SMU (and related partners) heat flow database, there are no plans to extend the use of this tool to thermal data that are contained in other nodes of the NGDS, such as all of the data that will be submitted by DOE-funded IET and EGS projects to the OpenEI system at NREL. This could result in having one set of high-quality data (hosted by the SMU site) and other sets of thermal data whose relative data quality is unknown.

2) The data analytics tools are not designed to assist potential users in the evaluation of heat flow and temperature data. It might be worthwhile to investigate if such tools could be developed and made accessible via the NGDS webtop.

3) The scope of this project does not include the development of a user interface - thus it was not possible to see how simple it will be for a user to access, search, and manipulate data that is contained in this database.

4) Ongoing work includes the development of a sustainability plan. While having an automated software system to extract and evaluate thermal data should facilitate future additions to the database, it is not clear how the software itself will be maintained and upgraded in the future.

5) It is not clear if the Siemens analytical software will be available to the general geothermal community - i.e., whether it will be open sourced, or if it will be considered to be proprietary in nature, and only operated in conjunction with the SMU database.

6) Specific details on how this database will be integrated into the NGDS were not provided - this may be due to the limited development of the NGDS itself. It remains to be seen how successful the integration of different data submission templates, metadata types, and data cataloging methods that have been developed by each project will be. This is not a weakness of this specific project, but is a concern for the overarching NGDS program.

PI Response:

1) The ability to leverage the analytical tools developed for this project for data from other providers will be largely dependent upon those providers' ability to present their data in a standard format. The team has made every effort to share the layout of the data structure for heat flow and for thermal conductivity data, but are unable to mandate that other groups expend the effort to use that standard format when providing their data to OpenEI. OpenEI is a file repository where files on any format can be uploaded and does not support WFS webservices. The work involved in mapping arbitrarily formatted data in OpenEI to the format the analytical modules would expect is variable and difficult to automate.

The SMU Geothermal Lab has been working with the team to create a new reliability tool to be used with the NGDS heat flow data, regardless of where it came from. This tool is being developed for application in a Microsoft Excel worksheet for users to run once they have all the data in one worksheet. It will give an assigned number based on the weighting of the parameters used to generate the heat flow value. The purpose is for users to be able to compare the different types of heat flow data (conventional and BHT) along with the heat flow from different time periods. There is a GRC paper on this proposed reliability code and application submitted for the Annual Meeting 2012.

2) Additional uses for the analytic tools are an area ripe for future development, if time and resources are available. Note: Siemens did use the tools to compare pressure data from production wells in Texas with overlapping temperature data, to determine if any interesting correlations existed, but the results were inconclusive.

3) That is correct. This project has never included development of any end user interface beyond what was required by the 7 organizations submitting data within the scope. However, the project team is making a concerted effort to leverage the investment in the interface for use by the data providers into something that will be useful to others as well, within the time constraints and resources available.

4) The underlyling system software components, the server hardware, and the network connectivity will be maintained by SMU's Information Technology Services, not SMU Geothermal Laboratory personnel. This maintenance will include backup and disaster recovery services as well. It is estimated that SMU ITS will charge the SMU Geothermal Laboratory approximately $3,000 annually for this support. No source of funding for the ongoing maintenance has been identified and this is an exposure to the future long term sustainability. The original statement of work called for the data to be 'submitted' to the NGDS at the conclusion of the project and it was only after the buget had been approved that the plans evolved into long term maintenance of the data at SMU facilities. While the capabilities are certainly present at SMU, had this implementation been part of the orginal understanding, funding to support the long term maintenance would have been requested. One alternative would be to contract for this support now, for some period of years into the future, using some of the funds available in the award.

Note: The software being developed by Siemens will contain documentation for maintenance and operation by SMU ITS, but it will not contain updates to the functions beyond what is delivered at the conclusion of the project.

5) The scope of the current project did not include open source software development. There are however ongoing discussions outside of this project to extend the software to additional use cases and make it available under an open source license.

6) Certainly, the success of the NGDS project as a whole will depend upon each of the key components, including but not limited to: the development of standard formats that are easily understood and implemeted by data contributors, the willingness of data owners to provide data in a common format or one that can be translated into the common format, the robustness of applications that will mine the different nodes of the NGDS (e.g. Geothermal Prospector and others), the usability of the end user interface, and the stablity of the various nodes and their network connectivity. This project is committed to providing high quality data on a stable system that is accessible via the internet using the CSW protocol to serve a catalog of data items linking to HTTP resources for files such as publications and linking to web services (WFS, WMS) with a paylod complying with agreed upon content models. This is how participation in the NGDS has been defined in collaboration with AZGS and BSU. When possible, data will be presented in the standard format, where standard formats have been identified before the end of the project timeline.

Reviewer 23640

Comment: The lack of a sustainability plan is a problem, especially as this project matriculates into Phase 2 and 3 of its life cycle.

PI Response:

The sustainability plan does need to be better documented and will be included in an upcoming quarterly report.

IMPROVEMENTS

Reviewer 23437

Comment: This is a very impressive project. The primary suggestion for improvement is to release a 'beta' of this capability to a limited audience representing interested individuals from industry, government, academia, finance - outside of the project - who the SMU/Siemens team imagine might gain value from the system. Their feedback gained from the beta testers could be of great value in fine-tuning the system prior to completion of this development cycle.

PI Response:

Agreed. The project plan has always called for a phased rollout. User credentials were just issued to each of the partner organizations. Following a period of review and input, a limited set of users beyond the partner organizations will be issued credentials and encouraged to provide feedback. Additionally, we are interested in testing the Web Feature Service capability of delivering data to an application, such as Geothermal Prospector. Note: The scope of this project has never included development of an end user interface beyond one for use by the 7 organziations providing the data into the system. While this remains the scope and focus of the user interface, every effort is being made to develop screens that other users, including the public, will find helpful. A demonstration of the software is scheduled for the Technical Working Group meeting on Thursday, June 21, 2012. When the time comes, beta users will likely be solicited from among this group, the graduate students at SMU and the other universities on the project, and selected industry contacts that the SMU Geothermal Laboratory and/or the GRC have established over the years.

Reviewer 23638

Comment: Suggested improvements are included in the Weaknesses section.

PI Response:

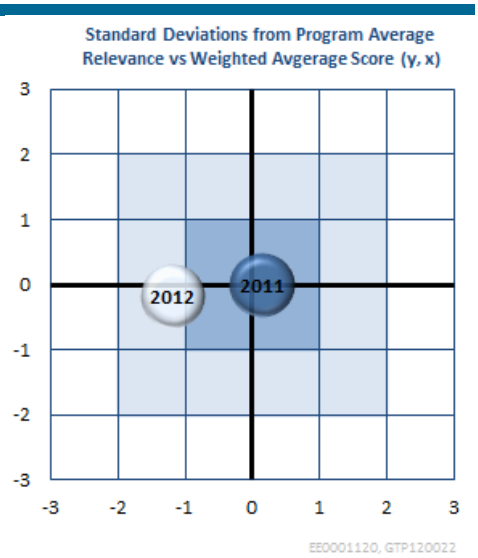
No response entered.

Reviewer 23640

Comment: This project needs to better describe its sustainability plan post award.

PI Response:

Agreed. A document describing the sustainability plan will be included in an upcoming quarterly report.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0001120
Project: National Geothermal Data System Architecture Design, Testing and Maintenance
Principal Investigator: Snyder, Walter
Organization: Boise State University
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23437

Score: 4.0

Comment: As the framework for integrating access to varied geothermal data resources, NGDS is crucial to the DOE vision of unlocking information assets in support of all aspects of geothermal development. This project has as one of its objectives to design and build this integrating framework, and its success is vital. Other objectives include making a number of high value geothermal information repositories available through NGDS protocols, which should also be of great benefit to the geothermal community.

PI Response:

Reviewer 23638

Score: 3.0

Comment: The objective of this project is to design and implement a national geothermal data system as a distributed network of databases and data sites. The project has undergone several changes in approach since its inception, and the project timeline has been revised to accommodate an earlier end date. The team, consisting of participants from a number of organizations, is focused on developing a system architecture that can interact with multiple independent data nodes using a shared data catalog and metadata system. This system is envisioned to allow for users to conduct searches for geothermal data using a web-based interface that seamlessly interfaces with a number of federated data nodes. This project provides the guts for the NGDS, and is thus of critical importance for the database system. Due to an earlier stop work phase and changes in strategy, this project is a bit behind schedule, but its completion is vital for the distributed data system to function. One web-based data analysis tool has been constructed (Geofrat) that can be used for financial risk classification.

PI Response:

Reviewer 23640

Score: 2.0

Comment: The NGDS presentation attempted to showcase the impact of the project on the overarching geothermal program's mission and goals. While there was one slide which provided some bullets attempting to show the impact, the specific items fell far short of any quantifiable impact statement. The presentation provided sufficient support for the relevance of the project to the larger geothermal program goals.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23437

Score: 2.0

Comment: Design and development of the NGDS framework - the catalog and Web services supporting integrated access to multiple distributed information repositories - is a substantial engineering effort requiring a mature system engineering approach. Unfortunately this project shows little regard for good engineering practices, instead opting for sloppy approaches in almost every aspect of development. The project has already gone through a redirection by DOE intended to correct this, and spur the project to employ more solid approaches. Yet the project to date shows little evidence that good practices have been adopted. By this point - around 40% of time and funding expended - any reasonable project of this type would have produced a significant set of engineering work products: customer and product requirements, architecture specifications, detailed software and data designs, etc. Almost none of this is evident. If this pattern continues there is little reason to believe the project will conclude by successfully delivering a quality product. There is hope. There are still sufficient funds and time to produce a quality product, if combined with good leadership, appropriately skilled staff, and good engineering practices. Other aspects of the project, especially preparing a number of high value information repositories for inclusion in NGDS, appear to be conducted with a reasonable approach.

PI Response:

Reviewer 23638

Score: 3.0

Comment: After numerous bumps in the road, this project now seems headed in the right direction. One of the core aspects of this project is the development of a catalog that provides links using metadata to all of the data entries available in the federated nodes. An initial implementation of catalog services on the project website can be used to browse suites of data and provide access to data on various nodes. A company with extensive experience with portal design has been brought into the project and will conduct a user-centered design study to help design an effective web-based user interface for the project. To facilitate the growth of the data network, the concept of a node in a box has been developed. The subawardees have focused on having their existing data scanned and cataloged using appropriate metadata terms so that it can be accessed by the new system.

PI Response:

Reviewer 23640

Score: 2.0

Comment: DOE involvement in the technical design of this project has been essential to the projects continued forward progress. Moving from an initial design of one central node with many external nodes feeding into one central registry, to a federated/nodal design has been crucial to this project's continuation. Prototypes, to-date, have been insufficient to the original tasks envisioned in the funding opportunity. New technical directions seek to improve on the original technical design as well as develop substantially increased capabilities distributed across the meta-verse of geothermal data nodes.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23437

Score: 2.0

Comment: The NGDS framework design and development work appears to have made little substantive progress. This part of the project is a substantial engineering effort and as a result there should be significant evidence of requirements and design work having been completed. Almost no such evidence exists. The data acquisition portions of the project appear to be progressing well. Other aspects of the project seem to be on track.

PI Response:

Reviewer 23638

Score: 2.0

Comment: The project is deemed to be 40% complete at this point as a result of earlier challenges. Thus, the project needs to make sure that it develops a comprehensive work plan, schedule, and budget if the work is to be completed on time and within the allotted budget. A number of new participants with extensive experience in web portal and database architecture design have joined the team, and should provide much needed assistance in these areas. A new project timeline has been proposed, indicating that there is little room for project slip. Key accomplishments include the implementation of an initial catalog system, categorization of geothermal data using metadata by the subawardees, and the development of a new management plan and initial system architecture design. Much work is needed (in coordination with other members of the NGDS) to finalize the architecture design and create and test a working system that can be used to conduct searches across the different data nodes.

PI Response:

Reviewer 23640

Score: 1.0

Comment: The progress on this effort has been minimal and has endured redirection and substantial involvement by the Department of Energy, in an effort to move the project along a path to success. To-date program management has been insufficient to the task and has, at every turn, caused this project to miss targets and milestones aligned to the original funding opportunity. Little to no appreciable progress has been completed on the overarching data system. The only positive statement re: results and progress, is the substantial amount of data acquired through the various subcontractors. This reviewer feels that those accomplishments have come despite the mismanagement of the project from BSU.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23437

Score: 2.5

Comment: The project appears to be spending at the expected rate. Coordination with sub-awardees appears to be conducted well, with an apparent exception in the case of the role of Arizona Geological Survey in system design. This is cause for significant concern, as without AZGS involvement it does not appear that the project has sufficient appropriately skilled staff to carry out the design and development portion of the project. More attention needs to be paid to applying appropriate rigor in project management for the engineering activities. Many opportunities for internal corrective actions have gone unattended, and as a result it appears DOE has had to intervene with at least one project redirection.

PI Response:

Reviewer 23638

Score: 2.0

Comment: After an initial review of the project by DOE, a revised management structure was developed to improve communication between the different team members. The project is adopting the Agile approach to management, which is intended to facilitate design and build on rapid basis (using scrums to attack each subset of the system). The data people will be reporting using the Agile system, with biweekly phone calls to keep communication open. The proposed implementation plan includes hiring a subcontractor with scrummaster credentials to oversee this process. Given that the timeline of this project is now condensed, proper coordination of future efforts is essential if the project is to be completed on time. Open communication is critical to ensure that problems between the different groups are identified and resolved quickly. Shifts in budget and staffing allocations between the different subawardees might be needed to complete the revamped project. This will require that consensus on these items can be obtained.

PI Response:

Reviewer 23640

Score: 1.5

Comment: The project management and coordination has been less than ideal for this project. An over abundance of working and technical oversight has lead to confusion in the design and development of this project. Personality conflicts within the BSU team and between the BSU team and its subcontractors has lead to missed targets and milestones. Without substantive change in project leadership, these conflicts will not be resolved sufficiently to enable forward progress on this project.

PI Response:

STRENGTHS

Reviewer 23437

Comment: It is hard to identify any stand-out strengths of this project.

PI Response:

Reviewer 23638

Comment: The revised vision of the project seems to provide a reasonable path forward for project success, provided that the project is managed properly, given the limited time remaining. The envisioned system architecture seems capable of connecting the user (who will access the system using a webtop portal) with a catalog system that will interface with all of the federated data nodes. A number of analysis tools (including Geofrat) will allow the user to take data obtained from a search of the system to conduct distinct types of data analyses. This system will be invaluable for current and future geothermal exploration efforts by providing legacy data for evaluating potential prospects, identifying data gaps, and constructing case studies that can provide lessons learned. The NGDS will also serve as a resource to a wide range of other users, such as researchers, regulators, educators, legislators, and the general public.

PI Response:

Reviewer 23640

Comment: The BSU team clearly brings rich subject matter expertise to this endeavor. Their lack of technical expertise in software development has only recently been identified. However, the BSU team is re-tooling their team. The technical efforts underway supporting a revised effort with the goal of deploying a "node-in-a-box" strategy shows considerable

promise for successful completion of this project within the allotted time and budget. International Geothermal Data Federation initiative may help with the development of a geothermal data ontology, thought its impact will be minimal.

PI Response:

WEAKNESSES

Reviewer 23437

Comment: Poor engineering practices for the design and development tasks. Inadequate engineering project management. Poor coordination with some subs.

PI Response:

Reviewer 23638

Comment: The primary weakness of the project is that the project has had a number of setbacks, so that it is significantly behind schedule. It is critical that there is improved project leadership and management to make sure that the subsequent phases of the project are completed on time and meet the needs of the project. It may be necessary to rely on previously developed software and hardware (thus utilizing products produced by some of the other database projects) instead of developing new products in order to meet the tight timelines. It is not clear if there will be a master catalog for the entire NGDS or a distributed federated catalog that operates between nodes. Whichever solution is selected will need to deal with slightly different data templates and metadata developed by the different database projects. A great deal of system development (such as a user-friendly web interface and an effective data search tool) remains to be completed. A comprehensive critical path management plan needs to be developed for the remaining phases of the project. A sustainability plan for this system also needs to be developed.

PI Response:

Reviewer 23640

Comment: A serious lack of understanding for the complexities in developing a solution of this magnitude and poor program and technical management are the core weaknesses for this project at BSU. Several years have been spent developing a solution without any substantive project results for the distributed data and application access system as envisioned in the original funding opportunity. Lack of development of an adequate solution which would adequately support the financial risk analysis of geothermal projects is one example of the weaknesses ingrained in this project. The projects reliance, to date, on meta-tagging and central cataloging of data shows a lack of understanding of Semantic Web and Open Data solutions. The impact of the personality conflicts within the BSU team and between BSU and its sub contractors is another significant weakness.

PI Response:

IMPROVEMENTS

Reviewer 23437

Comment: Employ good engineering practices starting now. Employ appropriately skilled staff or subs for the engineering tasks. Employ good engineering project management - pay attention to ensure the project is on track and take corrective action when it's not.

PI Response:

Reviewer 23638

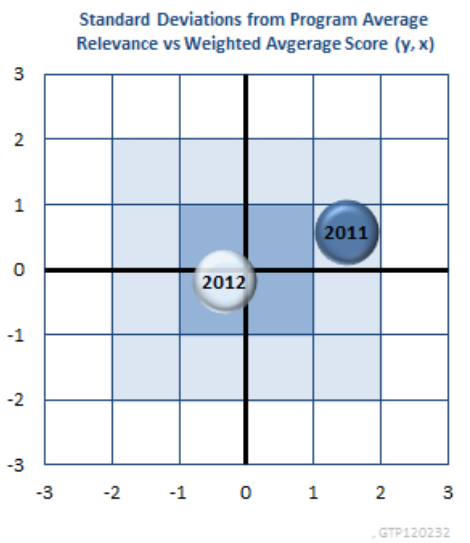
Comment: The suggested improvements are listed along with the weaknesses.

PI Response:

Reviewer 2364

Comment: There is a need for dramatic improvement in the technical development and management of this project within the BSU team. A rigid AGILE development effort needs to be in place with all team members trained in Agile development methods. More aggressive use of Semantic Web solutions for distributed data sets is necessary. A new program leadership team and technical development team will be required before this project can move forward

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0001501
Project: National Geothermal Resource Assessment and Classification
Principal Investigator: Williams, Colin
Organization: U.S. Geological Survey
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23444

Score: 3.0

Comment: This project focuses on developing new geothermal resource classification standards that incorporate a system-wide approach coupled with utilization techniques, expanding the low T resource assessment across 50 states (including low T, EGS and sedimentary basin geothermal projects) and improving assessment methodologies for EGS energy recovery and undiscovered resources. By aggregating existing data into one place, the geothermal community can save significant time, effort and cost when assessing and exploring new and potential fields. This study also contributes to ongoing efforts for the establishment of the NGDS. Thus, the study seeks to overcome market barriers to geothermal technologies and potentially lower risk and costs to increase resource development and inform decision-makers.

PI Response:

Reviewer 23552

Score: 2.0

Comment: The USGS project attempts to classify the United States in terms of their Low Temperature resource potential and EGS. It is not clear how this new classification compares to other classifications of geothermal potential, heat flow, etc. While the reclassification in a UN-motivated 3D space appears useful, only one of the component appears novel and might be best handled by a socio-economic GIS. While other studies (current and past) have focus increasingly on geothermal occurrence models, this study appears to return to a more static classification scheme that appears to pay little attention to geological occurrence models (e.g., less broad-brush structural setting). The project does not do a good job at articulating its goals and benefits and how the the project intends to serve not only legacy data, but new data in a dynamic fashion. The various case studies and the focus on sedimentary basins appear somewhat haphazard and not tied into a comprehensive easy-to-serve product. The project is interesting and important, but the case is not really made for it.

PI Response:

Reviewer 23625

Score: 3.0

Comment: The USGS has to provide the service to disseminate geological - and in this case - geothermal information to industry, universities, regulators and the public at large. The work presented covers this requirement.

PI Response:

Reviewer 23480

Score: 4.0

Comment: This work has exceptional relevance to the geothermal program's mission and goals. A reliable resource assessment is the starting point for a well-founded, productive R&D program and the means by which industry can assess the developmental potential of various resource areas. After a long hiatus in geothermal resource assessment, the return of the USGS to this area on an ongoing basis is welcome.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23444

Score: 3.0

Comment: The approach to EGS assessment involves characterization and mapping of subsurface features, computational modeling studies to evaluate potential reservoir performance, and field studies to acquire additional data for the hydrothermal system. These measured data will then inform methods for assessing potential EGS resources. Data will be compiled for sedimentary basins, an additional low T resources primarily by acquiring information.

There is abundant literature focused on modeling hydrothermal systems, Resource characterization and assessment involves a survey (literature? web-based?) of existing and potential resources. Such data is then aggregated in summaries. Computational modeling investigates the evolution of hydrothermal systems to develop LC models that are then used for assessment. Modeling of hydrothermal systems has been an active area of research since the 1970s and there is vast literature on this topic. it is unclear how the past literature informs this present work, but it should when developing 'classifications''.

Metrics used to evaluate the existing data are not included. Uncertainties in geologic data, i.e. geothermometers, what are they and how to do those effect overall assessment of Low T resources? Data may produce a number but what does it mean? Uncertainties need to be included in analyses, 10 degrees is within error of most geothermometers. Was previous work on fracture permeability included in this dataset.

UN queried this group and they are working together.

What is product? A classification scheme?

It is unclear how this data will be integrated with ngt database.

PI Response:

Reviewer 23552

Score: 2.0

Comment: The technical and scientific approach is very difficult to evaluate. The project appears to be a conglomerate of various case studies and foci, with little or poorly articulated approach to system analysis. The case studies appear to be a collection of random project that the USGS is involved in. Classification cannot just be based on subdivision of observed spectrum, but should be process oriented (based on sophisticated occurrence models). The lack of discussion of these aspects make critical evaluation difficult and makes the project "black-boxish". The integration of the new USGS product with previous and parallel products sponsored by DoE and the Federal Government and the NGD are vague. Is the project simply submitting data to the NGD or will the NGD serve as a portal to an interactive classication-based, but dynamic product? This is, however, crucial in my mind to keep this effort dynamic and current in the future; otherwise it risks being obsolete as soon as published.

PI Response:

Reviewer 23625

Score: 3.0

Comment: The USGS has probably the best access to geothermal data on a nationwide basis. Geothermal information is just another element of geological information to be added to the NGDS.

PI Response:

Reviewer 23480

Score: 3.0

Comment: The strategy of using pre-existing databases, models, and field studies is logical and reasonable for this project. Development of a classification system along the lines of the UN Framework Classification will allow the U.S. to conform to an international standard and promote broader acceptance of the system. The PI does not specify how the resource assessment will be extended to all fifty states. Nor is the scale of the assessment addressed to any extent---is the assessment site-specific, county-wide, regional, state-wide? The data come in rather differing scales, but the assessment would best be served by adopting a common scale, perhaps by quadrangle, for uniform consistency. This scaling issue has a major impact on what can be deduced from the assessment. The choice of a 90 C deg boundary for low temperature resources appears to be a holdover from earlier assessments. What about the case where a 90 C degree resource is found overlying a higher temperature resource? Should there be some depth consideration in cataloging resources? The constitutive properties of the EGS resource have yet to be defined or agreed upon. Perhaps the USGS should consider the EGS resource as everything that isn't a hydrothermal resource; that is, a hot rock mass with insufficient permeability and fluid content for sustained production. Note that geopressured resources fall in the realm of hydrothermal resources. The

use of the term, "unconventional" resources should be dropped; the resource space is a continuum and should be treated as such.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23444

Score: 3.0

Comment: Selected field work on various sites has been completed. Computational models have been developed. A preliminary resource classification scheme was developed as well as an assessment for EGS methods. The new EGS assessment revises preliminary work but no uncertainties are given on the geothermal data used to develop these new temperature estimates. 10 C is typically within the range of uncertainty so it is clear is this change in assessment reflects reality.

Sedimentary basin information has been compiled for the western US, but not for the mid-continent. With the number of wells drilled in sedimentary basins, it would seem this data would be available.

Although the modeling is to be used to support assessment, insufficient details were given to evaluate its feasibility and applicability. Models are only as good as the input data and assumptions of the models. This data is not yet integrated into the NGTS database. Results appear to follow milestones.

PI Response:

Reviewer 23552

Score: 2.0

Comment: The accomplishments of the project reflect the somewhat haphazard nature of the project and the three rather disjointed individual thrust of the project (conventional, EGS, and sedimentary basins). The accomplishments are directly tied to USGS or independent USGS aided geothermal projects in E CA, AK, OR, NV; project with very different tectonic, magmatic, or basinal properties and boundary conditions. The project also appears to act as the liaison for international classification efforts. One of the outcomes of the project is the revisions of the mean temp of Low Temperature resources. It is unclear why and how and most important whether the two estimates (old and newly revised) are statistically different at all. The results and accomplishment with respect to sedimentary basin appears to be mostly a literature review so far and a conceptual evaluation of porosity and permeability and depth.

PI Response:

Reviewer 23625

Score: 2.0

Comment: Difficult to assess, as there where no direct products of the achieved work presented.

PI Response:

Reviewer 23480

Score: 3.0

Comment: The endorsement of the UNFC approach is a positive step toward a comprehensive classification system for geothermal resources. The USGS is doing a commendable job using models and field studies to assess resources in sedimentary basins, a geologic regime that has received little attention from the geothermal community in the past. This work will be helpful in extending the assessment to the Midwest and East. The openness in sharing data with the NGDS is commendable. Results are still pending, especially those for EGS, but the prospects are promising.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23444

Score: 4.0

Comment: Project communication is on-going via web and phone. Internal USGS reviews facilitate tracking of the project. Budget variance due to funding and issues has been rectified, scopes reduced and moved so that the project is on time and budget. Project management appears satisfactory.

PI Response:

Reviewer 23552

Score: 2.0

Comment: The project appears to be well managed with respect to the individual components of the project. However, the integration of the various case studies and the three umbrella efforts appears lacking and not integrated into a cohesive effort. It is unclear what the final product of the project will be.

PI Response:

Reviewer 23625

Score: 3.0

Comment: Cannot be commented based on the presentation only.

PI Response:

Reviewer 23480

Score: 3.0

Comment: The USGS has done a very good job of coordination with universities and other organizations. However, more could be done, especially with industry (GEA) and other national groups, such as GRC and AASG. The latter should be helpful in collecting resource information east of the Rocky Mountains. Will the USGS continue to support this work after DOE funding ends? This should be a long-term commitment by the agency.

PI Response:

STRENGTHS

Reviewer 23444

Comment: Funding for this work was from DoE with a significant match by USGS. While the UN is developing a geothermal classification scheme, it is timely and useful that the US is also developing a scheme. Working with the UN to develop a consistent classification scheme is excellent. Completion of this work will result in a geothermal resource assessment across the US and provide information on low T to high T geothermal resources. Such information could help target new development and investments in geothermal energy.

PI Response:

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23625

Comment: The USGS is probably the best suited institution to collect and disseminate geothermal information on a nationwide base. In particular the compilation and low temperature information may become very useful in view of low grade heat extraction by ground coupled heat pumps.

PI Response:

Reviewer 23480

Comment: Adoption of classification standards in line with the UN Framework Classification is a move in the right direction. The assessment is encompassing of all major geologic environments, hence truly national in scope.

PI Response:

WEAKNESSES

Reviewer 23444

Comment: The ultimate product of this study is not clearly stated. Is it simply a report? It is unclear why we need a classification scheme.

PI Response:

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23625

Comment: A weakness may be that the area data density is insufficient to provide detailed maps eg. of low grade resources, that they would be useful for the site selection of low grade hydrothermal resources. This is however not a critic of the project but a limitation of the data density.

PI Response:

Reviewer 23480

Comment: The role of depth in establishing a practical resource limit is not addressed. The means for extending the assessment to all 50 states is rather vague.

PI Response:

IMPROVEMENTS

Reviewer 23444

Comment: There has been considerable effort and money extended toward the NGDS. From currently available web information, it does not appear that progress tracks expenditures so how this data will be incorporated is questionable. Demonstrate the value of an overall classification? Categorization is easy but clarify the ultimate goals and purpose for this work? Results need to be published in peer reviewed journals not just in abstract form and conference proceedings. Uncertainties in geothermometers need to be added to data analyses- what are they and how to do those effect overall assessment?

PI Response:

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23625

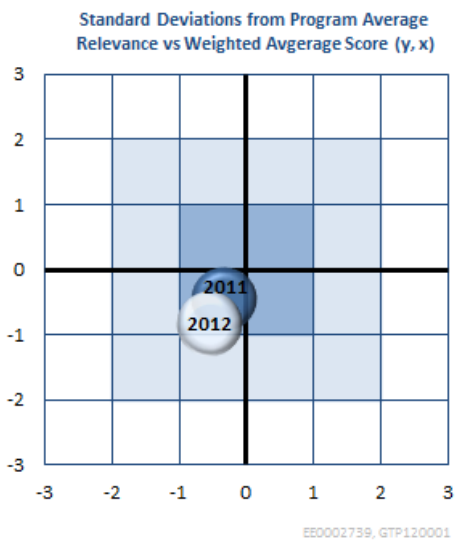
Comment: Communicate the existence of such important and publicly available information not only to the obvious users like industry, university and regulators but also to the public at large. It is not a scope of this project, but the education of the public could be an additional and important task of the USGS. Opposition to geothermal project comes from the uninformed, not from the informed.

PI Response:

Reviewer 23480

Comment: The USGS should apply its resource assessment techniques in an ongoing basis, using internally-developed data as well as that from other sources (e.g., NGDS). Once vetted and approved, the USGS should make a strong effort to educate stakeholders about the resource classification.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002739
Project: Estimation and Analysis of Life Cycle Costs of Baseline Enhanced Geothermal Systems
Principal Investigator: Turaga, Uday
Organization: Adi Analytics, LLC
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23444

Score: 3.0

Comment: To facilitate development of EGS technologies, data is needed for cost structure analysis for current and new technologies including novel process configuration. From this data, component costs will be aggregated and areas of high cost evaluated in order to identify areas for cost reduction. These data provide a baseline for economic comparison with other energy technologies. Results identify technology gaps, R&D needs and provide necessary information for policy and investment incentives. Such information is directed toward addressing knowledge gaps and eliminating market barriers to support DOE's mission for EGS deployment.

PI Response:

Thank you for your comments. We agree with your assessment of the relevance and impact of our project, which will indeed address a number of knowledge gaps and help understand market barriers to support DOE's EGS goals.

Reviewer 23600

Score: 3.2

Comment: Project addresses the main cost/economic drivers aspects of GTO. Good progress has and continues to be made to meet final project milestones. Project addressed a number of program barriers and goals, in particular the LCOE/KWh readiness of EGS. Project could have been more explicit on tying work/results to each barrier and goal. The exploration of a novel process (IGCC/CO2-EGS) and innovations are good starts. The latter needs to be tied to other power configurations being reviewed with EGS. In this way, a broader spectrum of means to reduce costs would be shown.

PI Response:

Thank you for your comments. We will ensure that our reports tie our work and results to program barriers and goals. Further, we will certainly consider your suggestion to expand our analyses to include evaluation of IGCC/CO2-EGS with other power configurations being proposed for EGS.

Reviewer 23411

Score: 1.0

Comment: I am very confused by this effort. In general, the work is certainly relevant but I am not sure what is being accomplished here that has not been covered by NREL. This type of activity is certainly important in helping guide the research portfolio for the DOE. However, it appears that ADI's activities are too broad to have any substantive impact on the program. A claim was made by the presenter that ADI is providing independent assessment of EGS costs and drivers, and that was of particular value to the program. I agree that independence can be valuable, but there was an obvious lack of ability (or desire) to filter the information that was provided during their expert solicitations - as an example the proposed potential cost savings associated with new drilling and completion technologies do not pass the laugh test and fly in the face of specific analyses of cost drivers performed by others. It is completely unclear why an analysis of IGCC/CO2 EGS analyses are being performed at this point in the program given the current state of EGS technology. At this point it does not appear that this project is producing much information beyond what is already known and in some cases is supporting unrealistic notions that there are magic bullet technologies that will provide 50% cost reductions in EGS development activities (e.g. drilling and casing costs). It is clear that ADI possess capabilities to help the program – perhaps a redirection to help fill holes in the DOE analysis portfolio would be advisable. One possible area would be to make sure their work in patent analytics is robust and covers technologies that are adaptable to geothermal development.

PI Response:

Thank you for your comments. Here is our response to the various issues you have raised:

Overlap with other projects

We share your concern that DOE projects should not duplicate other efforts. Therefore, we made concerted efforts during our project to thoroughly review literature including NREL reports, hold conference calls with researchers from various institutions including NREL, and actively participate in DOE-led working groups, e.g., Geothermal Strategic Planning and Analysis Working Group (GSPAWG), which includes NREL researchers. Based on these efforts, we believe that the bulk of our project work does not overlap with NREL efforts.

Specifically, we are unaware of any projects that overlap with our project's Task 2 (estimating economic impacts of new technologies), Task 3 (understand the state of innovation through patent analytics), and Task 4 (evaluate novel process configurations, e.g., IGCC / CO2-EGS).

Our project's Task 1 – obtaining an independent and current assessment of the cost structure of EGS – may have some overlap with other DOE-funded projects. But such overlap is only beneficial because geothermal energy technology is changing rapidly due to new investment and continual evaluation of costs is helpful -- a view other reviewers have also shared in this document. Further, multiple cost estimates developed in consultation with different experts enables a more representative assessment of costs.

Quality of technology improvement estimates

The cost impacts of new technologies were generated using a variety of literature and expert resources. So no one resource was used exclusively. Further, we gathered a range of estimates and requested and/or assigned probabilities across the range instead of relying on a single, absolute value or point-of-view. Several technologies could, in principle, deliver significant cost reductions but, in practice, are less likely (based on probabilities) to fully deliver those cost reductions. As a result, we observed small changes in LCOE when the cost reduction impacts of new technologies were modeled. For example, the decrease in LCOE of a near-field EGS plant is only one cent per kilowatt hour (c/kWh) (decreases from 20 to 19 c/kWh) the cost impact of new technologies are estimated. We hope this clarifies that we did validate and filter the information we gathered in our project.

Rationale for IGCC / CO2-EGS

The core objective of our project is to evaluate pathways that enable reduction in the cost of EGS. We hypothesized that one cost reduction pathway is the integration of CO2-EGS with IGCC. This configuration also offers several additional advantages, e.g., replacing water with CO2; a system-wide, integrated use of CO2; smaller environmental footprint; sequestration of CO2; and specific relevance to arid regions. Given such advantages, evaluating the technical and economic feasibility of integrating IGCC with CO2-EGS is useful irrespective of the maturity of either technology. A promising assessment could identify RD&D needs, incentivize developers, and facilitate technology leapfrogging.

Reviewer 23601

Score: 3.0

Comment: This project should yield very important and relevant information for the DOE GTO and the Geothermal community. It is focused on determining the LCOE for EGS. This will include establishing the degree of uncertainty in the LCOE, the key cost drivers, and the areas in which cost reduction is possible as well as the expected extent of that cost reduction. EGS is in its very early stages of development. There is a lot of speculation and differing opinions on the potential LCOE from this technology. This project should provide clearer insight into this issue. Unfortunately, the project scenario is for a small EGS facility of only 5 MW. This is much smaller than desirable as scene in the relatively high costs determined in this project. The results would be much more useful if the plant size chosen was 30-50 MW. This project is also analyzing the potential cost advantage of combining an IGCC Power Plant with EGS. This is an interesting approach to potentially reduce the LCOE for EGS. It is not yet clear what value the Patent Search and Patent Analytics part of this project will have. The project is also being effective in sharing the knowledge gained from this effort and helping to educate students about Geothermal energy. Both of these are also important to the DOE GTO.

PI Response:

Thank you for your comments. We agree with your assessment that our project will identify key cost drivers and estimate LCOE and analyze underlying uncertainties and support student education and research in geothermal energy.

Our project size assumption of 5 MW is indeed a small EGS facility but is congruent with the minimum desired output from a single well required for EGS viability and so solutions are scalable around this minimum component size. On-going work on learning curves may help us evaluate cost reduction potential in scaling up plant capacities.

Our patent analytics task will help benchmark technology, define R&D and technology gaps, identify technology improvement opportunities and innovation needs, and support our learning curve effort.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23444

Score: 3.0

Comment: Primary data comes from expert elicitations from various sectors involved with EGS technologies. This is likely one of the few viable approaches to acquire such data. The briefs contain key inputs but the level of granularity in the questions is not high, there appears to be much clumping of data. Metadata should be associated with data obtained. Data does not appear to be vetted for quality - although this may be difficult to analyze. Data analysis relies largely on a modeling program, GETEM, an industry standard that incorporates a patent analytics model among others. Patent

analytics relies on building a database of patents globally that can be used to follow new technology trends, correlated to output, and to forecast technological advances and to develop learning curves. This work takes advantage of that modeling program.

Additional EGS configurations are to be evaluated. Estimates of costs for new technologies are made and costs of supply chain impacts evaluated and into into likely scenarios. The approach seems to be broad.

PI Response:

Thank you for your comments.

Given our plan to source data from a wide range of experts and literature sources, we had to make trade-offs between the detail and accessibility of our expert briefs.

In regard to data quality, project data was generated using a variety of literature and expert resources. So no one resource was used exclusively. Further, we gathered a range of estimates and requested and/or assigned probabilities across the range instead of relying on a single, absolute value or point-of-view.

The choice of GETEM was based on guidance from DOE.

Reviewer 23600

Score: 3.4

Comment: Approach was systematic and well thought out. Used all available expert and DOE database information. The project team has acknowledged the difficulty in getting EGS demo project information along with relevant information from the oil and gas industry. They have addressed these areas but I must emphasize that the need to get the demo information to validate the assumptions used and conclusions made. As the main LCOE drivers parallel those in the oil and gas industry, more sharing of data and techniques needs to be explored.

PI Response:

Thank you for your comments. We continue to pursue all avenues to expand our expert interviews, access demo project data, and seek inputs and insights from the oil and gas industry.

Reviewer 23411

Score: 1.0

Comment: As an entity outside of the geothermal program, ADI set up a rational approach in their attempt to identify barriers and provide support to the GTO in setting priorities for the future. The program is well structured to do so, particularly the first three tasks. Unfortunately, it does not appear to have used previous analytical activities as a foundation for their work. The forth task, on IGCC/CO2 EGS, while academically interesting is not particularly well aligned with the general analysis tasks and so far down the road that is almost meaningless and should be eliminated.

PI Response:

Thank you for your comments. I hope that our response to your comments in the "Relevance / Impact of Research" section also address your comments here.

Reviewer 23601

Score: 2.7

Comment: The project has reached out to over 50 experts to seek their knowledge on EGS costs. It appears they have asked for information in sufficient detail to be able to develop a complete LCOE using the DOE GETEM model. They also solicited information from the experts on potential cost savings. This is an excellent approach. It would be better if they provided more information on the full level of detail they asked for from the experts. Unfortunately, the project scenario is for a small EGS facility of only 5 MW. This is much smaller than desirable as scene in the relatively high costs determined in this project. The results would be much more useful if the plant size chosen was 30-50 MW. It appears that the project used both a well drilling cost model and power plant cost model to be able to estimate the LCOE reductions from specific technology improvements in those areas. No details on these models was provided. These models could be valuable to DOE and the Geothermal community. It is not yet clear what value the Patent Search and Patent Analytics part of this project will have. It appears the project is taking a well thought through and knowledgeable approach to analyzing potential IGCC/EGS combinations to reduce the LCOE.

PI Response:

Thank you for your comments. I hope our previous comments explain the choice of our 5 MW project size assumption. Complete details of our methodology and models will be provided in our reports to DOE.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23444

Score: 3.0

Comment: Data has been obtained and evaluated to identify the component costs, potential impact of each component and uncertainties associated with costs, such that comparisons can be made with other LCOEs. Preliminary data provide cost estimates for near and deep-EGS and novel technologies.

Market economics have been assessed for new entrants and supply chain impacts of costs evaluated for downstream factors, drilling, well completion, simulation and plant construction. Patent analytics has been used to describe technology and forecast technology evolution such that learning curves are developed. Growth of EGS may impact supply chain, preliminary data were presented but do not appear robust. These studies suggest the economic value of R&D could be most valuable if directed toward technological advances. Without knowing model inputs, the robustness of the data is preliminary, at best. Preliminary results suggest likely costs for more novel EGS-coupled systems being quite expensive. These data suggest likely coupled approaches to avoid. Modeled process configurations were presented that attempt to tie fluid composition to temperature estimates but this data is difficult to evaluate and appears questionable. Results follow milestones. Communication with stakeholders, collaboration with partners and outreach activities are on going.

PI Response:

Thank you for your comments. Given the limitations of time and number of slides, we could not go into additional detail. However, we will provide the same in our reports to DOE.

Reviewer 23600

Score: 3.4

Comment: Solid results. Showed current LCOE for bounding EGS depths plus how impacts of improvements in drilling/completions/power plants (the 3 main cost drivers) impact LCOE. The project also shows areas that could make step changes to economics. These areas need better quantification and emphasis. It was good to see ranges on cost impacts. Please keep this up. They also looked at one combined process: IGCC/CO2-EGS. Conclusions were general about this configuration. This area needs to be expanded to include other combinations to give a range of benefits. I am concerned that the LCOE range for near EGS is too narrow and gives the impression of certainty. We also need to know, up front (not in the appendix), the main drivers of the LCOE. Task 3 (slide 11) is unclear and clarifications on what are meant by the axes needs to be given. Denoting why slow progress is being made on these areas would be of benefit. One of the objectives was to compare LCOE with coal and natural gas. This was not shown.

PI Response:

Thank you for your comments.

Our IGCC / CO2-EGS work is on-going and further detail about our methodology and findings will be presented in future communciations and reports to DOE.

We chose to use the same range for the x-axis for both the near- and deep-EGS cases leading to the impression of greater certainty for near-EGS. We will be sure to clarify this in future communications and reports to DOE.

The patent analytics results (Slide 11) certainly need additional background and in-depth explanation, which was not possible given the time and slide limitations for the Peer Review but will be provided in our reports to DOE.

Cost drivers were shared at the Peer Review last year and so we included it in the appendix. Our reports to DOE will introduce our work in a more logical fashion and provide additional context, including the comparisons with coal and natural gas.

Reviewer 23411

Score: 2.0

Comment: The project is currently under spent by something on the order of 30% but they do appear to have a plan and expect to increase spending over the summer. Despite the lower than expected spend rate, they do appear to be on task with the deliverables. They have been very active in publishing results, but I remain concerned that the results of the work are not adding significantly to the knowledge base regarding barriers – that is, they are producing results but are they of substantive value?

PI Response:

Thank you for your comments. I hope that our previous comments in this document show how our work is unique and insightful in understanding geothermal and EGS barriers.

Reviewer 23601

Score: 3.0

Comment: The project is very nearly on schedule and has produced very useful results on its key tasks and objectives. The future plan has the project finishing on schedule. It would be very valuable if the project provides DOE with the detailed data it has collected from the experts. It could provide the individual responses without naming the expert. It is assumed a complete and thorough report, and any models used will also be made available to DOE. If this report could be made public it would have even greater value. The value of the patent search and analysis is not clear.

PI Response:

Thank you for your comments. We will consider your suggestions for our reports to DOE. I also hope that our previous comments have clarified the value of our patent analytics work.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23444

Score: 3.0
Comment: The project is on schedule but facing technical challenges. To overcome these obstacles, a consultant was added to the project which will realign the cost structure and time line with that proposed. The level of partner participation is unclear. Otherwise, the project appears to be well coordinated and managed.

PI Response:

Thank you for your comments.

Reviewer 23600

Score: 3.2

Comment: Project was well laid out, timeline met, when task 4 was taking too long, it was addressed. Future plans are understandable and comply with project description. Well coordinated with experts for data gathering.

PI Response:

Thank you for your comments.

Reviewer 23411

Score: 2.0

Comment: The project seems to have been managed in an adequate manner. No further comments.

PI Response:

Thank you for your comments.

Reviewer 23601

Score: 4.0

Comment: It appears that this project has been well managed based on the results, approach, and timeliness.

PI Response:

Thank you for your comments.

STRENGTHS

Reviewer 23444

Comment: This study appears to be first comprehensive cost dataset for EGS although it focuses on providing downstream (sans exploration) cost data. Information on the economics of innovation and technology may allow for more targeted efforts to reduce potential EGS costs. This study suggests that R&D would be most beneficial if directed toward technology advancement.

PI Response:

Thank you for your comments.

Reviewer 23600

Comment: Solid project management, addressed the main cost drivers, project approach was systematic, well laid out. The project's goals were well laid out and understandable. Use of ranges was very good, needs to be continued. The project also noted technology areas that could lead to further cost reductions. Use of experts and the efforts to gather current information is commendable. Keep digging into getting comparable information from industry sources, within and outside GT.

PI Response:

Thank you for your comments.

Reviewer 23411

Comment: ADI appears to have a history of performing similar services for other sectors of the energy industry. They have a strong resume and could be a significant resource for the GTO. The work in patent analytics could be of value and should continue to be pursued with possibly a wider net.

PI Response:

Thank you for your comments.

Reviewer 23601

Comment: This project should yield very important and relevant information for the DOE GTO and the Geothermal community. It is focused on determining the LCOE for EGS. This will include establishing the degree of uncertainty in the LCOE, the key cost drivers, and the areas in which cost reduction is possible as well as the expected extent of that cost reduction. EGS is in its very early stages of development. There is a lot of speculation and differing opinions on the

potential LCOE from this technology. This project should provide much clearer insight into this issue. The project has reached out to over 50 experts to seek their knowledge on EGS costs. It appears they have asked for information in sufficient detail to be able to develop a complete LCOE using the DOE GETEM model. They also solicited information from the experts on potential cost savings. This is an excellent approach. It appears the project is taking a well thought through and knowledgeable approach to analyzing potential IGCC/EGS combinations to reduce the LCOE.
The project is also being effective in sharing the knowledge gained from this effort and helping to educate students about Geothermal energy. Both of these are also important to the DOE GTO.

PI Response:

Thank you for your comments.

WEAKNESSES

Reviewer 23444

Comment: Each EGS system is different in its geologic setting and may require individualistic development. It is unclear how this generic analyses cn adequately reflect an individual system. While clumping of data is useful, over generalizations can be misleading. Therefore, some explanation of data utilitity would be helpful. The supply/demand curves for the number of seismic crews appears to be reversed. According to AGI predictions for geoscientists, supply will be about 250,000 short of needed workers in 20 yrs. This analyses overestimates supply of exploration capacity crews (at least those who know geology). Such information on market demand and supply needs to be reevaluated. Educational component was largely lacking.

PI Response:

Thank you for your comments. We will address data handling in greater detail in our reports to DOE. We are re-examining the seismic crews supply / demand forecasts based on your comments.

We should have provided more information on our project's educational component, which is, in fact, very strong as reflected by our partnership with the Pennsylvania State University and the following accomplishments to date:

1. Taught educational modules on geothermal energy to undergraduate Energy Engineering classes at Penn State

2. Taught educational modules on geothermal energy to various schools and colleges in Greater Houston area

3. Presented seminars on geothermal energy industry and challenges to various energy / professional groups

4. Advised a Penn State student research team for their submission to NREL Rio Grande competition; effort resulted in a paper that was presented at Geothermal Research Council Annual Meeting in 2011

5. Advised two University of Texas at Austin MBA student teams on market research and analysis projects pertaining to geothermal industry

6. Advised graduate students and post-doc students on their geothermal energy-related research projects

7. Facilitated research credits for two undergraduate students at Penn State by providing research opportunities

8. Facilitated a geothermal design project for a graduate student team at Penn State

9. Facilitated student team presentations at EnergyPath 2012 Conference

Reviewer 23600

Comment: Not a lot here. Need to be more explicit on the Slide 11 as it is implied that big cost reductions could occur but the slide was too generic to be of any use other than to state that there was value there. The cost ranges (slide 9) seem too narrow and better explanation of why would be of benefit (or could it be an artifact of the statistical methods used?). It was noted that one of the objectives was to compare LCOE with coal and natural gas. It was not shown.

PI Response:

Thank you for your comments, which will be addressed in our reports to DOE as also described in our previous comments.

Reviewer 23411

Comment: ADI's "independent" position may have hindered their ability to provide meaningful insights to the GTO. It does not appear that a significant review of past work was performed and as a result they have repeated efforts previously performed in the program and may have worked from erroneous data (effects of future technologies).

PI Response:

Thank you for your comments. I hope that our previous comments address your concerns.

Reviewer 23601

Comment: The project scenario is for a small EGS facility of only 5 MW. This is much smaller than desirable as seen in the relatively high costs determined in this project. The results would be much more useful if the plant size chosen was 30-50 MW. It is not yet clear what value the Patent Search and Patent Analytics part of this project will have. It appears that the project used both a well drilling cost model and power plant cost model to be able to estimate the LCOE reductions from specific technology improvements in those areas. No details on these models was provided. These models could be very valuable to DOE and the Geothermal community.

PI Response:

Thank you for your comments. I hope that our previous comments address the issues you have raised.

IMPROVEMENTS

Reviewer 23444

Comment: Reevaluate the assumption that a single expensive component is the key driver to cost reduction. Could cost reduction be derived from eliminating several less expensive components? Additionally, the most expensive may or may not be valuable, perhaps it is improving the exploration and understanding of the system that is key, so that other components could be eliminated (exploration was not included). No single factor might be expensive but several in aggregate could reduce cost. Add a web-based educational and outreach component. Could these technologies be linked to GHG emissions as another measure of cost? Publications should include peer-reviewed journals for broader dissemination of information.

PI Response:

Thank you for your comments. We have indeed assessed exploration costs and impacts on LCOE but did not include them in our presentation. However, it will be addressed in our reports to DOE. Our approach and model allows component-wise analyses to facilitate LCOE reductions irrespective of how they are achieved, e.g., by focusing on a single expensive component or through multiple less-expensive components.

Our on-going work is already addressing your other suggestions, i.e. estimating EGS LCOE by monetizing GHG emission reduction credits, communicating our work through peer-reviewed journal publications some of which are currently being drafted, and facilitating outreach through a web site.

Reviewer 23600

Comment: Further cost reduction means: Look into other potential power configurations being reviewed with EGS in other research efforts. This would provide a broader spectrum of cost reduction methods. Must continue to look into means of getting current EGS demo data and also must work to get more information from the Oil and Gas industry, looking at service provider companies like Schlumberger or BakerHughes for relevant data. It would be good to compare the LCOE with coal and natural gas. Besides looking at LCOE, it might be of benefit to look at income margins (revenues – expenses) when comparing with coal and natural gas. It might be worthwhile placing a table in the appendix further explaining slide 11 graphs. In this way, other researchers could see how their work would impact your study.

Questions:

1. Please explain the graphs on Slide 11. How do you propose to get these technologies to mature? What are the barriers and how will these be addressed? Are some being addressed by the current GTO projects?

2. Please explain the process you are using to gather current EGS demo project data and also eliciting input from the O/G industry? Have you gone to the service companies (Schlumberger or BakerHughes)?

3. You noted the project is on schedule. Do you have enough resources and if not, how can the ones you have be better utilized?

4. You showed a reduction in LCOE from ~20 c/kWh to ~19 c/kWh with a number of new technology reductions included. Why did the range narrow and with the small reduction noted? What areas do you see driving the LCOE down materially? Have reductions like you noted been seen in the Oil and Gas industry? How much of this data/analysis is based on actual data?

5. Where is the information comparing the results to coal and natural gas (Task 1)?

6. Now that you are a long way into this project, reflecting back, would you do anything differently?

PI Response:

Thank you for your comments and suggestions, which we will consider addressing through on-going work as indicated in my previous comments. In regard to your questions, please see our comments below:

1. The patent analytics workstream is currently documenting our methodology and results and analyzing them to identify implications for our report to DOE, which will address your suggestions.

2. We have and continue to seek data, expert interviews, and insights from EGS demo project developers, service providers, technology developers, engineering firms, funding agencies, academics, and consultants. We began the process by generating a list of experts that has been continually expanded and refined through interactions with the geothermal community at conferences, DOE meetings, and referrals from DOE, national labs, and other experts. Experts have been interviewed via conference calls and in-person meetings at conferences using structured questionnaires and expert briefs. In addition, we are sourcing data from a wide range of literature sources, including peer-reviewed journals, conference presentations, databases, etc. from both the geothermal and oil and gas industries.

Regarding demonstration projects, we have a linkage with some via our partners. Although most of the demonstration project data is proprietary we are gaining some insights.

3. We evaluate the project schedule each quarter to identify options and strategies to stay in schedule and/or address any issues. We believe that our current resourcing is adequate.

4. As indicated previously, we wanted to use the same x-axis range for both the near- and deep-EGS cases leading to the impression that there is greater certainty for the near-EGS cases. In regard to your other questions, we are currently evaluating learning curves in oil and gas based on actual data and how they may apply to EGS. As part of this effort, we will attempt to understand the oil and gas industry's experience with new technologies to compare them with the cost reducation estimates we have identified for EGS. Our reports to DOE will address these issues in greater detail.

5. We will include it in our report to DOE.

6. In general, we believe that our structured approach and methodology has allowed us to advance this project well. If we had to do it again, we may have considered directly partnering with an EGS demo project developer although such a relationship might have impacted our percieved ability to be independent.

Reviewer 23411

Comment: DOE should consider working with ADI and other entities performing similar efforts to coordinate their work and collaborate more that it appears they have. ADI appears to have real strengths in analytics; a review of these strengths should be made to determine if their capabilities can be used to compliment some of the work where NREL is currently engaged.

PI Response:

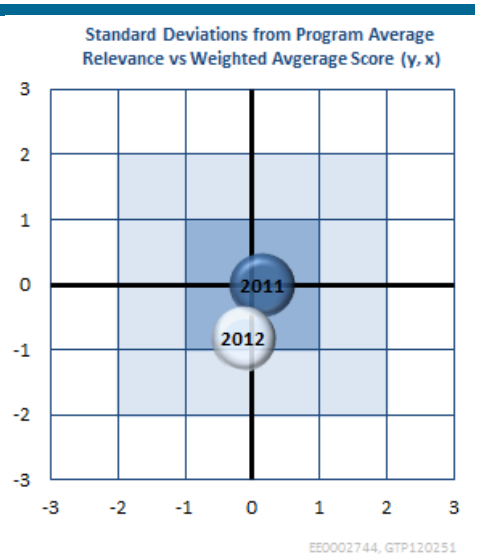
Thank you for your comments. I hope that our previous comments help describe how our work is unique and does not overlap with other projects. We welcome additional opportunites and discussions to facilitate coordination and collaboration with other entities. So far we have actively participated in the DOE-led Geothermal Strategic Planning and Analysis Working Group (GSPAWG), the Peer Reviews, and various conferences.

Reviewer 23601

Comment: It would be better if the project provided more information on the full level of detail they asked for from the experts. It appears that the project used both a well drilling cost model and power plant cost model to be able to estimate the LCOE reductions from specific technology improvements in those areas. No details on these models was provided. These models could be very valuable to DOE and the Geothermal community.

PI Response:

Thank you for your comments. We will consider how to include the additional information you have suggested in our reports to DOE without compromising our confidentiality commitments to experts.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002744
Project: Economic Impact Analysis for EGS
Principal Investigator: Gowda, Varun
Organization: University of Utah
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23444

Score: 3.0

Comment: To increase the use of EGS technologies, economic impacts need to be analyzed and cost analysis completed. Data developed by this project will allow better decision making concerning the economics of geothermal technologies and help the program analyze key elements necessary for commercial deployment of EGS technologies. Tools that evaluate the total cost of the technology as well as its dependencies are being developed to be used not only by DoE but also by industry to inform decision making and strategic planning. This analyses involves primarily downstream costs, estimates for the costs of drilling, well completion, stimulation and plant building and development. Providing the ability to estimate costs required for geothermal development may improve investment in EGS technologies. Given specific inputs, this new model predicts the jobs created which has the potential to overcome market barriers. These impacts and this code represent an advancement over previous modeling programs.

PI Response:

None

Reviewer 23600

Score: 3.0

Comment: The project provides a tool that can compute local job/income impact of an EGS deployment. The impact was previously unknown as data for this industry did not exist. This data will help the GT industry explain the overall community impact when deploying EGS. The project made good progress on its goal of an economic-impact tool but did not show any environmental impacts (a stated purpose and goal). Therefore, the results were not complete. There should also be a comparison with job creation from other types of power production.

PI Response:

None

Reviewer 23411

Score: 1.0

Comment: It is very difficult to assess the relevance of this work. At first blush, one would assume it is valuable to the program and to the geothermal community – however there was no information provided nor was the PI able to respond what the difference was between a $100M geothermal project versus, say a $100M construction project, or hospital, or any other investment. Given there are significant uncertainties in some of the costs that go into the model (e.g., drilling costs) and with the associated lack of examples from other industries, I seriously whether this work has substantive relevance. While I acknowledge I could be wrong, this project is almost over. If it is relevant, it is unclear that the tool will be maintained in the future.

PI Response:

It is hard for the PI to remember all the 428 sector impacts of geothermal investments and the scope of the study never involved hospitals or other investments. Hence, no further justification necessary. The finished tool however should enable stakeholders to assess the detailed impacts. Industry standard consultants and tools are available as a service for interested people to understand hospital and building construction economic impacts.

Reviewer 23601

Score: 2.5

Comment: This project is focused on understanding the costs of EGS and modeling the deployment impact on U.S. economic activity and job growth. Although economic activity and job growth have been key political issues since the start of the recession in the U.S. in 2008, they are not key drivers for the deployment of Geothermal energy. It is good to be able to understand the impact of Geothermal energy deployment on overall economic activity and job growth, but this knowledge will neither advance Geothermal technology nor impact its deployment. As part of this Project EGI has developed EGS well drilling scenarios and worked with its partners to use these to develop EGS well drilling costs. PacifiCorp supplied the power plant information and costs. These aspects of the project were not discussed but may be very valuable to the GTO Program and Geothermal community to improve cost estimates for well drilling and power plants.

PI Response:

Our hope is that the result from this project will provide the policy makers understand the positive economic impacts of EGS and compare and contrast them with other available energy development/generation projects. EGI will continue to host this tool and will make the source code available for the community to futher develop this if required.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23444

Score: 3.0

Comment: To evaluate economic impacts of EGS, the project begins with identifying cost drivers, gathering cost data, compilation of data, data interpretation, and economic impact analysis. System conditions, necessary parameters for evaluation, options for data input into a more complete modeling program are identified. To develop a more robust economic impact analysis requires additional code development, GEC - geothermal economic calculator, specifically designed for geothermal systems. Code development is informed by industry feedback, direct and indirect impacts are incorporated as well as feedbacks between industries and trade. Local and regional factors are included. Once developed, a feasibility test will follow as will outreach and communication. The code development appears to be well-informed and beta testing underway. The code is developed to be OS independent which increases its utility. It is essential that codes be

well documented and assumptions inherent in the modeling be explicitly stated. Flexibility of the software for incorporating new information, updating analyses,etc. is unclear.
PI Response:

No response required

Reviewer 23600

Score: 3.2

Comment: The project was well focused on an EGS-type development, building a customized geothermal industry economic model for Make and Use Tables. This was a rigorous effort and with the results will allow for economic impact quantification on the community of a project. Nothing was shown on environmental barriers or impact so this lessened the impact of the results. Procedurally, the model yielded highly precise output for a project with known uncertainties. Uncertainty analysis should be employed to make the results more robust, yielding a range of outcomes.

PI Response:

Uncertainty analysis can be done on standalone basis. We will embed download to csv and excel feature for further analysis. Direct embedding ca

Reviewer 23411

Score: 1.0

Comment: While I certainly question whether this work is relevant, It appears that the approach taken follows that used in similar assessments for other industries. It is fortunate that conventional geothermal systems were added to the project since that is where the majority of current activity is today. It would be interesting to see a comparison between the economic impact of EGS and conventional geothermal development. It is not clear is what level of detail in the geothermal cost models is required. What is most disappointing is that there is no comparison to other similar industries (O&G development, mining, solar). Did this work really need to be done? No rational and defensible assessment of the need appears to have been performed.

PI Response:

In our opinion this work will immensely benefit the geothermal community, particularly because economic impact estimations are expensive to get done and the generic tool we are building should be useful and will help the community perform such assessments free of cost. While we disagree with the comments above, we recognize the differences in opinion and respect that.

Reviewer 23601

Score: 4.0

Comment: This Project has taken an excellent approach to achieving its objectives. It started by developing the capital and operating costs for EGS utilizing well drilling models from EGI, power plant information from PacifiCorp, and using the INL GETEM model. After gathering the cost data for EGS, the economic impact analysis study involved constructing a model of trade between industries, and the flow of funds between industry, and households to estimate the associated impacts of EGS development. The model takes a given EGS development scenario as its input, and gives as output an

estimated number of total jobs created and economic flows—including those indirectly created because of inter-industry dependencies and feedback between industry, households, and government. The Geothermal Economics Calculator (GEC) tool being created with this study is capable of helping end users (public and the industry) perform region specific economic impact analyses for different geothermal technologies under EGS that will be used for electric power production. This tool will be capable of estimating both direct and indirect economic impacts resulting from EGS deployment.

A particular challenge in estimating the economic impacts of a geothermal power project is that such an industry does not yet exist in the available published Make and Use tables. To remedy this, the availability of detailed cost data makes it possible to create, in effect, a custom geothermal power industry as a weighted combination of the many industries represented in the cost data. To this end, a data "bridge" was created which will link the industries represented in the cost data with the industries as they are classified (by the North American Industry Classification System) in the Make and Use tables. This was an excellent approach to solving this challenging issue.

This Project utilized excellent partners in its efforts.

PI Response:

No response required

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23444

Score: 3.0

Comment: Cost analysis were completed. Cost expenditures for downstream portions of EGS were developed by the project. Substantial code development has been completed and tested. As a proof-of-concept, economic impacts were analyzed for construction and operations of a specific EGS scenario. One-time cost expenditures were calculated for specific aspects of these downstream phases and regional cost and employment impacts estimated. Comparisons of different EGS technologies can be made. The code is currently uploaded to the web and has a GUI interface for ease of use (hosted by EGI). Output results are graphical and numerical. A variety of data is generated related to costs, labor, resources required, etc. Data sharing of models is in excel - not a robust output form nor OS independent. Accomplishments meet milestones.

PI Response:

No response required

Reviewer 23600

Score: 3.5

Comment: Project results for the economic impact were complete and met the project's objectives. No environmental results were shown. Project needs to give results in ranges as there is uncertainty associated with the inputs. To enhance the output, comparisons to economic impact of non-geothermal power plants should be given.

PI Response:

No response required

Reviewer 23411

Score: 2.0

Comment: A working model seems to have been developed and is about ready to go public and it appears they are on task with the proposed effort. With completion of the software they plan on a Utah wide study and to initiate an outreach effort through GRC/GEA. If this effort does prove to be relevant, an explanation and a plan (future costs) for code maintenance would be beneficial.

PI Response:

Minor application maintenance and server upkeep will be handled by EGI but ultimately this tool will rest on NGDS platform and NGDS will be responsible for maintaining the software application and running it.

Reviewer 23601

Score: 3.8

Comment: The Project is doing an excellent job of accomplishing all of its objectives. It has completed gathering the data needed and utilized the GETEM model to develop capital and operating costs for EGS. There is not sufficient detailed information provided to judge the quality of the data gathered and used but the overall cost results presented appear to be reasonable.

The economic impact analysis study involved constructing a model of trade between industries, and the flow of funds between industry, households, and government to estimate associated impacts with EGS development. The model takes a given EGS development scenario as its input, and gives as output an estimated number of total jobs (and income) created—including those indirectly created because of inter-industry dependencies and feedback between industry, households, and government. The Geothermal Economics Calculator (GEC) tool being created with this study is capable of helping end users (public and the industry) perform region specific economic impact analyses for different geothermal technologies under EGS that will be used for electric power production. This tool will be capable of estimating both direct and indirect economic impacts resulting from EGS deployment and is very nearly completed.

PI Response:

No response required

PROJECT MANAGEMENT/COORDINATION

Reviewer 23444

Score: 3.0

Comment: Project phases appear to be on time and within budget. Some tasks have been completed, several are underway, and selected phases in the initial stages. Data sharing is underway. Collaborations are good and have informed original

code development, identified important components necessary for analyses. This suggests that the project is well managed and coordinated.

PI Response:

No response required

Reviewer 23600

Score: 3.0

Comment: Project was well constructed in phases and on time. Future plans need to be augmented with a statistical approach to end results, given the uncertainties surrounding this. Incorporating the environmental results would be beneficial. Environmental results need to be given or dropped from the objectives.

PI Response:

No response required.

Reviewer 23411

Score: 2.0

Comment: The project appears to have been well managed with appropriate outreach to other organizations.

PI Response:

No response required.

Reviewer 23601

Score: 4.0

Comment: This project has been very well managed. All of its objectives are being achieved in a technically sound and timely manner. There were a number of people and organizations involved that all had to be well coordinated in their efforts and support.

PI Response:

No response required

STRENGTHS

Reviewer 23444

Comment: The interaction between code developers and stakeholders is a strength of the project. Developing a code that contains the necessary parameters for evaluation is best informed by the end user. Such collaborations are underway

among industry, academics and national lab personnel. Having a tool to analyze the specific economic costs and impacts of geothermal technologies will facilitate use and better inform decision makers.

PI Response:

No response required

Reviewer 23600

Comment: The creation of the Make and Use tables must be commended. This is a solid accomplishment. The project was well focused on an EGS-type development, building a customized geothermal industry economic model for Make and Use Tables. This was a rigorous effort and with the results will allow for economic impact quantification on the community of a project.

PI Response:

No response required

Reviewer 23411

Comment: If an IE tool is needed for the geothermal industry, then this project will provide one.

PI Response:

No response required

Reviewer 23601

Comment: The economic impact analysis study involved constructing a model of trade between industries, and the flow of funds between industry, households, and government to estimate associated impacts with EGS development. The model takes a given EGS development scenario as its input, and gives as output an estimated number of total jobs (and income) created—including those indirectly created because of inter-industry dependencies and feedback between industry, households, and government. The Geothermal Economics Calculator (GEC) tool being created with this study is capable of helping end users (public and the industry) perform region specific economic impact analyses for different geothermal technologies under EGS that will be used for electric power production. This tool will be capable of estimating both direct and indirect economic impacts resulting from EGS deployment.

As part of this Project EGI has developed EGS well drilling scenarios and worked with its partners to use these to develop EGS well drilling costs. PacifiCorp supplied the power plant information and costs. These aspects of the project were not discussed but may be very valuable to the GTO Program and Geothermal community to improve cost estimates for well drilling and power plants.

This project has been very well managed. All of its objectives are being achieved in a technically sound and timely manner. There were a number of people and organizations involved that all had to be well coordinated in their efforts and support. The approach taken to the project objectives was excellent

PI Response:

No response required

WEAKNESSES

Reviewer 23444

Comment: Once the code is developed, it appears to be static with no plan for continued maintenance, bug fixes, updates, changes to tax codes/incentives, archiving, etc. Because of the high cost of code development, a robust plan for maintenance and updates needs to be included for maximum usage. The code needs to be well documented, including data sources and assumptions used in building algorithms. A users-manual should accompany the code. Outreach and communication should incorporate web-based approaches so that the widest audience is informed.

PI Response:

As mentioned in our scope of work we will develop a user manual.

Reviewer 23600

Comment: The lack of showing environmental information (as stated goal) and being too precise on income and jobs created were drawbacks. The project did not show a comparison of jobs/income created with GT and those same parameters for other types of power plants. This would place the results in context.

PI Response:

CO2 emissions offset as a result of comparable geothermal development is being build and will be integrated into the final release.

Reviewer 23411

Comment: This should be clear from my earlier comments - no hard evidence is provided that such a tool is needed.

PI Response:

No response required

Reviewer 23601

Comment: This project is focused on modeling and understanding the costs of EGS and its deployment impact on U.S. economic activity and jib growth. Although economic activity and job growth have been key political issues since the start of the recession in the U.S. in 2008, they are not key drivers for the deployment of Geothermal energy. It is good to be able to understand the impact of Geothermal energy deployment on overall economic activity and job growth, but this knowledge will neither advance Geothermal technology nor impact its deployment. The Project developed a web based version of the INL GETEM model. GETEM is a very valuable cost model for the Geothermal industry. However, the model continues to be improved over time and the DOE makes it available as an Excel model on its website. It is not clear that the web based version developed in this project will have value.

PI Response:

Web based model will help us sytematically simplify the number of inputs required for a non-GETEM friendly user to use the tool.

IMPROVEMENTS

Reviewer 23444

Comment: Develop a plan for continued code maintenance, bug fixes, updates, changes to tax codes/incentives, archiving, etc. Make sure that the code is well documented, including data sources and assumptions used in building algorithms. Develop a users-manual to accompany the code and one that includes the documentation and sourcing. Would it be possible to incorporate or link environmental impacts (GHG) into this analysis?

PI Response:

GHG is being incorporated and will be available for the final release.

Reviewer 23600

Comment: Type or Paste Text Here

The model yielded highly precise output for a project with known uncertainties. Uncertainty analysis should be employed to make the results more robust, yielding a range of outcomes. Dealing in ranges for the output is a must for this type of analysis. It is suggested that comparisons be made with non-GT power plant job/income creation.

Questions:

1. What are the environmental results from your study (item 3 on the project schedule)?

2. Have you considered comparing the job/income growth of EGS to that of other power generating plant types? How similar or dissimilar are the results?

3. Is the Make/Use table regionally specific in nature? How current is the data being used? Have you received industry support for gathering the data?

4. How does your environmental work compare to that of the “Life Cycle Analysis of Geothermal Systems” emission work?

5. How does the cost data compare with that used in “Estimation and Analysis of Life cycle Costs of Baseline EGS”?

6. Since you used publicly sourced data, how does it compare with actual EGS plants? Have you obtained any real data from EGS plants?

7. Your model gives very precise output for the given inputs. The inputs, though, have uncertainty associated with them. Wouldn’t it be better to talk in ranges of job/income to a region versus values to many significant figures?

8. What future work, that you have uncovered, is needed to enhance your study?

9. What are your largest uncertainties associated with this work and how are you overcoming them or quantifying them?

PI Response:

1. The environmental results will be the GHG offsets and the models are currently being built and will be released shortly.
2. EGS plants will have higher job/income growth as per our observations
3. Make/Use table is regionally specific, the data is the most current released by Bureau of Economic Analysis (BEA) and they update that every 10yrs. There has been considerable industry support.
4. Our environmental work will only take into account GHG offsets as a result of geothermal development and limit the scope to that only.
5. Cost data has been complied from various sources but we haven't compared with "Estimation of Lifecycle costs of baseline EGS". We have shared our data with that project.
6. There are no EGS plants in the US and hence no data has been obtained from real plants. EGS well data is however incorporated.
7. Thinking in ranges is always good but to add the packages that enable us to do (statistical software), license limitations exist
8. None at this time (real EGS plant data when available in the US will help refine our assumption further)
9. Plant costs - we have no way of overcoming this challenge as the entire industry is struggling with it. Unless a few EGS plants are built around in the US such challenges will continue to exist.

Reviewer 23411

Comment: Tis project is just about over. Little budget or time available to change but I would suggest that a robust description of what this tool will do relative to other tools is needed.

PI Response:

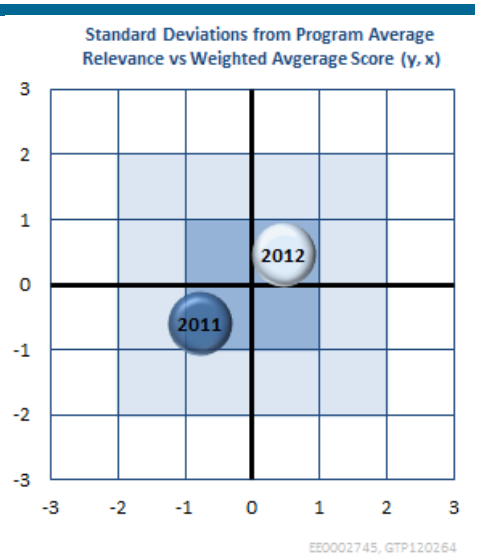
The final report will have this.

Reviewer 23601

Comment: It would be very valuable if this Project makes available all the data and information generated to estimate the cost of EGS and its source.

PI Response:

We will make all the data, assumtions, models generated and the source code available along with the final report. Being part of a University, we highly value in dessiminating the knowledge and data generated through this project effort for the purpose of education.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002745
Project: Analysis of Low Temperature Utilization of Geothermal Resources
Principal Investigator: Anderson, Brian
Organization: West Virginia University
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23444

Score: 4.0

Comment: To increase the potential use of geothermal energy as a portion of the US's energy portfolio, more emphasis must be placed on Low Temperature technologies and applications. To date, the primary use of EGS is for electricity generation. This project focuses on EGS applications beyond traditional electricity generation to expand and improve markets while reducing GHG emissions. To evaluate the use and potential application, a comprehensive technological and economic analysis is needed to understand the future markets and applications. This study seeks to fill a knowledge gap in this realm, provide data to overcome potential market barriers by analyzing the cost structure, and showcase and demonstrate the innovative technological utilization of Low Temperature geothermal resources for a wider variety of energy needs while reducing GHG emissions. Data can then be upscaled to develop regional models of low T geothermal utilization.

PI Response:

Reviewer 23600

Score: 3.4

Comment: Project is midway through its projects. It has and continues to address the GTO mission on hydrothermal systems, investigating the low temperature range with innovative schemes. The range of options reviewed is good and ranges of output costs/mmbtu are good. The project is clearly focused on the market aspects of this underutilized resource.

PI Response:

Reviewer 23411

Score: 3.0

Comment: Low temperature resources are an important part of the geothermal energy portfolio and this project is providing methodologies and insights in the exploitation of the resources. By their nature, geothermal resources tend to

be local and while I applaud the effort to establish a "national map", I remain a bit skeptical that such a map will have significant impact. However, the effort is worthwhile and can provide a general sense of the techno-economic viability of low temperature resources using population density, energy costs, and assume subsurface conditions. What is particularly valuable in this effort are the site specific assessments that are being performed. The site-specific assessments provide others valuable examples of for future local evaluations.

PI Response:

Reviewer 23601

Score: 4.0

Comment: This Project is aimed at determining if there is any economic and/or environmental advantages to utilizing low temperature EGS resources as a source of energy for direct heating, electricity generation or in combination with biomass for co-generation or hydrogen production. There is significant low temperature Geothermal resource in the Eastern half of the U.S. It is important to understand if Geothermal energy derived from this resource can be economical. This Project should provide a comprehensive answer to this issue. The Project is taking a rigorous approach to the analysis of the most promising potential uses of low temperature EGS resources. This includes detailed ASPEN modeling of above surface operations and state of the art modeling of below surface reservoirs and reservoir performance. These approaches should have broader application for Geothermal Energy analyses beyond low temperature EGS.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23444

Score: 3.0

Comment: The primary approach is to complete a comprehensive analyses of four case studies currently using Low Temperature geothermal sources. Each of the four studies identifies a different use for low temperature sources. A geologic framework was developed for each of the case studies to be used as input for modeling. Modeling studies are used for various techno-economic aspects of the overall geothermal system to provide the basis for evaluation. Process modeling uses Aspen Plus. Reservoir and subsurface modeling (using TOUGH2 and developed code) provided the framework for likely heat and flow scenarios based on simplified geology and wellbore geometries. These studies were fed into process modeling of the specific case studies which were then used for economic models based on GETEM and MiT EGS data and modeling. Resource assessment maps using ArcGIS info. All modeling approaches are industry standard programs. To upscale, climate, resource potential and population density maps were develop to analyze likely regions as most effective targets.

Geothermal systems are inherently geologic and driven by fluids as well as heat. The geologic description of the field sites for the case studies seem simplified. Numerous assumptions were made in the reservoir models without an apparent understanding of their impact on the resulting models. Modeling studies could have been more rigorous with respect to including the necessary components of the geology, specifically fluids. Beware of control volume methods that deviate

from orthogonal geometries and understand the impact on the accuracy of the modeling results. The quality of the initial geologic simulations is unclear. Models inform models, so identifying the uncertainties inherent in the models is needed. The approach to assessment using case studies of four different geothermal systems is good. Case studies will be upscaled to develop a regionalized model of low T geothermal resources. Difficult to evaluate the reliability of upscaling.

PI Response:

Reviewer 23600

Score: 3.2

Comment: The project is focused and approach will meet its objectives. Significant progress has already been made on a couple of the objectives and a lined-out scope of future work is known. It would be beneficial to ensure that the following are in the final work phase: ranges of outcomes, consideration of specific locale issues to implement this type of project, and current competition costs of energy. Assessments of how to make GT use more competitive should be given.

PI Response:

Reviewer 23411

Score: 3.0

Comment: Overall, the approach appears disciplined and well thought out. In an attempt to provide a comprehensive assessment of the Low Temperature potential, the project team has taken on a monster task. It is not completely clear what resolution the "map" will be, but they are making a noble effort to develop a tool for this resource. While it is somewhat straightforward how the surface based parameters will be determined, I am suspicious that that parametric modeling being performed will quantify resource parameters needed to be useful for site-specific applications. I can't offer a better approach, but appropriate notations of the uncertainties should be included in the final product. The use of site-specific examples being investigated (e.g, WVU heating system) are valuable example to other but also illustrate the need to understand site-specific conditions.

PI Response:

Reviewer 23601

Score: 3.5

Comment: Overall the Project is taking an excellent approach to achieve its objective of determining if there is any economic and/or environmental advantages to utilizing low temperature EGS resources as a source of energy. The approach is comprehensive and rigorous and includes:
- Designing, assessing, and evaluating innovative uses for geothermal-produced water such as:
  Utilization of geothermal in district heating for community redevelopment projects,
  Hybrid biomass-geothermal cogeneration of electricity and district heating

Efficiency improvements to the pretreatment of carbon-based fuels, such as coal and/or biomass drying.
Use of low temperature geothermal resources for electricity production utilizing an ORC cycle.
- Utilizing Four Specific Case Studies
A retrofit and expansion to a district heating system in a community redevelopment project at West Virginia University
A hybrid biomass-geothermal co-firing cogeneration and district heating system at Cornell University
A system for cellulosic biomass gasification and utilization at Iowa State University
A geothermal system (direct-use or cogen) within the West Virginia 'hotspot'
- The results from the four case studies will then be generalized for use on a regional basis at non-specific sites.
- The best use for low temperature EGS will then be integrated into regional energy demands based on population density and available Geothermal resources.
- Detailed process modeling using Aspen Plus for surface plant evaluation
- Subsurface modeling using TOUGH2 and WVU's wellbore simulator
- Economic modeling using GETEM and MIT EGS model
- Geographic deployment models using ArcGIS

The Project has put an excellent team of experts together from WVA U., Cornell U. Iowa State U., and NREL. The addition of some people from the Geothermal Industry to help vet the inputs and results in the cost modeling would be beneficial.

In the final stages of the Project, the plan includes developing modification of the SEDS, ReEDS and NEMS models to incorporate Low Temperature geothermal resources. This would require a great deal of effort as well as generalization of the geothermal system costs for the more promising systems studied. This part of the Project will be difficult at best and the generalization in costs required may make it inaccurate to the point of being misleading.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23444

Score: 4.0

Comment: To analyze supply and demand for low T geothermal systems and the likely target areas for deployment requires assessing climatic regimes, population density and resource availability. For a first order approximation, the team developed US maps for climate, geothermal resource potential, and population density to serve as basemaps for low T geothermal development. Such a visually based assessment provides a valuable result for future development and study.

Accomplishments include results from the first case study for WVA heat and chilling system using Aspen Plus. A large number of subsurface modeling studies have been completed for a wide range of parameters. Sensitivity analyses were done for specific rock properties and pumping scenarios. Pure H2O was included as the only fluid. Effects of fluid composition are not included. Benchmarking for TOUGH2 was completed by comparison with 1D analytical solutions - but this does not account for variations with respect to control volumes. Aspen models for geothermal electric power generation cover a range of working fluids and pumping configurations. The second case study for biomass use has been largely completed. These studies can then be used as a basis to evaluate regional upscaling of these uses for low-T geothermal energy production.

Overall there appears to be excellent progress in modeling, simulations and data aggregation.

PI Response:

Reviewer 23600

Score: 3.4

Comment: Project has results for some objectives. The WVU study is done with a range of Levelized Energy costs given versus current energy costs. This is good and will give other regions/utilities something to consider when looking for heating/cooling cost reductions. The biomass processing using steam is reasonably competitive. The more real-life results can be given, the better. It is recommended that you output ranges of costs in your regional study to provide context to results.

PI Response:

Reviewer 23411

Score: 3.0

Comment: While it is not completely clear how all of the data will be fused to develop a low temperature geothermal cost model/map, the accomplishments to date seem to be building to the generalization of low temperature geothermal costs on a regional scale. The results of the WVU case study provide a good model for future evaluations.

PI Response:

Reviewer 23601

Score: 3.3

Comment: The Project has accomplished a great deal and the results generated to date should be very valuable. It is 1 QTR behind the original 3 yr schedule but only because the students were not available during the 1st QTR of the project. The accomplishments to date include:
- A feasibility analysis of the WVU case study using both energetic and economic analyses to assess scenarios of the potential integration of direct geothermal heating energy has been completed. Process simulations were performed using Aspen Plus to simulate the steam distribution system based on the current distribution pipeline on the WVU campus. Based on updated drilling costs in the Appalachian Basin using the Joint Association Survey Drilling Costs for 2009, the cost for direct-use geothermal on the WVU campus would be between $5.30-$12.72/MMBtu depending on the flow rate obtained from the subsurface EGS system and the level of retrofit necessary to equip the campus with the geofluid distribution system.

- To provide the regional and national supply curves with realistic reservoir data (wellbore and reservoir pressure drop, temperature decline, and thermal breakthrough) for various geologic systems, a sensitivity analysis was performed using TOUGH2 and a database of possible reservoir scenarios was built.
The various reservoir scenarios were designed to accommodate varying sizes of Low Temperature geothermal, direct-use systems and include doublet, triplet, and quadruplet configurations. These varying wellfield system sizes are designed to provide geofluid flow to various sizes of population centers. Approximately 600 reservoir simulations have been performed for the three different wellfield designs.
- A techno-economic study of geothermal energy utilization in biorefineries was conducted using ASPEN Plus and corresponding economic analysis tools. The biorefinery is based on a gasification platform to produce synthesis gas, which in turn is synthesized to produce liquid transportation fuels. Geothermal energy is used for biomass drying as well as pre-heating in a number of unit operations. Two studies have been completed for geothermal utilization scenarios for biomass hybrid systems.Geothermal energy is used for gasification and steam-methane reforming instead of purchased steam. The price of the transportation fuels obtained from the present economic analysis indicates that geothermal steam can be used as a substitute for the purchased steam. De-centralized Biomass Drying: In this scenario, geothermal energy is used to dry biomass instead of combusting char to produce the process steam. This results in decreased greenhouse gas emissions and allows for extra revenue generation from the sale of biochar.
- Models of subcritical and supercritical ORC for power generation were developed using Aspen Plus V7.0 simulation software. The turbine inlet and outlet pressures have been optimized for each configuration of the power plant as well as a range of geothermal fluid and ambient air temperatures. A wide range of 25 working fluids was considered in this study.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23444

Score: 4.0

Comment: Project communication appears excellent using a variety of technologies including web-based approaches and in person meetings. This robust and multidimensional approach keeps the participants on schedule, highlights areas of needs, and assures that the participants interact and are 'all on the same page'. The flow chart highlights the clear division of duties and the projection coordination for the four case studies. The project is on schedule for technical advances and on budget. Coordination appears to be highly successful.

PI Response:

Reviewer 23600

Score: 3.2

Comment: Project management is good and running well now. Good use of meetings and collaboration between the project’s participants. Future plans are well explained.

PI Response:

Reviewer 23411

Score: 3.0

Comment: The project is appears well managed and coordinated among a number of partners. Like many university-based efforts, they are subject to the availability of students but they seem to be moving forward. However, I am concerned that with 34% of the budget remaining they will not be able to complete the work on 12/31/12 as shown in their slide pack. I assume a no cost extension is being planned.

PI Response:

Reviewer 23601

Score: 4.0

Comment: This project has been very well managed. All of its objectives are being achieved in a technically sound and timely manner. There were a number of people and organizations involved that all had to be well coordinated in their efforts and support. Project management includes regularly-scheduled webinars with rotating presentation schedules, yearly (at least) in-person meetings, working subgroups meeting (virtually) more frequently, and internal data-sharing via a "wiki"-style project site.

PI Response:

STRENGTHS

Reviewer 23444

Comment: The use of case studies as a basis for evaluation of low-T geothermal resources and their potential for upscaling is a unique and strong aspect of this work. Such an evaluation, based on currently used technologies, provides more confidence in modeling the complete system as well as upscaling of the technologies to regional settings. The comprehensive approach of technological and economic analyses strengthens the work and the objectives.

PI Response:

Reviewer 23600

Comment: It has and continues to address the GTO mission on hydrothermal systems, investigating the low temperature range with innovative schemes. The range of options reviewed is good and ranges of output costs/mmbtu are good. The

project is focused and approach will meet its objectives. Significant progress has already been made on a couple of the objectives and a lined-out scope of future work is known. Good project management.

PI Response:

Reviewer 23411

Comment: The research team is strong and passionate about the topic. This is may result in a valuable tool for the community.

PI Response:

Reviewer 23601

Comment: This Project is aimed at determining if there is any economic and/or environmental advantages to utilizing low temperature EGS resources as a source of energy. There is significant low temperature Geothermal resource in the Eastern half of the U.S. It is important to understand if Geothermal energy derived from this resource can be economical and or a significant GHG mitigation strategy. This Project could provide a comprehensive answer to this issue. The Project is taking a rigorous approach to the analysis of the most promising potential uses of low temperature EGS resources. This includes detailed ASPEN modeling of above surface operations and state of the art modeling of below surface reservoirs and reservoir performance. These approaches should have broader application for Geothermal Energy analyses beyond low temperature EGS. Overall the Project is taking an excellent approach to achieve its objective of determining if there is any economic and/or environmental advantages to utilizing low temperature EGS resources as a source of energy. The approach is both comprehensive and rigorous. The Project has accomplished a great deal and the results generated should be very valuable. This project has been very well managed. All of its objectives are being achieved in a technically sound and timely manner. There were a number of people and organizations involved that all had to be well coordinated in their efforts and support.

PI Response:

WEAKNESSES

Reviewer 23444

Comment: From the data presented, the geologic subsurface models appears to be lacking in the actual geology. Fluid compositions control many of the flow and thermal parameters, yet those are no included in the analyses. While important to benchmark a code, 1D analytical solutions cannot assure the accuracy of control volume codes for flow and transport. However, TOUGH is an industry standard.

PI Response:

Reviewer 23600

Comment: I am concerned about them getting the work done within the project schedule. It was noted that the full potential of LT GT energy utilization would be investigated. It would be good to state why these cases were picked and how they bracket the full potential.

PI Response:

Reviewer 23411

Comment: Not clear how refined the final resource model will be in the end. The research team needs to ensure that the final "model" contains the appropriate caveats to ensure that it is used in a realistic and appropriate manner.

PI Response:

Reviewer 23601

Comment: The addition of some people from the Geothermal Industry to help vet the inputs and results in the cost modeling would be beneficial. In the final stages of the Project, the plan includes developing modification of the SEDS, ReEDS and NEMS models to incorporate Low Temperature geothermal resources. This would require a great deal of effort as well as generalization of the geothermal system costs for the more promising systems studied. This part of the Project will be difficult at best and the generalization in costs required may make it inaccurate to the point of being mis-leading.

PI Response:

IMPROVEMENTS

Reviewer 23444

Comment: Subsurface modeling should incorporate more realistic geology for the regions being modeled. Fluid compositions control flow and transport and could easily be evaluated. Are the fluids in WVU H2O-rich? Perhaps seeking the expertise of a geologist would be beneficial and improve the models developed for subsurface geology. Have any 3D models been run for the subsurface reservoirs being modeled? How is the quality of the simulations being evaluated? This is an excellent study. It would be nice to link it (to GHG emissions (or quantify emissions) for comparative purposes, although this may be beyond the scope of the current project.

PI Response:

Reviewer 23600

Comment: It would be beneficial to ensure that the following are in the final work phase: ranges of outcomes, consideration of specific locale issues to implement this type of project, and current competition costs of energy. Assessments of how to make GT use more competitive should be given. It is recommended that you output ranges of costs in your regional study to provide context to results. The project's conclusions would be bolstered if LT GT implemented projects in various locales were linked to it.

Questions:

1. Are you sure you are going to get all the work done? Do you need more staff?

2. You note that this project is to provide a comprehensive assessment of the full potential of LT GT energy utilization. How do you know you have provided the full potential? Did you solicit utilization methods from colleagues and industry? What is not being considered and why?

3. Besides lower cost benefits, what other barriers are there that keep this energy source from being used?

4. The WVU case study yielded a range of Levelized Energy Costs. What caused the range and how do you see the range being impacted by regionally specific issues?

5. The reservoir simulations yielded nearly radial results. Are there cases where rock heterogeneities cause premature breakthrough/cooling of the reservoir?

6. What were the results of the Aspen model for geothermal electric power generation?

7. What methods would you suggest be investigated to lower the cost of LT GT uses? In your study, did you assume some exploration wells were unsuccessful, causing the well cost to go up? Were emissions reduced such that this would be a noticeable benefit from using LT GT?

8. Have you implemented the WVU or Cornell feasibility studies? If not, why not?

9. How has this study been received by the GT and power industries in your areas?

10. How do the risks associated with LT GT reservoirs compare with other types of GT reservoirs?

11. What future work, that you have uncovered, is needed to enhance your study?

12. What are your largest uncertainties associated with this work and how are you overcoming them or quantifying them?

PI Response:

Reviewer 23411

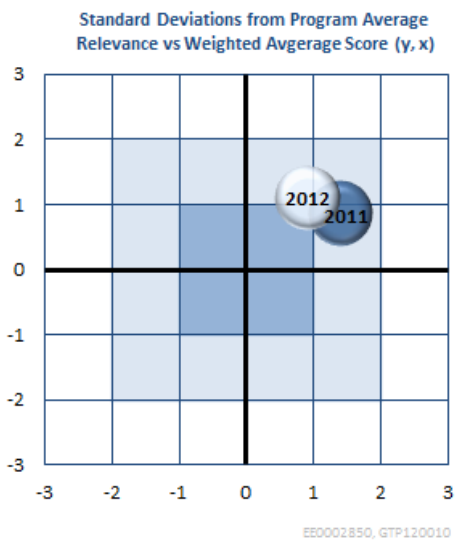
Comment: See above comments.

PI Response:

Reviewer 23601

Comment: The addition of some people from the Geothermal Industry to help vet the inputs and results in the cost modeling would be beneficial. In the final stages of the Project, the plan includes developing modification of the SEDS, ReEDS and NEMS models to incorporate Low Temperature geothermal resources. This would require a great deal of effort as well as generalization of the geothermal system costs for the more promising systems studied. This part of the Project will be difficult at best and the generalization in costs required may make it inaccurate to the point of being mis-leading. Consider deleting this part of the effort.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002850
Project: State Geological Survey Contributions to NGDS Data Development, Collection and Maintenance
Principal Investigator: Allison, Lee
Organization: Arizona Geological Survey
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23437

Score: 4.0

Comment: This project is collecting a treasure trove of data assets from all of the state geological surveys. This is a very ambitious objective and the resulting collection of information assets - made available through an open information system - will contribute significantly to the set of knowledge needed to accomplish a primary NGDS design objective: to drive down the overall risk of geothermal development by making information available to those that need it, when they need it. The information asset collection is already impressively large and increasing in size rapidly. It is being made available on line as the assets come in, and appears to already be adding value to various geothermal development efforts.

PI Response:

Thank you for these comments; due to the scientific rigor with which the work plans and deliverables from each of the data providers (subcontractors) are reviewed by an external Science Advisory Board, we feel that the data collected will benefit the GTO's goal of reducing the overall risk of geothermal exploration.

Reviewer 23638

Score: 4.0

Comment: This project will provide access to a wide range of geologic, geochemical, and geophysical data that have been collected by geological surveys in all 50 states. To date, hundreds of data sets and over a million records are on line or in the process of review. Once completed, this system will provide the user with the ability to search and download a wide range of geothermally relevant data for any area of interest. One key aspect of the system that remains to be demonstrated is what resources will be needed to maintain and update the data network after the project end date. A sustainability plan is still being developed. A number of data content templates have been developed to help standardize data submissions. A beta version of an access portal with limited search capabilities has been developed. This web-based framework with access to different data nodes, when integrated with the NGDS, will provide an impressive array of geoscience data that can be accessed and utilized by the geothermal community for exploration and development activities.

PI Response:

Thank you. We agree that one of the most important aspects of this project will be the data and system maintenance and sustainability plan. Initial discussions with data providers, hub nodes, and NGDS participants have commenced. A formal hub workshop will take place in September to discuss mirroring and back-up issues associated with the data

system. Additionally, we will be working with the NGDS Design-Test project to provide all data providers with a data maintenance plan and overall network sustainability plan.
Reviewer 23640

Score: 4.0

Comment: The relevance of this project to the geothermal programs larger goals is clear. State level data discovery, access and cataloging/tagging are crucial to the larger NGDS goals. This project's impact on the interoperability of information and data is clear and it continues to improve in all areas.

PI Response:

Thank you, we too feel that this project is a succussful case study of data interoperability from multiple data providers and hope that the success of this project leads to a new paradigm in data management. Our whole team is delighted with the positive feedback from the reviewers and will continue to strive to meet or exceed expectations.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23437

Score: 3.5

Comment: The approach for acquiring data appears to be exemplary. A huge amount of work has gone into developing procedures for data acquisition and formats for data submission. It appears this has been accomplished with a significant degree of collaboration, both with the funded project participants (the state surveys) and with external groups such as the other NGDS-related project teams. Inclusion of unexpected participants - such as the Western Regional Partnership - is a welcome bonus and is a signal that the team's approach is attractive in a broader context. The only concern at this point is that a significant amount of system development work is needed to manage the incoming information assets. The team indicates that there have been some issues maintaining qualified staff support to complete this development work. Nevertheless, the team has produced an impressive information management and visualization capability in spite of these staffing issues.

PI Response:

While there has been a significant amount of system development work needed to manage incoming information assets we feel that this process is already simplifying as data providers (State Geological Surveys) become trained in data management and tools for automating data registration become easier. We are adding tutorials and training materials as the project matures, that provide a growing set of resources to assist both existing and new data providers.

Collaboration with external groups is one of the most exciting and rewarding components of the project. It is allowing us to expand the project scope and deliverables, leverage additional resources, and test and validate our technical and business models. This approach is helping ensure that NGDS will be part of the growing national and global cyberinfrastructure and compatible with initiatives such as the White House's Big Data and Digital Government programs, as well as compatible efforts across the private sector.

Hiring and maintaining staff has been a difficult component for us. We believe that the issue arises from the unique skill set required, that is, the combination of the geoscientist and the computer scientist. We hired highly skilled IT professionals at the start but a number of them were not challenged by adapting or deploying existing technology. We

have had great success in hiring recent geoscience graduates with some computer and data management skills. The area that we had difficulty with (primarily at the onset) is skilled labor, which has been attracted to higher wages in the private sector.

Reviewer 23638

Score: 4.0

Comment: The project has developed a federated catalog of distributed geothermally relevant resources derived from the geological surveys in all 50 states using USGIN. A coordinated effort has developed a series of standardized templates to guide data submissions using a consistent set of metadata. These templates were developed based on community standards/models and have been reviewed by the project's technical working group. A beta version of the user interface now available, and will be improved based on user feedback. It is not clear who has used the system to date - this might help in identifying groups who have not used the system, either due to lack of knowledge that the system is now available, difficulties in accessing data through the portal, or that data that is wanted has yet to be uploaded to the system. A great deal of outreach has been conducted to educate the participating geologic surveys about the system (to guide them in the data submittal phase) and to potential users of the system. Analysis tools for evaluating data have yet to be developed. The review process does not include an analysis of data quality - this will be up to the groups submitting the data and to the data users.

PI Response:

We will continue to engage the user community at trade shows, technical meetings and events and implement these suggestions in our user interface. At this time, the system has primarily been adopted by those uploading data into the system since a fully functioning user interface is still in development. Based on community engagement at events, end users are excited about the possibility of finding geoscience and land-use data in one location for an initial review of geothermal sites.

We addressed the reliability of the data (i.e., QA/QC) to some extent in the reply to last year's Peer Review comments also noting that as long as we are funding organizations we can require them to meet certain standards. But as the NGDS starts linking additional, volunteered data and services, new mechanisms are required to provide users effective tools and procedures to identify data reliability and measures to promote improvements. As we also noted, numerous other groups and network developers are struggling with these issues. We are developing formal and informal relations with these others to 1. Learn from them, and 2. Promulgate more cross-disciplinary standards and protocols on data reliability.

The issue of validation of data (QA/QC - quality assurance/quality control) is a huge, complex topic that extends well beyond the scope of this project and is being dealt with by communities in the data management and library science fields as well as by the domain science fields. We are currently negotiating to join the NSF-funded DataONE system as a member node, which will partner us with a leading national team that is investing significant resources into data quality issues.

Meanwhile, the State Geological Survey contributions to our project are undergoing extensive QA/QC prior to submission to the system. As long as AZGS is project manager and is providing funding for the project to sub recipients all sub recipients are required to submit data in predefined and peer reviewed data templates; some templates are already industry standards, others could become industry standards as more and more data are captured within the template. Some data validation is electronic, particularly data associated with the metadata catalog, the mechanisms of which are discussed below. However, some data resists automation and requires manual review. Currently, data templates submitted to AZGS for review are processed by skilled geoscientists to identify extraneous or misplaced data. If such data are found, the data set is returned to the author for correction or validation. Upon completion of the funded portion of the project,

AZGS intends to implement a peer review process, such as crowd-sourced quality ratings, on the contributed data, which will allow users to evaluate and rate data, provide feedback to data providers, and create pressure for data providers to meet higher standards. This is more in keeping with the nature of the scientific process as it currently exists.

Current Metadata Validation Procedures:

In order for the U.S. Geosciences Information Network (USGIN) metadata catalog, which is being implemented for NGDS, to be successful, verification that the metadata records are of good quality is important. There are many levels on which a record may be determined to be good or bad, and there are currently thousands of records that require this kind of validation procedure. In order to do this, we have developed a simple, Python-based tool for metadata validation. The tool is already a standard part of some of our cataloging workflows, and in the near future will be implemented more systematically.

After determining whether or not any XML document (including metadata records) is syntactically correct, the first step at determining the document's quality is schema validation: are all elements and attributes that should be there present, and are they in the right places within the document? ISO 19139 provides a well-defined schema to accomplish this.

In addition, we have defined our own USGIN-profile for ISO 19139 which adds some additional rules on how we want metadata to be structured in order to work in the system. Some of these rules are difficult to test using simple XML-schema validation. Examples of these rules include situations where at least one element from some set should be present, where we want to insure that the content of a particular element is valid, or where our profile requires an element's presence that the default ISO 19139 schema does not require. For example:

- Contact information must contain at least one of: email address, phone number, or mailing address
- Metadata standard must be identified as ISO-NAP-USGIN
- If distribution information is provided, a distribution format must be presented

These are the types of rules that our Python-based validation approach allows us to check for. At present, the tool allows us to define a number of different types of rules:

1. Exists Rules: Check if a particular XPath exists.

2. Valid URL Rules: Check if a URL provided in the document is valid (i.e. works as it should)

3. Value in List Rules: Checks if the value at a given XPath is contained in some predefined list. For example these rules can check if the language code given for a document is valid.

4. One of a Set Rules: Checks that at least one of a set of XPaths exists in the document.

5. Content Matches Regular Expression Rules: Checks that the value at a given XPath matches some regular expression. This allows us to do things like check if dates are formatted correctly, or that a field which should contain a phone number does not contain any letters.

6. Conditional Rules: Allows "chaining" of the above defined rules. If one rule is satisfied, then another has to be satisfied.

Based on these six classes of rules, we can begin to define a set of rules that goes further than schema validation can towards checking a metadata document's quality. However, some things are still difficult to assess in an automated fashion. For example, Content Matches Regular Expression rule may be able to check that a metadata record's abstract has at least 50 characters in it, but it cannot verify that the text is grammatically correct. Similarly a Valid URL Rule may be able to check that a given URL resolves to an actual internet resource, but it cannot insure that the linked resource has any relevance to the metadata record itself.

For these types of issues, it is difficult to replace manual inspection, and as a result it is still an integral part of our cataloging process. As we continue to expand our Python-based rule set and integrate it into our various metadata collection processes, we hope to accomplish a significant amount of quality-control without the need for record-by-record visual inspection.

Reviewer 23640

Score: 3.0

Comment: Limited Federated catalogue leveraging CSW services is a strong system supporting the need for a data system. True data/catalog federation is preferred, but the USGIN solution approach is a solid step in the right direction. The AZGS project has worked to bring large amounts of data into their system, from across all states.

PI Response:

The current catalog system is still operating from a single node. We have been working with the USGS to deploy another catalog node based on the same CSW service and metadata profile, as well as in discussions with the BSU developers over the last year in efforts to get multiple catalog nodes operating. These efforts are near fruition, at which point we will begin to explore and evaluate various approaches to federation as the system matures.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23437

Score: 4.0

Comment: This project has accomplished much. There is a large and growing collection of information assets acquired from the participating states; the incoming assets are being assessed and incorporated via a quality process; the assets, once acquired, are being managed and visualized via a capable information system. Because the information is being made available as it is incorporated, it appears it is already proving valuable to others outside of this project. All indications are that the project will continue to meet project and technical objectives.

PI Response:

Thank you, we are excited about the prospects for engaging the geothermal community further as more data becomes registered in the catalog and a user friendly interface is developed.

Reviewer 23638

Score: 3.0

Comment: The project has uploaded an impressive amount of data that has been submitted by a large number of team members representing all 50 states. A web tool with a map allows for easy tracking of the progress of data submission for a range of data types for each state - in addition, a summary report for each state can be accessed. The project is a bit behind schedule due to delays in developing contracts with the many participating partners - a no-cost extension will allow the project to be completed by the revised project end date. In addition to submitting new data, data gaps that were identified at the start of the project were used to target specific field projects to provide new data to fill in these gaps. A beta version of a user interface has been developed and is being tested and improved - this was not part of the original scope of the project. This interface is a bit challenging to use in its current format, as it is a bit challenging to access, download, and display the data. It is not clear how extensive the search engine is for the available database, i.e., does it only search on terms listed in the metadata categories, or can it conduct a more detailed search. For example, I typed in the search term "Newberry", and got a few hits on wells named "Newberry", but did not get any information on geothermal data related to the Newberry volcanic system in Oregon. When I did a search of geothermal data available for Oregon, I was able to find in the flat files thermal spring data for the Newberry area - these did not pop up using the search term. It will be critical to have a comprehensive search capability to enable the user to obtain all relevant data, preferably prioritized in a ranked list that provides the most relevant data at the top of the list. This search ability may come out of the BSU portion of the NGDS.

PI Response:

We have received notice from DOE that our no-cost extension has been accepted. This will help provide all subrecipients the time required to complete three full years of data collection. The no-cost extension will also permit us to adequately test the system design and data integration with the NGDS Design-Test project.

Thank you for the user interface feedback, we agree that the current version is suboptimal and will be improving upon it as time allows given that this was not part of the original statement of work. We had anticipated that the Boise State NGDS Design-Test project would provide the portal and Geothermal Desktop applications to serve as the initial user interface. With the delays on that project, AZGS took on additional responsibilities to provide basic services to users. The project website - www.stategeothermaldata.org - was not designed or intended to be a portal to the NGDS. We are setting up a new, more user-friendly site - www.geothermaldatasystem.org - to serve as a portal to data and services produced by all the NGDS participants. In the next year, we also plan on having guidelines and tutorials released to help third parties set up their own portals into NGDS and develop client applications ("apps") that can use the data and other resources in NGDS.

Reviewer 23640

Score: 3.0

Comment: The project has successfully engaged all State Geological Surveys able to participate directly and those that can only participate indirectly with this effort. The project has managed to develop substantial data resoruces at the state level which will serve the broader needs of the NGDS.

PI Response:

Part of the success of the project is due to a well-established collaborative community of state geological surveys and State Geologists. Those states that can not participate directly have opened up their files to sister organizations to harvest the data. The Association of American State Geologists (AASG) views the NGDS projects as opportunities to build, populate, and deploy a sustainable national data infrastructure that can leverage additional resources and enhance services to the geothermal communities.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23437

Score: 4.0

Comment: This is a large project with a large number of participants. The AZGS team has done a fine job of managing the work of all these groups, and has at the same time managed to produce a significant amount of work of its own - especially regarding development of an information system to handle all of the incoming information assets. Project management is proceeding well, particularly in the face of unanticipated changes that challenged both performance and schedule. Appropriate adjustments to these challenges were implemented and the project appears to remain on a path toward successful completion. The team is coordinating well with other groups within and outside the context of NGDS.

PI Response:

We appreciate the recognition of the team's efforts. The Science and Management advisory boards, with DOE participation on both, have been excellent resources to help guide the project, ensure we stay on track, and provide critical feedback on directions and decisions. We've had tremendous cooperation with the SMU and USGS NGDS projects and the "reboot" of the Boise State Design-Test project is encouraging for improving that interdependence.

Reviewer 23638

Score: 4.0

Comment: Given that there are 44 subawardees as part of this project, the task of project coordination is formidable. It appears that the project leads have developed an effective system to coordinate the work flow, resulting in a large amount of data having been submitted by the different participants in an organized manner, using agreed upon templates for each data type. A web-based map is used to track the progress of each group's data submissions. There is a wide range of resources available to each subawardee, so a great deal of effort has been expended to provide hands-on training to facilitate the team members' familiarity with the federated data catalog, the data submission process, and the overall project. Based on the results to date, the project management and coordination efforts appear to have been successful. One issue that has not been finalized is how these efforts will be sustained after the project has ended. Continued support of the system through timely submittal of new data will be required to keep this system up to date. It remains to be demonstrated how useful each of the participating members finds this system to be - if it is deemed to be a valuable resource, then the likelihood of active participation in the system is increased. The presentation did not mention how much of an impact user feedback has had in improving the data submittal, metadata cataloging, and user interface systems.

PI Response:

This raises an important issue that we have been focusing more attention on during the past year - sustainability not only of the system but of the data and services from each of the participants. From the beginning, we viewed this not as just a 3-year project but as long-term sustainable infrastructure. The data integration framework we are building on is scalable and transportable to other fields of endeavor. This provides multiple benefits - more data providers will use it, offering a wealth of data and data types not envisioned in the original plan (such as land-use data from 15+ federal agencies via the Western Regional Partnership), greater ability to use infrastructure capabilities developed in other projects, and shared responsibility among a broader set of communities to maintain and grow the system. During the next year we expect to

adopt a sustainability plan that we hope will encourage all the existing participants to continue their roles in the system and ways to continue to add data, services, and new nodes without having to rely on DOE for all of the support.

Reviewer 23640

Score: 3.0

Comment: Project has a strong management component and outward facing exposition and consultation effort associated with it. External user research in support of the task is ongoing and shows that the management team understands the value of user centered design.

PI Response:

We appreciate the recognition of our efforts in this area. We have been showcasing the system at tradeshows, technical meetings, scientific conferences, and to individual groups with intent to solicit feedback and input. A beta-level functioning operational capability was unveiled at the GRC-GEA annual meeting in Fall 2011 for the first time with the specific goal of getting geothermal industry comments. Again, we had not expected to be constructing the primary user interface when the project began but have taken on more of that responsibility in order to be able to demonstrate the data discovery, access, and analysis capabilities of the system that we are building. The www.geothermaldatasystem.org portal we are presently setting up will allow us to present a more comprehensive interface and seek more coherent feedback from users.

STRENGTHS

Reviewer 23437

Comment: A broad base of contributors and partners covering the entire US. A large and growing collection of valuable information assets. A quality process for acquiring, assessing and accepting contributed information assets. A solid architecture based on industry standards. An accessible information system that is already being used.

PI Response:

We couldn't have said it better ourselves. Thanks!

Reviewer 23638

Comment: The main strength of this project is the comprehensive team that has been arrayed to capture relevant geoscience data from geological surveys from all 50 states and have this submitted in a systematic way to the connected regional data hubs. There has been an extensive outreach effort to bring all of the different groups up to speed on the data submittal process using a standardized series of data templates. A web-based map system was developed to facilitate monitoring the progress of data submittal for each state. A large number of data files have already been catalogued, or are in the process of review. The project appears to be making good progress to achieving its objectives within the budget and revised timeframe. The USGIN system should provide a robust and open sourced mechanism for developing a way to organize and catalog the large number of data files and data types.

PI Response:

This describes well the overall goals and concepts we laid out at the start of the project. It was a daunting task, but we feel that our team at AZGS, the participating state geological surveys, and our other partners have been innovative, accomodating, and enthusiastic in building a community of practice that is scalable and sustainable.

Reviewer 23640

Comment: Data interoperability and interchange formats are very strong for this project and should be incorporated into the larger NGDS. The project has worked deliberately to provide open access to available data assets including API and mobile application development. Team has a strong user centered design effort supporting the development of the platform and its extensible applications. The team has cataloged a significant number of data sets from across the States.

PI Response:

Interoperability is the "holy grail" of the project. The support and guidance from DOE and the other projects have greatly aided achieving this goal. There are research efforts underway in other areas of the sciences but they are more research oriented or of limited duration to test concepts. DOE is visionary and bold in taking the USGIN framework and putting it into fully operational mode on a national scale. This is attracting attention throughout academia, industry, and government and around the world.

WEAKNESSES

Reviewer 23437

Comment: No serious weaknesses observed. I do wonder, however, why it appears difficult to attract and retain staff for some activities.

PI Response:

We addressed that somewhat above, but a primary reason is the newness of the field of geoinformatics and the fact that we are putting an operational system in place rather than doing cutting-edge research. There are no formal educational programs producing graduates with combined geoscience-IT expertise. We have to find those who are self motivated to pursue such hybrid approaches. Early on, we hired senior programmers but they all found the programming challenges rather mundane and moved on to more challenging IT jobs. We've been more successful at hiring people who demonstrate an interest or propensity for informatics and training them inhouse. Recently, we are talking with some very bright grad students coming out of emerging informatics programs about joining our program.

A secondary issue may be hosting the project in a state agency during a time of downsizing, salary limitations, and concerns about longevity of positions. However, the State of Arizona has given us near complete freedom and support to take care of our personnel needs.

Reviewer 23638

Comment: The current beta version of the access portal needs more work to make it more accessible to the user. The search capabilities of the current version seem somewhat limited. Tools to display, download, and analyze data sets also need further development. A sustainability plan is needed to ensure that each of the different groups participating in this

effort will continue to play an active role. It might be useful to implement a tracking system to find out who is using the system, what their impressions are (so that their feedback can be used to improve the system), and also to find out who is not using the system. This might guide future outreach efforts to educate groups who are not currently using the system to see that they could benefit from this database. Other user derived feedback might be a data ranking system so that users could alert other potential users (as well as the originators of the data) to potential problems in data quality. One item that was noted is that while this system uses a standardized data submittal template, a less rigorous data submittal approach has been adopted by the BSU team for the data submittals that will be provided by all of the DOE-funded PIs. This might result in some discrepancies in the metadata categories used for each data type. It might take some additional work to make sure that the two systems interface with each other effectively.

PI Response:

We concur that some of these are weaknesses but in the overall NGDS and not just with this particular project. We would not characterize other items in this list as weaknesses, so much as those aspects of the project that have not yet been tackled. Most of these items though, are in work plans for the future.

The access portal is a temporary measure that we cobbled together after BSU advised DOE in Fall 2011 that they would no longer work on that or the Geothermal Desktop as had been expected. AZGS stepped up to provide basic discovery, access, and visualization capabilities even though that is outside the scope of our project. We are going to divert more resources to making this more robust and user friendly. In the few weeks since the Peer Review meeting, BSU has changed their project management team and is rescoping the project to better carry out the original project objectives. This includes a strong user-centered design component and a renewed commitment for an effective user portal. AZGS is working closely with the BSU team to support this effort. But we will continue on an improved user portal on our own, since it may be towards the end of the project before the BSU deliverables are ready to deploy. Also, it is part of our design of NGDS that the components are decoupled or loosely coupled. Development of another portal will serve as a reference implementation for third parties to build their own portals into NGDS.

In addition to the renewed user feedback from the BSU project, AZGS will be seeking feedback via the new portal at www.geothermaldatasystem.org that is being rolled out momentarily. We have exhibit booths planned for the annual GRC-GEA meeting, as well as at the upcoming Geological Society of America and American Geophysical Union annual meetings. In addition, we are meeting with our external partners to test components and usability with them one on one.

The idea of a data ranking system is a good one. We have discussed some kind of crowd-sourcing review system for users and have that in the work plan for the next year.

The spector of divergent systems between the BSU and AZGS project has been a problem for the past two years. But the change in project management at BSU in the past few weeks has led to a rescoping of their direction and strategies. AZGS is a subcontractor on the BSU project but our contributions had largely been ignored or misunderstood. The new management appears to embrace the AZGS work and a new Resource-Loaded Plan incorporates the AZGS content templates and work plans to implement them with all the BSU subcontracts. As we found with some of the State Geological Surveys, their initial hesitation to use the content templates dissipated with training and discussion. The templates are robust and intended to be capable of handling the most sophisticated data held by providers. However, the bar is extremely low for anyone to meet the minimum threshold to submit data using the templates. The concerns raised by the former BSU project manager were misplaced and we are increasingly confident that the BSU and AZGS projects are going to be fully integrated as initially proposed.

Reviewer 23640

Comment: Delays due to subcontractor awards has been a significant challenge to the successful completion of this project. Where are the software applications in the system? This system only focuses on data. Data conversion is a significant problem for this effort, including time and money.

PI Response:

The focus of the AASG project was originally defined to be data acquisition and access, not user-software applications. The geothermal community user-facing application was to be the Geothermal Desktop developed by the NGDS Design-Test project. We recognize that the user applications are still deficient, and look forward to seeing more development this year. Data curation for long-term utility is a major geoinformatics problem that will require ongoing investment and resources. The conversion of data and metadata to documented and widely used formats by this project is a concrete step forward in this process.

IMPROVEMENTS

Reviewer 23437

Comment: Incorporate additional automated quality assessment to streamline acceptance of information assets. Get broader input on the content models - not just from the NGDS groups but from others who might be accessing the data through these interchange formats.

PI Response:

A more automated assessment is in everyone's best interests. The initial process is time consuming and labor intensive, but it has also helped instruct us about how to organize the process and to see first hand what issues the data providers are dealing with, both technically and conceptually. The project technical team will pursue automated processes.

The content models are being drawn from criteria established by the specific domain authorities wherever possible but broader input is desirable. For example, we've had conversations with the GEO organization about using the ground source heat pump industry's content model. We attempt to obtain comments from as wide a spectrum of users as we can, but in general response to request for comment is sparse. To a large extent, the interchange formats are designed to accommodate information that project partners actually have. We view the formats in use as a starting point, anticipating that as system utilization increases, more and better feedback and input on content models and interchange formats will be easier to obtain.

Reviewer 23638

Comment: Suggested improvements are provided in the discussion on weaknesses.

PI Response:

See response above.

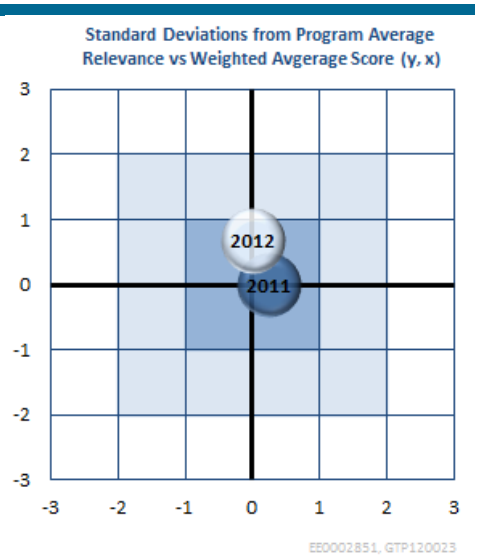
Reviewer 23640

Comment: The technology stack for this project is sufficient for a hub and spoke data environment. However, for this project to synchronize with the larger NGDS system, still in development, there will need to be improvements and probably simplifications in the underpinning technology stack for this project. The user interface while being adequate, may not be 508c compliant. I recommend a compliance check for this project. What is timeline for increasing the data interoperability portions of this project, versus data conversion.

PI Response:

We are exploring a reference implementation for the data provider technology stack with the Design-Test project that will lower the barrier to entry for new data providers and provide technology for federating nodes. We view the service protocols and interchange formats as the defining components of the system, decoupling particular server-side and user-application implementations, and we anticipate that the technology used for client and server implementations will be evolving continuously. The Design-Test project was originally tasked with the geothermal-user facing applications, and we hope that project will come through with the necessary tools and compliance; the interfaces we have built have been stop-gap measures. We will learn more about 508c compliance to factor that into any subsequent development work done in our project.

Increasing data interoperability is an ongoing effort that we will continue to pursue with new content models, demonstrations, tutorials, outreach, and engagement with the national and international standards communities. The technology is not the barrier, rather it is user adoption for publishing data and developing applications. We feel that development and deployment of some compelling user applications to demonstrate the benefits of interoperable data delivery will greatly assist our continuing efforts.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002851
Project: DOE Geothermal Data Repository
Principal Investigator: Snyder, Walter
Organization: Boise State University
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23437

Score: 4.0

Comment: As the landing place for data from all DOE-funded projects, this is clearly critical to the DOE Geothermal Program. As data accumulates in the DOE-GDR the collective and growing knowledge base will be invaluable for future research, education, policy and development activities.

PI Response:

Reviewer 23638

Score: 3.0

Comment: This project is critical to ensure that the results of the ~170 DOE GTO R&D projects are captured by the NGDS. The project had a major change in design from being a database that was hosted and curated by BSU to one that was hosted by NREL (using the OpenEI system) and curated by BSU. The project has made important strides in creating required and recommended lists of data types needed for data submittal, and is starting to interact with the different projects to facilitate the data submittal process. The OpenEI system is now available for users to submit data, and currently 15 data sets are undergoing the review process prior being posted in the DOE-GDR data node. When completed, these data sets will be a great help in supplying background information for current and future geothermal exploration efforts, as well as serving as data resources for case studies of geothermal systems and providing lessons learned from past exploration efforts.

PI Response:

Reviewer 23640

Score: 4.0

Comment: Project is designed to ingest and curate ARRA and non-ARRA funded projects. Through the secure services of NREL's OpenEI.org platform, this project enables the ingestion of those data resources from pilot projects in as efficient a process as possible bringing increased data resources online quickly.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23437

Score: 2.5

Comment: The approach employed on the project appears to be a bit haphazard. It appears that the GDEx team is and has been taking a an "any and all" approach to receiving data, permitting a data provider to submit data as they see fit, and not requiring consistent formats for common types of data. This will ultimately make using the data a bit more difficult. Fortunately there is some consistency being required for the submission of metadata, which will facilitate discovery of the various data assets. Despite shortcomings in the approach, the team appears to be making good progress. The decision to shift the focus from a home-grown repository environment to the NREL-supported OpenEI is a good move, and allows the GDEx team to focus on ensuring the quality of the process and of the submissions.

PI Response:

Reviewer 23638

Score: 3.0

Comment: The decision to move the DOE-GDR node from BSU was based on two factors: a data security issue relating to data that would be quarantined for a specified period of time, and a logistical decision for long-term operations. The OpenEI system is now operational, and has a portal for PIs of DOE GTO-supported projects to submit their data for review and posting in the database. Because of the large number of groups (~170 projects) that will be submitting data, a decision was made to allow for a more relaxed style of data entry, with requests for minimal and recommended metadata types. Thus, the more constrained data submittal templates that were adopted by the AZGS group are not being used by the Geothermal Data Exchange group. Hopefully, there will be enough consistency between these groups (as well as the SMU group) so that the data catalog and search system will be able to query each node in a similar manner. The current emphasis is on the capture of data being generated by the current set of DOE-funded projects, as this project is slated to be completed in January of 2013. Another goal of the project is to capture key legacy data sets, especially geothermal data generated by the USGS. The key aspect to facilitate search and use of this data base will be generated by the NGDS project, which will provide the overall architecture and user interface needed to link and access the federated collection of data nodes.

PI Response:

Reviewer 23640

Score: 3.0

Comment: System's approach to data acceptance for a broad variety of data formats is a strength for this project. Secure submission process via openei.org coupled to the data curation efforts of BSU are another strength of this project and its technical approach. The inclusion of the strong Cyber rules and strong authentication for file access ensures that protected data is secure and exploit free.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23437

Score: 2.5

Comment: Thanks to the shift to OpenEI the project appears to be on track to deliver a populated and useful repository. However, the accomplishments to date do not line up well with the amount of money spent. Very little data has been acquired, and very little development work completed (other than that by separately-funded NREL). To the project's credit the studies of the categories and types of data to be submitted are certainly useful; the planning, communication and setup were significant efforts; the process and protocols for submitting data are nicely laid out.

PI Response:

Reviewer 23638

Score: 3.0

Comment: The project is now deemed to be 80% complete. Quite a bit of progress has been made since the move was made to host the GDEx system at NREL. The OpenEI system is now functional, and at least 15 data sets have been submitted using this portal. Submitters are urged to consult with the project team at BSU to discuss how data should be entered using a series of suggested data templates that provide guidelines for minimum and recommended metadata types. After the data have been submitted through the portal, the files are then scanned for viruses before being placed inside the secure database system. DOE can review data, and then the data will be validated by an NREL subject matter expert before being placed in the main repository. Data that have been submitted at present are still waiting for data review and curation procedures to be finalized (these should be completed within a few months) – The review procedure is mostly a verification process that will depend on data format and templates used. There are many DOE projects that have yet to begin the data submission process, so it is critical that each group interact with the BSU-NREL team to facilitate the data entry process.

PI Response:

Reviewer 23640

Score: 3.0

Comment: Data is being consumed by OpenEI.org though curation protocols are still under review. Sufficient progress has been made on this project to indicate a high likelihood of success.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23437

Score: 3.0

Comment: The project generally seems to be managed reasonably well. However, it does appear that it wandered a bit off course at one point and recovered largely as a result of intervention by DOE. Claimed progress and spending to date seem to line up well, and there appears to be a high likelihood of successful completion. Coordination with various stakeholders seems adequate.

PI Response:

Reviewer 23638

Score: 2.0

Comment: This project involves many collaborators, including the team leads at BSU and NREL, the EERE Chief technology Officer and other DOE staff, as well as the PIs from 170 DOE GTO R&D projects. There has been a successful transition between hosting the DOE-GDR at BSU to NREL using the OpenEI system. The biggest challenge will be to reach out to the GTO project leads and facilitate the data submission process. Only a few of the projects have initiated their data entry into the system using the OpenEI portal, so much work will be needed to train the PIs in how to format their data and enter it into the system. This step is critical to the overall success of the project. Given that many of the DOE projects will not be completed until about the time of this project (or even after this project has reached its end date), a major coordination effort will be needed to ensure that the DOE project data is captured and cataloged properly in the data system.

PI Response:

Reviewer 23640

Score: 3.0

Comment: Project management and coordination between BSU, NREL and DOE has been consistent and produces iterative deployments of increasingly capable solutions to funded projects for submission and curation of data into the GDR.

PI Response:

STRENGTHS

Reviewer 23437

Comment: The processes to support data submission and curation seem to be of high quality.

PI Response:

Reviewer 23638

Comment: The main strength of the project is that a working version of the data submittal portal is up and running within OpenEI on the NREL website. A series of suggested data formats have been generated to provide a list of required and recommended metadata types that need to accompany the data entries. Instructions are available on the website to assist in the data entry process, and the BSU-NREL team is available for consultation to help in this effort.

PI Response:

Reviewer 23640

Comment: This project's ability to ingest and curate project data in a secure fashion is a core capability and a strong reason to continue the project. The technical architecture is solid and has enough dynamic components to allow for adapting this project to new requirements as other associated projects re-tool (NGDS).
PI Response:

WEAKNESSES

Reviewer 23437

Comment: It does not appear the project was diligent to observe issues in technical performance or to take corrective action on those issues. As it was it seems it took intervention by DOE to initiate corrective action. A more rigorous internal approach to ensuring technical performance, attending to such issues, is recommended.

PI Response:

Reviewer 23638

Comment: The current project has a number of identified weaknesses. There are only recommended guidelines for data formatting and submittal, so it is not clear how well the imported data will conform to the way that the AZGS and SMU datasets have been cataloged. While the data submittal portal is now operational, only a small fraction of the DOE projects have actually submitted data for review; thus, there will be a time crunch during the remainder of the year as all of the remaining groups need to be trained in how to format and submit their datasets. It is not clear how DOE-funded groups who have not submitted their data into the system will be encouraged/coerced into doing so prior to the end date of the project. A sustainability analysis (i.e., how to encourage data providers to keep on submitting data into the system) has not been performed yet. The initial groups that have submitted data into the system have not been queried to see what they thought of the formatting and submittal process - such feedback might help in making improvements to the system and streamlining future data submittals. The data review process does not include a data quality step; thus all users will need to evaluate the data on their own. There is no automated method for data submitters to find out where their submitted data are within the data submittal and review process. The data review and curation protocols have not yet been finalized. It is not clear when legacy data (especially USGS data) will be entered into the system.

PI Response:

Reviewer 23640

Comment: Other than the project needing to work harder at getting PI's to submit data, it has no serious weaknesses

PI Response:

IMPROVEMENTS

Reviewer 23437

Comment: See "weaknesses" for primary improvement recommendation.

PI Response:

Reviewer 23638

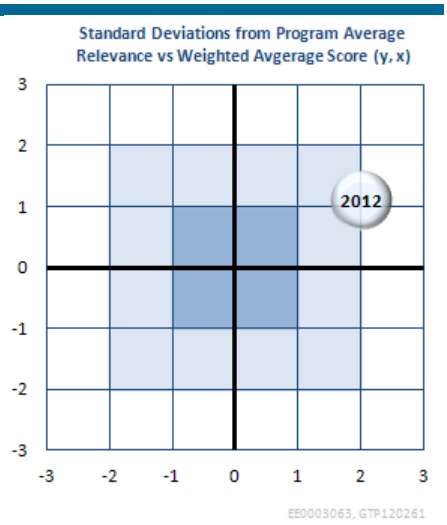
Comment: Suggestions for improvements are incorporated in the weaknesses section.

PI Response:

Reviewer 23640

Comment: This project has to work more aggressively to get data from the PI's.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0003063
Project: GEOTHERMAL WORKFORCE EDUCATION DEVELOPMENT AND RETENTION
Principal Investigator: Calvin, Wendy
Organization: University of Nevada, Reno
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23552

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23480

Score: 4.0

Comment: This project directly addresses a longstanding concern of the geothermal industry: Lack of a well-trained cadre of new professionals who can fill the voids left by the departure of experienced staff. The U.S. has not had an established venue at which students and new industry hires can receive training in geothermal science and engineering. Student training programs in Iceland and New Zealand have been successful over the years in garnering business for geothermal companies in those countries. DOE recognizes this shortcoming and included education and training as GTO goals. This project provides the means of achieving those goals.

PI Response:

Reviewer 23533

Score: 4.0

Comment: This unique US facility fills the need to prepare "geothermal engineers", via an 8 week summer camp organized in 'modules'. Doubts subsist regarding employment possibilities for graduates. 1st year fully subsidized by DOE.

PI Response:

Reviewer 23478

Score: 3.8

Comment: This project is fully and completely relevant with respect to the goals and objectives of the GTO. The NGA is the culmination of years of discussion among the leaders of the US geothermal community and its activities are critical to offset the retirement of many of America's ageing geothermal experts. The impact of the NGA work will not be felt immediately (hence the slight deviation from a perfect score of 4.0), but within a few years, after the early graduates have found niches in the industry, and as more and more students graduate, the impact on the U.S. geothermal industry will be very significant. The NGA, in concert with the GPO training offered by TMCC, are great steps forward in the effort to keep the US leading international geothermal development.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23552

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23480

Score: 4.0

Comment: The Center's strategy of establishing a National Geothermal Academy is a proven means of meeting the training/education challenge, as similar programs in other countries have shown. Offering credited coursework over an 8-week summer period seems the optimum approach given the available resources, especially faculty. The coursework is intensive and all-inclusive, covering all aspects of geothermal development. In particular, the coverage of economic, environmental, public policy, and financing issues is notable, in that these topics are often given scant attention in technically-oriented courses.

PI Response:

Reviewer 23533

Score: 4.0

Comment: 'Modules' are taught by visiting experts. Industry provided input on the content of the courses and their topic. Most of the aspects are covered with the exception of 'geomechanics' (i.e. 'drilling' as well as 'reservoirs' modules) do not include this specialty.

PI Response:

Reviewer 23478

Score: 3.5

Comment: The NGA has obtained advice from geothermal industry leaders as to the optimum curriculum to be taught. Expert, highly qualified instructors, most with many years of teaching experience, have been hired to teach these courses. There has been adequate time allocated in each module to allow student to obtain more than a rudimentary understanding of virtually all of the topics involved in geothermal energy projects. Of added benefit is the fact that several modules can be combined for a geology or an engineering slant, or individual modules can be taken so as to increase specialization. Despite too many finance-related obstacles, understaffing, and delays in acquisition of contracts and authorized funds, the NGA has already graduated its first class in 2011 and has plans for teaching a fully subscribed program during the Summer of 2012. Of special note is the fact that students will work in the classrooms and also in the field, with visits planned to several of the most interesting examples of dry steam, flash, and binary operations in the western US. It is of great concern that the implementation of this field work has meant the elimination of Direct Use courses in 2012 at the direction of the DOE. Hopefully, this loss will be felt and the decision reversed in 2013.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23552

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23480

Score: 3.0

Comment: The first year of the Academy has been successful by any measure. The schedule for summer 2012 contains some awkward scheduling of field trips which does not make the best use of site visits as a learning experience. There were 20 fewer applicants the second year; does this suggest waning interest? The increase in the number of international

applicants is encouraging, but only if the Academy intends to expand its efforts. The Academy should not compete with foreign training sites but provide a continuous stream of trainees for US-based companies.

PI Response:

Reviewer 23533

Score: 3.0

Comment: The program is, so far, not accredited...as stand alone, but involves three separate departments. No great support by university management, raising the question of survivability once DOE's funding is reduced. Fees, this year, did not cover instructors' time. Starting this academic year, DOE will not any longer help for students' stipends.

PI Response:

Reviewer 23478

Score: 3.5

Comment: The NGA schedule comprises 9-10 modules covering most of the important aspects of geothermal project development. The teachers employed have created their own materials for each module, obtained software when appropriate, assigned relevant homework, and in general attempted to make their courses optimally useful for future adaptation to real-life geothermal industry work. The NGA has marketed and advertised the availability of the program in the US and internationally, and as a consequence, the student body, in 2012, will comprise almost the same number of foreign students and American students. Again, considering the impediments imposed on the NGA by federal and state financial constraints and understaffing, there is no way in which the NGA could have accomplished more. Their record has been indeed admirable.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23552

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23480

Score: 4.0

Comment: The Academy's faculty is world-class and renowned. As a result, coordination and collaboration with a wide range of geothermal stakeholders has been excellent. While well conceived and executed, the operating costs suggest the Academy cannot be self-sustaining. Long-term, reliable funding support will need to be found. DOE can provide interim funding, but the GTO is not a final solution, as DOE funding priorities change constantly. Management is doing an exceptional job, given the limited resources and modest support from UNR and outside sources. Hiring a full-time AD with primary responsibility for managing the Academy is a positive step.

PI Response:

Reviewer 23533

Score: 4.0

Comment: Principal Investigator needs to be congratulated for her enthusiasm and achievements under such difficult circumstances.

PI Response:

Reviewer 23478

Score: 3.5

Comment: Considering the problems faced by the NGA program management (as related to staff layoffs, timely receipt of contracts and funding, etc), project performance has been very good. There has been excellent communication and coordination with course teachers, government agencies, academia, and industry representatives. The NGA project is on budget for 2012 and hopes to obtain more funds for 2013 and later operations. It can not be overstated that if these funds are not committed, hopefully for multiple years at a time, the NGA could easily be financially starved to death. The NGA project is complex, including logistics, IT requirements, lodging, multilingual communications, etc. The PI, in her position of leadership, has managed to control and coordinate all these matters with remarkably few hiccups. Inevitably, some things "fall through the cracks" , but on the whole, the NGA is off to an excellent start. All this is due to the expertise of management and the team-members with whom they have communicated and collaborated.

PI Response:

STRENGTHS

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23480

Comment: The NGA is one-of-a-kind in the U.S. and meets a pressing need for training geothermal professionals. The coursework covers all aspects of geothermal development in an 8-week period.

PI Response:

Reviewer 23533

Comment: Enthusiasm of all participants (i.e. lecturers and management).

PI Response:

Reviewer 23478

Comment: The strength of this project is the fact that the NGA finally exists after all these years of talk but no action. For the longest time, the Iceland, New Zealand, and Pisa, Italy geothermal schools were the only ones around. Now we have an American school and it will be more comprehensive and practical than the other three. The USA needs to maintain a lead in the International Geothermal community, and the NGA will greatly help us do this. The courses offered are excellent, the teachers experienced, and the outcome will be welcomed all over the world. This denoted Great Strength.
PI Response:

WEAKNESSES

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23480

Comment: The Academy is not self-sustaining at the current tuition level.

PI Response:

Reviewer 23533

Comment: Financially speaking, this effort will probably not survive. No jobs opportunities for graduates. No interest, nor support by university management.

PI Response:

Reviewer 23478

Comment: The weaknesses of the NGA appear to be the uncertainties created by short-term funding, changing staff, and delays in consummating contractual commitments. It is critical that these problems be solved and/or mitigated. Long-term funding must be found, perhaps via corporate sponsorships, or through Nevada State Academic sources, or via assistance from the GRC, the GEA, or the IGA. As soon as possible, a small, but capable, dedicated staff should be employed and there should be at least 5 years worth of money available with which to hire and keep part time instructors and to pay all NGA-related expenses. I see no real weaknesses in the curriculum except for the absence of Direct Use courses. Most of the geothermal BTU's in the world today are applied via Direct Uses. To leave it out of the NGA coverage makes no sense.

PI Response:

IMPROVEMENTS

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23480

Comment: Cut costs by using instructors from UNR/GBCGE as appropriate in exploration and geoscience subject matter. Employ outside faculty sparingly on an as needed basis, perhaps as guest lecturers. Recruit from Reno-based companies for volunteer, company-paid instructors in other technical areas. Seek scholarship grants from GEA/companies and Federal agencies for qualified students. Recruit a local geothermal operator to allow its geothermal facilities to be used as a field training laboratory.

PI Response:

Reviewer 23533

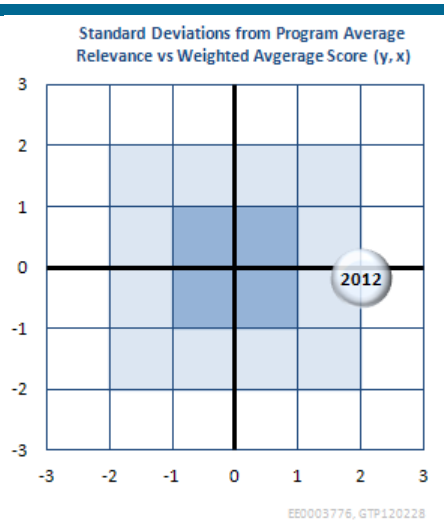
Comment: No suggestions.

PI Response:

Reviewer 23478

Comment: Please see my suggestions under the previous heading "Weaknesses."

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0003776
Project: Northern Nevada Renewable Energy Training Project (NV)
Principal Investigator: Nichols, Jim
Organization: Truckee Meadows Community College
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23552

Score: 3.0

Comment: This project is not a research project, but rather a very interesting and potentially important technical education and formation project administered through a 2-year college. While I would rate this program as successful in terms of creating a new curriculum and degree program from scratch, the outcome is at best vague and uncertain and will be guided by the economic future of geothermal and alternative energy generation. Given the uncertain footing of exploration efforts and the lack of funds for production and power plant construction, the project seems directly tied to that uncertain future. The need for power plant operators is not really documented and so one is left to wonder if there are other career paths that lead to becoming a power plant "operator" or what alternative careers graduates might have. Nevertheless, the effort is extremely commendable and hopefully a successful investment in the future of our nation and the next generation.

PI Response:

We are aware of the downside potential for growth in the industry. Our advisory committee strongly suggested that we broaden the program to address power plant technology in general since many of the same courses could be applicable to other methods of steam generated power. Also, the application to mining or any other discipline which involves heavy rotating machinery should be a potential opportunity.

Reviewer 23480

Score: 4.0

Comment: This project addresses a longstanding need of the geothermal industry for trained geothermal plant operators. Normally, this level of training could only be attained with on-the-job training. The project meets the training need by giving students the opportunity to attain certificate and associate degree awards after completion of a curriculum of courses. These awards will carry more weight than a summer course or some other instruction of limited duration.

PI Response:

While the curriculum is planned to result in degreed programs there is also room for summer workshops and other course delivery options.

Reviewer 23533

Score: 2.0

Comment: Curriculum addressing the needs for Plant operators. No apparent impact on research.

PI Response:

No response entered.

Reviewer 23478

Score: 3.0

Comment: This project addresses one of the important aspects of the GTO goals and objectives, namely, education of workforce candidates. There has never before been an educational facility for Geothermal Plant Operators outside of those run by various corporate entities owning or managing power plants. Accordingly, the creation of a College based training center, open to all, is very much in keeping with GTO plans and will serve the industry very well. For the moment, the impact of this new school cannot be felt, but beginning in late 2012 and more so in 2013, qualified and well trained GPOs will be available for hire by companies with power plants or planning to have power plant operations in the near future. Though the number of such opportunities may be relatively small in the US, when the world-wide geothermal industry is considered, there may indeed be many openings for GPOs. The impact on the geothermal community will therefore grow and eventually be moderately to considerably important.

PI Response:

With this potential need in mind, the curriculum must have a rigorous assessment component to it to verify that the coursework meets the needs of a very broad community both domestic and international.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23552

Score: 2.0

Comment: The detailed curriculum and teaching standards is difficult or really impossible to evaluate given the submitted and presented materials. The program relies on industry donations of materials and instructor time. The list of collaborators and volunteers is impressive, but there is a need for a clearly defined, marketable, and streamlined curriculum. Again there is no information of course or degree content, student learning evaluation, beyond the promise. In my mind, the program has the potential to be a national leader in the field. However, plans to proliferate and go on-line are very vague and poorly articulated.

PI Response:

Due to the time constraints of the presentation we could not “drill down” into course content and learning outcomes and measuring instruments. In order for this certificate to be approved by the TMCC curriculum committee and the NSHE

Academic Affairs committee, these course descriptions had to include all of these elements. They are available on the website.

Reviewer 23480

Score: 3.0

Comment: The means of achieving GPO certification are straightforward and reasonable. The use of an advisory board assures that the curriculum meets the needs of the user community (students and industry). The level of instruction is unclear, but appears to be fundamental and consequently may lack sufficient depth to address many real world situations at operating plants. The qualifications of the faculty teaching the classes are not specified. Use of an Advisory Board and the approach to designing the curriculum are commendable.

PI Response:

This is the job of the assessment instruments set up for the curriculum. These instruments will question students, employers and the advisory committee about the applicability of the curriculum to the job requirements. The faculty are a mix of academics with expertise in geothermal geology, consultants from industry on well design and engineers who teach the power plant courses. The industrial tech courses are all taught by seasoned faculty as part of other degree offerings.

Reviewer 23533

Score: 2.0

Comment: Relevant tasks. Course curriculum chosen, based 'on best practice'. Industrial Advisory Board. New laboratory donated by industry.

PI Response:

No response entered.

Reviewer 23478

Score: 3.4

Comment: The approach to initiation of this project is good to outstanding. The advice of recognized geothermal industry experts has been used to identify needed skill sets and to help develop the curricula. There will be strict College oversight to maintain the educational standards, and current published guidelines for Renewable Energy education programs will be consulted and used as appropriate. There are plans to increase and/or modify the curriculum as dictated by industry needs in the future. Plans are to make the courses available electronically so that students in rural areas of the US and international students will be able to "attend" lectures. Obviously, the problem of "hands-on" training for these off-campus candidates will have to be addressed. The only matter that tended to lower the score on this criterion was the fact that the actual teachers of the courses were not identified. It is assumed that the teachers will comprise University professors, hopefully augmented by visiting lecturers having significant Power Plant experience within the geothermal industry. Ideally, the industry professionals should be the lead instructors, but it is almost impossible for an industry person to get permission to leave his/her job long enough to teach a full semester course.

PI Response:

See the above comments.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23552

Score: 3.0

Comment: The program has successful started a degree (pending regent approval) program with a growing curriculum and a long list of collaborators, contributors, and volunteers. Many of the curricular, content, and staff details remain murky. Learning goals and student learning tracking are not adequately addressed. The project appears to be on track, despite the search for a programmatic home.

PI Response:

The program has found a home in the new Energy Technologies program under the Advanced Industrial Technologies department within TMCC. The Energy Technologies program offers curricula in solar (PV and solar thermal), wind and geothermal power technologies.

Reviewer 23480

Score: 3.0

Comment: The project shows meaningful progress on both the COA and AAS. Recruitment of 22 students for 2012 is excellent progress and shows high interest in a new degree program. Certification by the State is still pending for both COA and AAS, and this is the ultimate measure of the project's success. The AAS is especially critical, as this gives geothermal legitimate standing in TMCC's degree program. If AAS approval is not forthcoming, the project's future value as a training vehicle can be called into question. Funding for a laboratory is a significant accomplishment.

PI Response:

The COA has been approved by the State. We anticipate the approval of the AAS by the end of the year. We can see no obstacles to that goal

Reviewer 23533

Score: 4.0

Comment: Curriculum has been approved by Nevada Higher Education. Also Associate degree approval pending. 22 students enrolled so far for 2012/2013. 200 K$ anonymous donation.

PI Response:

No response entered.

Reviewer 23478

Score: 3.8

Comment: The list of accomplishments recorded to date is very impressive. The Advisory Board has been populated, Curricula have been designed and implemented for both Certification and for Courses leading to an Associate of Arts degree, Marketing of the opportunity is in progress, Student recruitment is in progress, and most impressively, a geothermal training laboratory has been designed and constructed. The latter was undertaken with the help of a single, large anonymous donation, but funds are still being sought for the purchase of more required equipment. Donated equipment is now in use, and more donations would be appreciated. Enough progress has been made so that the first students are currently being trained. By 2013, this outstanding educational facility should be in full operation and graduating its first classes.

PI Response:

The lack of demonstration equipment, simulators and cut-a-way models is lagging. Currently there is a college effort to develop a "business plan" for the program to ensure its continued support. This plan should be complete within the next month.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23552

Score: 2.0

Comment: The project appears to be well managed. However, as pointed out above, the program needs a detailed teaching portfolio, learning goals and standards, an approach to tracking student learning, and a way into the future. The teaching approach comes across as antiquated, while trying to attract and Internet-savvy generation into the geothermal power generation. It appears imperative to explore interactive and on-line learning, esp. the geographic boundary conditions of the program, to ensure the future of the program and the success of its graduates.

PI Response:

As earlier discussed, after we complete the pilot presentations of our courses, the development of other delivery methods (on-line, hybrid, boot camps, teachers travelling to plants) to offer courses will be explored and merged with demands to provide a viable distribution system.

Reviewer 23480

Score: 3.0

Comment: The project is progressing in a logical, organized manner. The curricula are reasonable, and the new course offerings under development will have the level of detail needed to train students on all aspects of geothermal power plant operations. An in-depth course on the geoscience (geology, geophysics, hydrology) of geothermal systems is needed to complement the plant engineering courses. An operator must be aware of the how geothermal reservoirs behave in order to run the plant efficiently. Collaborations have been good, but could be expanded to include GEA, GRC, and companies with operations outside Nevada. Not clear the project can be self-sustaining after Federal support ends.

PI Response:

Currently TMCC offers a three credit course in the geology of geothermal resources. The professor, the chairman of the physical sciences department at the college and holding a Ph.D. in geology, has developed and taught the course for approximately four years and it is one of the most popular courses in the department. The comment about including GEA and GRC is excellent. We will pursue this. Much of the ability to sustain the program after federal funding ends depends on the health of the industry and how it sees the value in our graduates. Possible collaborations with UNR and other colleges in California and Idaho could raise the profile of the program and offer other opportunities.

Reviewer 23533

Score: 3.0

Comment: Model used: Community College.

PI Response:
No response entered.

Reviewer 23478

Score: 3.2

Comment: Little real information has been made available regarding the actual management of this project. Accomplishments have been stated (more than once), but it is difficult to know who has responsibility and who has been the driving force in this effort. Obviously, the success of the program to date attests to very effective management, and adherence to the budget and time line has been excellent. It would be useful to have a list of instructors and the names of the classes now being taught and planned for the future. There has also been close coordination with the Advisory Board members and the several consultants identified. Though there has been a delay in acquisition of State Approval for the planned AAS Degree due to budgetary concerns, this approval is expected in 2012 so that the program can get back on schedule. This is clearly not a project management failure!

PI Response:

The management of the project has been handled by Jim Nichols, a retired civil engineer who has been teaching at TMCC for the past 6 years. Prior to that he owned and was CEO of an engineering firm of 50 people. One of the services the firm offered was in technology transfer to “bring the state of the art to the standard of practice”. This is what we are doing with this project. Assisting Mr. Nichols is Dr. Norma Velasquez-Bryant, a civil engineer with Ph.D. in Educational Research and an emphasis in instructional design. She will be critical to the project as the program evolves into different delivery systems.

STRENGTHS

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23480

Comment: The school (TMCC) has committed to a degree program for geothermal plant operators.

PI Response:

No response entered.

Reviewer 23533

Comment: Offering an approved and recognized degree. Seeks input from geothermal plant operators.

PI Response:

No response entered.

Reviewer 23478

Comment: The strength of this project is the degree to which it will address a recognized need for geothermal power plant operators and the rapid time frame in which it has been put in place. The fact that skill sets have been identified, curricula established, courses designed, opportunities marketed, students recruited, and classes begun in a new, purpose-designed and built laboratory, shows excellent management and strong commitment to the project concept from numerous people.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23480

Comment: The degree program may not be sustainable once Federal funding is spent.

PI Response:

No response entered.

Reviewer 23533

Comment: Needs to seek financial help from industry. Needs to diversify lecturers.

PI Response:

No response entered.

Reviewer 23478

Comment: It is hard to find any weaknesses in this project. It would help if specific classes were identified and initial instructors (and their affiliations/credentials) were to be named. A little more detail regarding project management and the budget would also be helpful in assessing the project. But, having said this, one cannot quarrel with success and this project shows many signs already of being successful. Few endeavors are devoid of weaknesses, but this one appears to come close, judging from the materials available to review. Implementation of an intern program, either during the teaching process or upon award of certificates or degrees, would be an excellent expansion of the offering.

PI Response:

No response entered.

IMPROVEMENTS

Reviewer 23552

Comment: Clearly document the curriculum, the learning goals, the tracking of student learning. Develop and on-line, possibly interactive, teaching tool. There should be significant funding available at state and federal level for such activities. Articulate a plan for the long-term health and feasibility of the program (maybe in different stages and on different scales). Volunteer efforts are likely not sustainable in the long run and ties the program's health and success to personal factors. Develop a sustainable and proactive plan. This program could be a national poster child if done right.

PI Response:

Excellent comments which will provide roadmap for future.

Reviewer 23480

Comment: The program would have even greater vitality and staying power if an actual operating plant were made available for training purposes. There are a number of small units in northern Nevada that could serve this purpose if an operator is willing to cooperate. Perhaps this field laboratory could be pursued through the advisory board.

An in-depth course on the geoscience (geology, geophysics, and hydrology) of geothermal systems is needed to complement the plant engineering courses. TMCC should coordinate with UNR/GBCGE on employing UNR instructors and perhaps Academy faculty to teach portions of the curriculum.

PI Response:

We will pursue the availability of a plant. The distances in Nevada may make it difficult for this to happen. However, with proper planning it may be possible.

Reviewer 23533

Comment: Need to increase enrollment costs if wants to survive.

PI Response:

No response entered.

Reviewer 23478

Comment: I have very few suggestions:

1) Identify individual course names,

2) Identify instructors, their affiliations and credentials,

3) Identify project managers and their responsibilities, and

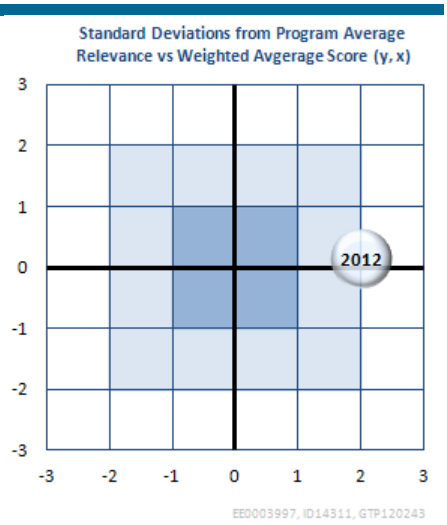
4) Provide some budget details and forecasts.

5) Begin an intern program involving the geothermal industry.

Otherwise, this appears to be a well thought out, well and efficiently implemented, and desirable project for the College and for the geothermal industry.

PI Response:

We will offer more detail as you require.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0003997, ID14311
Project: UNR - Great Basin Center for Geothermal Energy (I\IV)
Principal Investigator: Calvin, Wendy
Organization: University of Nevada, Reno
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23444

Score: 3.0

Comment: This project derives from DoE earmarked funding to UNR that is then redistributed to other PIs. Because this project overview focuses on the summation of all funds, the specific relevance and impact of the funded projects and research is difficult to evaluate. Consequently, comments are made en mass (without sufficient information on any one award). The overall goal of the funding is to provide a regional assessment of geothermal resources through research, database development, measurement of new data, and actual field and geologic mapping (creating original data). This combined information has identified new geothermal systems in NV and has the potential to increase markets for geothermal energy. The data appears to fill a technological gap in understanding the potential for geothermal resources in the state of NV and could ultimately lead to development of additional geothermal resources.

PI Response:

Reviewer 23552

Score: 3.5

Comment: The Great Basin Center for Geothermal Energy is clearly a tremendous success story and has had a significant impact on the research and education in geothermal energy in the State of Nevada and beyond. The opportunities created by the program at UNR and affiliated institutions have created leadership within the applied academic and geologically-oriented branch of geothermal exploration.

PI Response:

Reviewer 23625

Score: 2.0

Comment: The funding of individual grad and post grad researchers is useful and necessary, but as long this research is restricted to one school and one limited area, this should not be the scope of DOE funding.

PI Response:

Reviewer 23480

Score: 4.0

Comment: Over the years, the Center has been quite successful in applying earmarked funds to support geothermal projects in the Great Basin. These projects have produced results, especially exploration information, that has proven useful to geothermal developers in Nevada. These achievements have directly supported GTO goals related to increasing geothermal power generation and other applications of geothermal energy.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23444

Score: 2.0

Comment: Basic research is the primary approach for discovery and mapping of geothermal potential and for the educational component. One must assume appropriate methods have been utilized. These data are synthesized to create new models for geothermal systems with a focus on NV. No details are provided. Few specifics are included for educational objectives other than training of graduate students through funding of their research and outreach other than broad statements. The educational component could be more robust and creative.

PI Response:

Reviewer 23552

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23625

Score: 1.0

Comment: This is direct funding of individual research projects. There does not seem to be a thematic coordination, except for being geothermal. The project title states public outreach. This task has not been addressed nor is it addressed in the future directions.

PI Response:

Reviewer 23480

Score: 3.0

Comment: The fact that the Center's research projects are competed and peer reviewed sets its program apart from other earmarked programs. The approach may have to be modified as the earmark contract expires. This challenge is being met with the plans for graduate-level research and "seed" grants. This is an efficient use of shrinking funds. Perhaps more effort could be placed in teaming with private industry and other universities outside Nevada.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23444

Score: 3.0

Comment: This criteria is difficult to evaluate because of the nature of this award. Follow-on funding generated from the original funds is greater than the original award, suggesting substantial accomplishment. Educational components resulted in numerous graduate students receiving their degrees through funding; 22 over 10 years for 2/year avg. Numerous publications and presentations resulted, although more could be in peer reviewed journals. Some patents were submitted and commercialization of software occurred. These appear to achieve the original broadly stated objectives. Data dissemination appears to be well underway with more planned. Too few technical details are provided to adequately evaluate technical targets.

PI Response:

Reviewer 23552

Score: 3.0

Comment: The accomplishment of this program are wide ranging as illustrated by the student opportunities created, faculty projects sponsored, etc. However, it is too bad that many metrics have not been collected, such as student career tracking (somewhat inexcusable for the university). The biggest worry at this point is the long-term sustainability of the program and the future ability to serve the community with the uncertainties at UNR and the NBMG. Longevity of the program likely depends on a more diversified funding portfolio that does not as heavily rely on ever-uncertain and

questioned ear-mark funds. Given the impact and benefit to the private sector, a buy-in from industry seems pertinent and more than justified.

PI Response:

Reviewer 23625

Score: 3.0

Comment: The funding has resulted in the output of an impressive number of MSc's and PhD's. This is highly commendable. But this should not be the objective of DOE funded research.

PI Response:

Reviewer 23480

Score: 4.0

Comment: The number of student degrees and the contributions to new geothermal development projects in Nevada by the Center are commendable. With few exceptions, the earmarked funds have generated useful results. The challenge will be to maintain the level of accomplishment moving forward.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23444

Score: 3.0

Comment: This project consists of many subawards. Consequently this evaluation refers to project management between UNR and the subawards. UNR handles the earmarked funds and makes yearly requests that the University must approve. Therefore there is much organization required. Call for proposals go out and successful applicants are from industry, the government, First Peoples Nations, national labs and other Universities requiring much management. As presented, it appears to be coordinated and managed in an appropriate manner. New staff has been added to alleviate burden on the PI.

PI Response:

Reviewer 23552

Score: 4.0

Comment: The program thrives on the shoulders of the Director. She is clearly doing a marvelous job managing the program and steering the ship through the currently choppy seas. As mentioned before, however, I think it is time to think increasingly about a more diversified funding base. Job well done.

PI Response:

Reviewer 23625

Score: 3.0

Comment: The project management has to be rated as very successful as it achieved to grant funding to a large number of individual researchers.

PI Response:

Reviewer 23480

Score: 3.0

Comment: The list of collaborators is impressive, but perhaps should include DOE (Nevada Test Site) as well as BLM and other universities in the Great Basin. The shares of the budget applied to R&D, education, public outreach, and management overhead are not specified. Only 3% of funding for the new contract award has been spent. Plans for spending/obligating the remaining funds before the end of the fiscal year are not specified.

PI Response:

STRENGTHS

Reviewer 23444

Comment: Having a focus of geothermal energy research in a single area (NV) could be good.

PI Response:

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23625

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23480

Comment: The GBCGE is well-run with a well-qualified, hard-working staff. The Center has the backing of the University with good working relationships with the geothermal industry in Nevada and the geothermal community at large. The Center has an exceptional publications record.

PI Response:

WEAKNESSES

Reviewer 23444

Comment: The educational component of the proposal is largely traditional and narrow, in that this project provides funding for individual graduate students to pursue research. To underscore the utility of this training, graduates should be followed past their degree program to understand how their research has impacted their career, how many have chosen to stay in the field of geothermal energy or other energy sectors, and what types of career trajectories students have taken. While important, it does not appear that broader educational impacts have been forthcoming. Educational modules could be developed that are web-based and disseminated more broadly.

PI Response:

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23625

Comment: The support of this project sets a precedence funding an individual university to provide grants for its students. The result is commendable. But this should not be the scope of DOE funding.

PI Response:

Reviewer 23480

Comment: The Center has tended to remain somewhat insular in its conduct of funded studies; few investigators from outside the UNR system participate. The scope of studies is limited to exploration topics.

PI Response:

IMPROVEMENTS

Reviewer 23444

Comment: Students graduating from this program (or using this money for their graduate education) should be tracked to better understand the impact of this funding on careers, its impact on the geothermal workforce, and to assess that the stated outcomes of the educational objectives have been achieved. Metrics for determining the success of the educational programs need to be developed. Does this program provide a pipeline into industry? Advertise the program more widely to allow others the opportunity to participate.

PI Response:

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23625

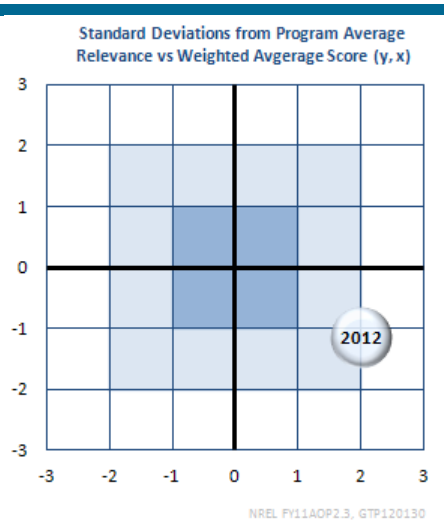
Comment: Address the obligation for public outreach.

PI Response:

Reviewer 23480

Comment: Geothermal science/engineering can only gain academic legitimacy when the specialty is offered as a degree program at the undergraduate/graduate level. UNR, through the GBCGE, has the resources to offer such a degree. The Center's scope should be expanded to include other geothermal-related topics, such as reservoir engineering and drilling. Geothermal experts from other schools should be encouraged to participate as co-PIs.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: NREL FY11AOP2.3
Project: Hydrothermal and Resource Confirmation analysis - Data Gap Analysis, Exploration Success Metric and Case Studies
Principal Investigator: Young, Katherine
Organization: National Renewable Energy Laboratory
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23444

Score: 3.0

Comment: This study attempts to determine exploration tools needed for geothermal resource discovery. To do this, this project surveys available data on methods and techniques used to locate and discover geothermal resources. Such data for geothermal exploration can be used to prioritize collection of data for future geothermal funding opportunities. The ultimate goal of providing relevant information is to enhance the discovery and development of undiscovered geothermal resources. Key to this data is determining what data are critical for funding, not all data is needed for all discoveries. As such, this analysis addresses knowledge gaps that detract from exploration and development of resource potential. Such information could be useful in overcoming market barriers and in accelerating growth in the use of geothermal technologies by lowering risks and costs of exploration.

PI Response:

No response entered.

Reviewer 23552

Score: 3.0

Comment: The geothermal data gap analysis and identification program is an out birth from the recommendations of the Blue Ribbon Panel. The project is important and the data should be revealing and powerful. The project consists of exploration success metrics, case studies, and an exploration data collection cost matrix. The project does not intend to serve data, but rather metadata in terms of data gap analysis. This is an intriguing approach, but only if combinable with data from the NGD or NREL efforts; I think this is a critically important linkage that has to be fully established.Costs are ever increasing and so this is a valuable; however, the geothermal industry commonly claims to be cutting-edge in terms of exploration, while really applied techniques that have been applied in oil and gas for years and academy would not consider appropriate or innovative. Capturing data, techniques, and costs beyond the industry std and the obvious will be crucial. In fact, this could really drive the proliferation of novel techniques if properly handled. While the project is relevant some of the metrics and metadata are difficult to define and potentially lack useful attribution. In particular, the term success created a lot of confusion as success was defined in a rather odd way (more along the lines of useful applicability, rather than exploration usefulness). Serving metadata and identification of data gaps with industry and public is an important concept, but it also has its dangers (just because there is metadata does not and should not mean that the area should be ignored by explorationists).

PI Response:

The reviewer makes a valid point regarding the use of the term "success" - perhaps a better term to use going forward would be a GTO funding "impact" metric, rather than GTO funding "success" metric.

Reviewer 23625

Score: 1.0

Comment: The compilation of metadata without quality control of the data content is not a research item but a service. It is questionable how relevant this data scouting is for geothermal project developers.

PI Response:

The compilation of metadata for the data gap project works to compliment the work being done on the NGDS, where data quality control occurs. The goal of this dataset is not directly for geothermal project developers - we understand they conduct their own extensive data gathering efforts. Instead, this project INdirectly impacts geothermal project developers by providing data coverage information to GTO to help guide their future funding efforts in potential green-field hydrothermal locations by mapping where previous efforts have been made.

Reviewer 23480

Score: 2.0

Comment: The project has disparate impacts, due to its multitask approach. Data gap analysis is an important contribution to establishing where future data collection efforts should be focused. In general, data exist at different scales, and this has to be taken into consideration for gap analysis. Just because a particular survey may be available for an area doesn't mean the survey will meet exploration requirements. A gap may exist despite the coverage. The success metric task seems of limited utility to industry and may not prove useful to DOE if the cost data are unreliable and unreliable. "Price" and "cost" differ, and NREL should be sensitive to this in soliciting industry input as this could skew the results. Case studies can be valuable tools for assessing what worked in the past.

PI Response:

This is really 3 separate projects, the request to present it as one project at the peer review made it difficult to synthesize it's impacts.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23444

Score: 2.0

Comment: The approach involves locating sources of data, surveys of available data, analysis of such data and determination of missing data for the most essential methods and techniques. Additional data for analysis is to be collected via a web-based input tool. Cost data is also to be collected largely from industry (via some method of query, email, letter? phone?) Results will be used to develop a baseline of exploration activities that have the highest likelihood of success. These results are then used with exploration case studies to provide a proof-of-concept to target other areas. A

success metric tool will be developed. Implicit in this analyses is that data for one field is equally valuable for another field, which may not be the case. Hydrothermal systems are heterogeneous geologic systems with different physical and flow characteristics. A rigorous approach needs to highlight the critical data for each field rather than simply all the data that is generated for a field. Some data may be gathered but it does not mean that it was useful or the unique data that identifies the hydrothermal source. Is data gathered on why a specific technique was used? Assessing the key components for discovery could be challenging. Perhaps what is most missing from the sample set is geologic data i.e. defining the flow path, resource areas, etc. - are industries not aware of its utility? Or was it not included? Data derived from industry only may not provide a robust tool for discovery. How is the quality and utility of the data being evaluated?

PI Response:

When available, data are being gathered and cataloged on the impetus behind using a particular exploration technique at a given locaiton.

Reviewer 23552

Score: 2.5

Comment: The project is philosophically intriguing and aims at guiding data collection in the search and definition of data gaps. In order to develop the analysis tools and benchmark the model the team has chosen two case studies to develop baselines (in terms of data collection metadata, success metric, and costs of data collection). It is unclear to me why the NDG can not serve both metadata and data and where the GAP project sees its niche (other than proprietary data)? One might ask if DOE should spend funds to catalog metadata of proprietary data that will not be available. Equally problematic, but mostly confusing, is the success metric. It is still not clear to me what the intention is if actual exploration success is not tracked. The question of "what technique was the most helpful"? A question frequently asked in R&D sessions these days. How will this be addressed technically? What is the metric of funding success? Discoveries, publications, jobs? I think this are important questions that this project could contribute to; a major issues DoE needs to address with respect to peer-review.

PI Response:

It is hoped that the NDGS will be able to serve metadata and provide this gap analysis in the future. GTO intends to put out a FOA in FY13 before the planned completion of the NGDS and therefore needed this analysis to be done sooner. As development of the NGDS progresses, it is planned that this functionality will migrate to the NGDS so there is no duplication. Because the goal is to identify areas of future GTO funding, even the location of proprietary data is useful so that GTO doesn't propose projects in a developer's "backyard."

Perhaps a better term to use in place of "success" is "impact" … the goal is to define a measureable metric (the impact of project funding on exploration cost and time) by which GTO can measure its funding impact. There are a number of metrics that could be used and that GTO is trying to develop. Exploration "success" is a metric that was evaluated for this purpose but was not chosen for a number of reasons (for more information on why, please feel free to contact me).

Reviewer 23625

Score: 2.0

Comment: From the presentation and the summary the quality of the scientific/technical approach to collect and process the data cannot be assessed.

PI Response:

No response entered.

Reviewer 23480

Score: 3.0

Comment: The approaches for each task are reasonable. The use of dataset maps for each exploration variable makes good sense and allows users to conduct their own gap analysis. The cost survey should allow NREL to develop a statistical data base to facilitate the analysis. Are the costs current (i.e., 2012); have they been inflation-adjusted? Note that "price" and "cost" can be different. Case studies are most useful when they cover a broad range of conditions (physical, regulatory, etc). Relying on just two cases may lead to inconclusive or misleading results.

PI Response:

The goal of the case studies this fiscal year was to develop the template and test out the template at two locations. We agree that the more case studies that are conducted, the more useful they become. The plan is for additional case studies, including at locations that have not been developed, to be conducted at additional locations in future years so that comarisons can be made. Case studies are also being conducted in other areas (e.g. regulatory)

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23444

Score: 3.0

Comment: Collection of data and associated metadata, primarily from NGDS and individual nodes on the NGDS is underway. Companies have been contacted with over a 50% response rate - which is quite high. Cost data has been collected for 89 methods but the number of sources is not given. For the example data, mineralogical (XRD) and fluid composition (geofluids) data (in addition to fluid inclusion) are lacking but paramount to understanding fluid-rock reactions in the reservoir, the flow path, the size of the alteration halo, potential scaling and degradation of the reservoir. To help fill in data gaps, an industry feedback tool is in development so that information can be forthcoming for this study prior to entry into the NGDS. Relying on a single source of data (NGDS) may bias the data and can cause unnecessary delays. There have been technical challenges in obtaining data sets from NGDS but the project is moving forward. Areas of highest hydrothermal/geothermal potential have been targeted and mapped in an effort to identify regions of likely demand. Case studies for hydrothermal projects that reflect the level of exploration required to develop a 'successful' project are also being developed. Two well-known fields have been analyzed to date. Perhaps the most useful data would derive from the fields that are considered 'failures'. After developing the tool for identification of exploration optimization, it would be interesting to test a failed field.

PI Response:

No response entered.

Reviewer 23552

Score: 3.0

Comment: The team appears to have extensively worked with the NGD crew to metadata mine and initial tools have been developed to serve the metadata. However, effort is not very far advanced due to lack to population of NGD and data availability. Still the question remains, how the effort will be different from what could be and maybe should be done on the NGD (NGD must be developing tools for their nodes, no?). The metrics tool is interesting, but really not far enough along to critically evaluate the success (of this effort). Industry self-reporting is a can of worms at best. Collection of methodology and costs is still rather incomplete, but already very interesting, illustrating the large spectrum. Little is know about the tools being developed; should be flushed out and feedback from users should be requested.

PI Response:

No response entered.

Reviewer 23625

Score: 1.0

Comment: The presented table of exploration success metric does not provide useful information for any decision process of a project developer.

PI Response:

No response entered.

Reviewer 23480

Score: 3.0

Comment: The early data gap maps look promising. Not clear how supply analysis and demand analysis operate in the gap analysis. This requires explanation. Responses to the cost survey are exceptional. Exploration cost data collected from industry are impressive, especially if they have been adjusted for temporal variations. A vetted template for the case studies will be valuable in resolving differences in terminology/approach used by the early explorers.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23444

Score: 4.0

Comment: The project is progressing on time and schedule and within budget despite challenges. Therefore it appears that project management, staffing, and activities are well coordinated and appropriate.

PI Response:

No response entered.

Reviewer 23552

Score: 4.0

Comment: Project management appears excellent. The three very different tasks are nicely integrated and packaged and effectively served to the community. This is clearly a modern project in terms of content, philosophy, management, and interactive dissemination. Job well done.

PI Response:

No response entered.

Reviewer 23625

Score: 2.0

Comment: Cannot be assessed from this presentation only.

PI Response:

No response entered.

Reviewer 23480

Score: 2.0

Comment: This project involves three independent tasks---the integration of those tasks under the project as a whole is not obvious. Despite assurances, the remaining work appears to exceed the budget and time remaining for the project. Presumably, past and current operators at Raft River and Coso have been directly involved in the case study task. This was not apparent from the presentation. Those organizations/institutions collaborating on the project are largely not identified or only mentioned in broad classes (e.g., ARRA projects).

PI Response:

No response entered.

STRENGTHS

Reviewer 23444

Comment: Providing cost information for geothermal exploration of hydrothermal systems has the potential to help industry further the development and use of geothermal technologies. It provide necessary data for determining economic strategies and plans for development and implementation of geothermal technology.

PI Response:

No response entered.

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23625

Comment: The project is actually an information scouting service.

PI Response:

No response entered.

Reviewer 23480

Comment: The gap analysis should provide a database of general utility to both industry and government. Similarly, the exploration cost database will make a useful future planning tool for stakeholders.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23444

Comment: It is unclear how the quality of the data is being analyzed and marked as relevant. While some exploration strategies target a variety of methods, some methods may be more useful for a specific geologic situation than others. Identification of these critical methods could enhance this study.

PI Response:

No response entered.

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23625

Comment: Questionable relevance to project developers and/or industry. Metadata sets are available on a commercial basis.

PI Response:

No response entered.

Reviewer 23480

Comment: The three tasks of this project are not well integrated; they could have been done as independent projects. Including them under one project umbrella could dilute the effort/emphasis placed on each task.

PI Response:

I agree. It was difficult to present these projects as a single project for Peer Review.

IMPROVEMENTS

Reviewer 23444

Comment: Identify critical methods for exploration of hydrothermal systems. While defining and describing a set of geological environmental types for hydrothermal systems in the US may be important, work within the considerable existing literature and framework of hydrothermal systems. (a vast geologic literature). Use caution in extrapolating from one geologic system to another recognizing that the systems are inherently different as well as heterogeneous and dynamic systems. The geologic state of one system (on the prograde or retrograde path) may not be reflective or representative of another hydrothermal system therefore exploration and development may be different.

PI Response:

No response entered.

Reviewer 23552

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23625

Comment: Produce a prototype data set for a particular area and test the impact at the addressed clientele before you expand in a nationwide data collection exercise.

PI Response:

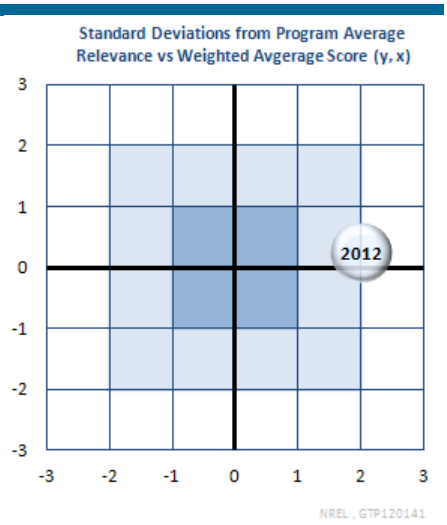
No response entered.

Reviewer 23480

Comment: Consider prioritizing the three tasks relative to their potential contribution to finding geothermal resources. In this regard, the "Success Metric" has the least utility, although the cost data would be valuable when integrated with the remaining tasks. Case studies should be expanded to include application of the exploration template to pre-existing data sets from other sites as well as new sites volunteered by industry. As a benchmark, cost data from the case studies should be compared to that obtained from the industry survey.

PI Response:

No response entered.



Review: 2012 Geothermal Technologies Office Peer Review
ID: NREL
Project: Geothermal Prospector and other data provision tasks at NREL
Principal Investigator: Witherbee, Kermit
Organization: National Renewable Energy Laboratory
Panel: Systems Analysis, Resources Assessment, Data System Development & Population, Education

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23437

Score: 4.0

Comment: There is great need for an analytic platform in support of Geothermal activities, especially in support of identifying prospects for geothermal development. By collecting, consolidating, correlating and visualizing a variety of geothermal-relevant data assets, the Geothermal Prospector appears to be targeted correctly at this need and has great potential for facilitating the laborious processes involved in the early portions of the geothermal development life cycle.

PI Response:

No response entered.

Reviewer 23638

Score: 3.0

Comment: The use of OpenCarto, a GIS based tool, will allow for the analysis of spatial data to screen geothermal areas. Most of the tool development to date has been based on land use identification and data gaps. Brief mention was made of the potential application of this system in the identification of hidden geothermal systems and prospective EGS sites, but it was not clear what criteria were involved in the analysis tools that were being developed for these applications. It is recommended that more community input is obtained to identify what analysis tools are desired, and what features they should contain. Also, one shortcoming of the data gap analysis is that it presupposes that the system will have access (via the NGDS) to all relevant geothermal data. However, it may be that there are available data that have not been entered into the system. It will require a significant outreach effort on the part of the Geothermal Prospector team to canvas the geothermal community to identify areas where there are (or will be) geothermal data that do not appear in the standard geothermal data bases that will be queried by the system. One challenge is that because the NGDS isn't yet active, it is hard to see a real demonstration of the the power of this application right now. One analysis tool that would be really helpful is the use of a data contouring application that could be used to evaluate measured subsurface temperatures. If you could create depth slices at specified elevations and plot or project temperatures at different temperature gradient wells, then a contour map could be created to identify areas with elevated temperatures. Similar maps could be made using heat flow data. For this tool to have an impact, it will critical that this tool is advertised via webinars, demos, and publications. The plan to have a paper at the upcoming GRC meeting will help.

PI Response:

No response entered.

Reviewer 23640

Score: 3.0

Comment: The scientific analytic and GIS application(s) being developed are clearly needed in this space. They will provide substantial usability and accessibility for audiences of all levels to geothermal data.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23437

Score: 4.0

Comment: NREL is building Geothermal Prospector on their OpenCarto platform, which has already impressively proven itself in support of several other renewables-related applications. The approach of using a GIS map-based capability as the primary visualization mechanism makes perfect sense in the very geographically sensitive arena in which Geothermal plays. The data assets being acquired and included in Geothermal Prospector seem well suited to support its role in support of geothermal development. NREL is also to be commended for the versatility of OpenCarto, and the ability to reuse that architectural foundation for a diverse array of useful apps, including this one.

PI Response:

No response entered.

Reviewer 23638

Score: 3.0

Comment: The use of OpenCarto is an appropriate method of having a way of spatially displaying and analyzing data that are relevant to geothermal exploration and development activities. The system requires that some data are contained within the system, such as the BLM land use data. It will be critical to make sure that these data are updated regularly to make sure that the information contained within the system is up to date. It would be helpful to identify which data types have been loaded into Geothermal Prospector, how recently they have been updated, what are the sources of the information for each data type. This information will be supplemented through access to the NGDS and other relevant databases. It will be really helpful for the system to have an easy-to-use (i.e., drop down) set of data options built into the user interface so that the user can put together a customized set of data (or utilize a series of preset groups) that can be overlain on each other spatially. It will also be useful to have a way to download the data and displays in a way that the information can be used outside of OpenCarto if the user chooses to do so. More interaction with the prospective user community will provide useful feedback as to the types of data and analysis tools that are wanted.

PI Response:

No response entered.

Reviewer 23640

Score: 4.0

Comment: Leveraging the OpenCarto platform to support the development of this project presents a low cost, least time development pathway. I am concerned at the need to have data stored locally for this project to perform analysis, however, the results as demonstrated are considerable and offset any worries I have.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23437

Score: 4.0

Comment: The project appears to be progressing reasonably; tasks are being consistently completed timely and with useful and relevant results. All aspects appear heading toward successful achievement of technical goals. The analytic features and capabilities being added as the project proceeds should add significant value to the final user experience of Geothermal Prospector. Data set acquisition is proceeding well and the inclusion of support for NGDS-based layers should provide the ability to truly gain a comprehensive picture in support of geothermal development activities.

PI Response:

No response entered.

Reviewer 23638

Score: 4.0

Comment: The work on this project is on schedule and budget. A beta version of this program is already available for trial on the NREL website. This version has a number of data layers that are currently operative, along with two analysis tools (data gap analysis and geothermal analysis). The user interface could be improved to make accessing the different layers a bit easier. It is not clear how external data sources will be queried using this system in its current form. For example, it might be helpful to tie in to the USGS's National Map system (nationalmap.gov) to display the geology - right now, the system has options to display the geology of selected states. Having access to the USGS fault data base (earthquake.usgs.gov/hazards/qfaults/) would also be helpful. As mentioned in an earlier comment, getting user feedback and developing a more robust set of analysis tools will make this a more powerful application.

PI Response:

No response entered.

Reviewer 23640

Score: 3.0

Comment: This project has delivered the application based on the OpenCarto platform and provides considerable data analysis capabilities. The dynamic charting and support for external layers is especially exciting. Finally, the acquisition of 37 data sets with a total of 83 identified for acquisition is a considerable accomplishment. I look forward to seeing this project mature.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23437

Score: 3.5

Comment: Given the information at hand it appears this project is being conducted in a professional manner and in general coordination and collaboration are being handled well. The only possible exception to this is it would appear that coordination with the various NGDS projects (led by BSU, AZGS and SMU) could be better.

PI Response:

No response entered.

Reviewer 23638

Score: 3.0

Comment: The project is on budget and schedule. My main critique is that it appears that this system was developed in-house with little input from the different user groups within the geothermal community. This input would be highly beneficial in designing a more user-friendly interface and developing analysis tools that people will actually use. For this system to be adapted as a integral analysis tool, this type of community interaction is needed. Such communication with different potential geothermal user groups (such as industry, researchers, educators and students, regulatory agencies, legislators, the financial community, and the interested public) will be very useful to garner feedback on what features are wanted/needed, what data types are critical, and how to improve the interface to make the system welcoming to the user. The program is slated to end very soon (in September of this year), so this interaction needs to start right away. It was not clear how this system will be sustained in the future to create data base updates, add new analysis tools, and continue to interact with the geothermal community so that the tool is adopted as a standard way of querying and assessing geothermal data.

PI Response:

No response entered.

Reviewer 23640

Score: 4.0

Comment: This project is on track and moving at a fast pace to reach its milestones. The development of the analytical layers and modeling capabilities, to-date, are considerable and likely due to the effective management of the NREL team.

PI Response:

No response entered.

STRENGTHS

Reviewer 23437

Comment: Capable domain-aware leadership. Capable technical team. Coordination with related activities both within NREL and outside (e.g., NGDS). Reuse of the versatile OpenCarto platform. Ever-expanding set of analytic features and capabilities. Inclusion of external data layers, esp. from NGDS. GIS map based UI makes sense for geothermal. Visualization capabilities shown to date are impressive. Potential for continued growth in data available for analysis.

PI Response:

No response entered.

Reviewer 23638

Comment: The strengths of the project include:

1) A working beta version of Geothermal Prospector is already available for use on the NETL website.

2) The application is a web-based GIS tool that is based on the OpenCarto system.

3) The project is on schedule and within budget.

4) The development team at NETL has experience in developing other geothermal analysis tools.

5) The system has dynamic charting and selected analysis tools available to evaluate user-specified regions that are easily selected using polygon tools.

6) A number of different data sets have already been incorporated into the system, and other data sets will be added in the next few months.

7) It will be possible to utilize data from external databases (such as the NGDS) with this system.

PI Response:

No response entered.

Reviewer 23640

Comment: Dynamic charting, GIS layers, Data visualization export abilities are all considerable strengths which showcase the exceptional capabilities of the project team.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23437

Comment: No significant weaknesses observed.

PI Response:

No response entered.

Reviewer 23638

Comment: Some of the perceived weaknesses of the project include:

1) It is not clear how the system will be sustained after the project end date is reached. It will be critical to have periodic system updates, with new analysis tools and updates of the internal data sources, for this tool to be useful in the future.

2) A more vigorous outreach effort is needed to determine the needs of the varied prospective user communities, and to convey how this system will help the geothermal community in exploration and development activities. Such outreach could be through publications, webinars, demonstrations at geothermal meetings, and e-mails to the prospective user community.

3) A more user-friendly user interface would be helpful. Different classes of data need to be easily identified and toggled on or off.

4) The data gap analysis depends on having all available geothermal data actually accessed by the system - otherwise, the data gap may just be a lack of data seen by the system, rather than an actual lack of information that exists for a given area.

5) The current data analysis tools are quite limited. A more robust set of data analysis methods need to be developed using feedback from the user community to ensure that this system will be utilized.

6) The system needs to have clear links to external databases (such as the NGDS) for it to contain the information needed to conduct rigorous analyses. The origin of the data sets being used need to be easily traced.

7) The best developed application to date is the land use evaluation. For this tool to be relevant, it is essential that changes in land use be updated regularly.

8) Having options to export the map and analysis displays will make this system more widely used.

PI Response:

These are all valid points and ones that we hope to address through ongoing work.

Reviewer 23640

Comment: I am concerned about the process for data acquisition and analysis beyond award period? Additionally, I would like to see this project begin development of resources supporting mobile platforms.

PI Response:

We agree with the concern but ultimately will allow users to keep the data refreshed as a community effort. Mobile platforms is a great idea but beyond our scope; it may be something the private sector can accomplish as an add-on.

IMPROVEMENTS

Reviewer 23437

Comment: Coordinate better with other data-related projects, esp. those aimed at developing and populating NGDS.

Maintain awareness of data as it enters NGDS and other repositories for geothermal-relevant data assets.

Develop improved methods for mining meaningful data from unstructured data assets - these contain a treasure of data that to date has been locked up in PDFs, PowerPoints and Word documents.

Stay in touch with potential users to uncover needs for new types of analyses that could be supported.

PI Response:

No response entered.

Reviewer 23638

Comment: I have included suggested improvements in my description of project weaknesses.

PI Response:

No response entered.

Reviewer 23640

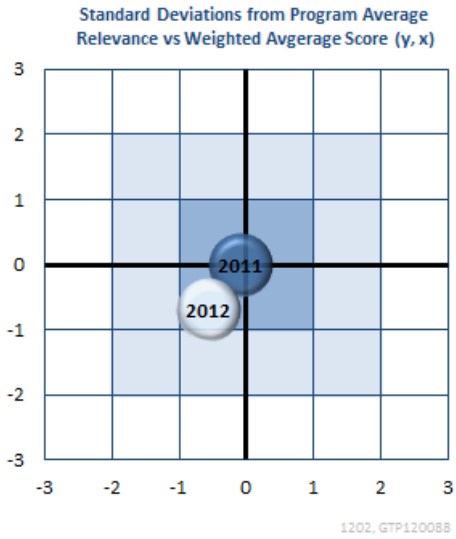
Comment: I recommend that a mobile development effort be included and funded for this project.

PI Response:

No response entered.

TRACERS AND TRACER INTERPRETATION

Review: 2012 Geothermal Technologies Office Peer Review
ID: 1202
Project: Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS Systems
Principal Investigator: Kennedy, Mack
Organization: Lawrence Berkeley National Laboratory
Panel: Tracers and Tracer Interpretation



RELEVANCE/IMPACT OF RESEARCH

Reviewer 23563

Score: 3.0

Comment: Focus on the novel use of natural reactive tracers interacting with newly stimulated rock surfaces (out of equilibrium with the flowing fluid) to assess potential for deriving information on altered permeability and fracture surface areas. This attempts to address a key area (gap) to identify new tracers for evaluating EGS system behavior as well as using tracers to monitor enhanced properties of geochemical reservoirs. The impact could be significant if the role of complex mineralogy can be adequately assessed.

PI Response:

We are in full agreement.

Reviewer 23450

Score: 3.2

Comment: The project objective is rather ambitious to estimate changes in reservoir permeability due to mineral precipitation and dissolution, and estimate the surface area of fluid rock interaction. This is important field operational problem, as it has direct bearing on the ability predict scale formation from rock/water interactions and provide insight on how to use this data in other ways. The lab bulk reactivity experiments are interesting, though it is difficult to know how to use the lab results in interpreting isotopic shifts in fluid composition due to rock/water equilibration following stimulation. Problems encountered with clays should have been anticipated and may limit the practical utility of this approach.

PI Response:

We agree that this project is ambitious, but the problem being addressed is extremely complicated and not well constrained, which requres an ambitious approach. We do not understand the comment regarding the intepretation of isotopic shifts. When interpreting geochemical process (dissolution and precipitation along a fluid flow front), the isotopic compositions aquired by the fluid from the dissolution of differetn mineral phases in the bulk rock provides an additional contraint for interpreting the changing chemical composition of the fluid. For inatance, it is clear form our experiments, that although fluid Sr concentrations approach constant values (implying quasi-equilibrium), precipitation and dissloution

of Sr-bearing phases must still be occuring to account for the continued cahnge in Sr isotopic composition. In our experiemnts, the Sr isotopes clearly indicate that calcite, being very reactive, dissolves early in the experiment, followed by subsequent dissolution of less reactive Sr-bearing phases with isotopic compositions more similar to the bulk rock. This insight into the geochemical processes occuring over time would have been completely lost without the availabiltiy of isotopic data.

There appears to be a common misunderstanding about the presence of clays and their impact on our experiments. The only "problem" with the clays is that they make comparisons of "geometric" surface area estimates of the different grain size fractions with measured BET (adsorption) surface areas difficult , if not impossible. With respect to heat exchange, it is the geometric surface which is more relevant and the clays make it difficult to use BET measurements to constrain the geometric surface area. Nevertheless, our data clearly show that there is a direct relation between mass of crushed grains and the bulk reactivity or release rate of several elements. Therefore, there must be a direct relationship between bulk rectivity and surface area. The troubling question is what is that area, if it's not the geometric area.

Reviewer 23572

Score: 2.0

Comment: Fracture area estimation is a of vital importance, and tracers can contribute to this estimation. Oddly, the non-uniqueness of the area-to-heat-transfer relationship is rarely addressed by tracer investigators; i.e., tracer tests give no information about (average) fracture spacing or orientation. If pursued from early in a project, the use of natural tracers as advocated in this project could help estimate fracture area. This would require careful sampling (composition, temperature, and rate) of injected and produced water for the results to be quantitatively analyzed. This analysis could also be used to estimate change in solid volume in the reservoir, helping to constrain estimates of permeability change (although, crucially, the spatial distribution of this porosity change is not well known; small porosity changes in the matrix would typically affect the matrix permeability more than equal changes would affect fracture permeability). Depending on sampling costs, the proposed analyses could provide much-needed information on stimulation. However, concrete results and detailed methods are not likely to be obtained in the current phase of this research.

PI Response:

It is important to keep in mind that tracers and tracer analyis provide the only known technology for estimating fracture surface areas. Prior studies, related to the Yucca Mountain Project, have clearly demonstrated this capability. Furthermore, as proposed in DePaolo (2006, GCA, v70), simulation studies conducted as part of Task 2 of this project have clearly demonstrated the sensitivity of chemical and isotopic tracers for estimating average fracture spacing, from which surface area of fluid-rock chemical exchange can be estimated from the reservoir sweep volume. It is true that tracer analysis alone cannot estimate fracture orientation. However, one cannot expect a single technique to address the multidue of problems related to understanding engineered geolthermal systems.

With regard to changes in reservoir volume, some clarification from the reviewer would be helpful. It is not clear to us what the relationship is between temperature, tracers and reservoir volume. We are hoping to use natural tracers to evaluate observed changes in permeability (e.g. an increase in well head pressure at a constant injection rate). First by determining if the permeabilty change is being driven primarily by chemistry (e.g. dissolution of asperity minerals) and if so, what minerals are involved and what the long term impact may be on reservoir performance.

Reviewer 23401

Score: 3.0

Comment: Important topics and presenter displayed a good awareness of the need to get laboratory work into the field.

PI Response:

We agree and it is hoped that we will be able to apply what we are learning from the laboratory experiments to real world EGS. But there is still a lot to be understood from additional laboratroy experiments, particularly with respect to bulk reactivity determined from flow through reactors and the impact on bulk reactivity related to different fluid compositions, particularly fluid compositions that are closer to equilbrium with the rock phase (Task 1.3).

Reviewer 23577

Score: 2.0

Comment: This an interesting concept, but the results don't seem to be field ready at this time. It seems like the laboratory results and modeling are so tenuous that under field conditions the approach is unlikely to be able to determine natural tracers above background noise. With that being said, I think this was important work to do. I have wondered independently about the viability of an approach like this for some time. I am glad to see that it has been evaluated. The project would benefit from hypothetical analyses or models of synthetic fractures to look at the viability of the approach. I would be even better if the approach incorporated fracture surfaces into the lab studies.

PI Response:

We are also concerned about the sensitivity of our approach when the injected fluids are not far out of equilibrium with the reservoir lithologies. Task 1.3 was porposed to address this issue in the third year of funding (slide 8 of review presntation). To incorporate fracture surfaces into the lab studies, we have already initiated bulk reactivity experiments using flow through reactor cells in which fresh fracture surfaces will be exposed to fluid flow.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23563

Score: 2.0

Comment: Initial idea was to quantify reactivity of a number of natural tracers as a function of newly formed surface areas and fold the results into numerical tracer analysis models to gain insight into the value of this new tracer behavior. At first blush this seems reasonable, but was naïve since the possibility that fresh surfaces could expose complex mineralogy to the fluids was missed. Studies characterizing surface minerologies of freshly cleaved reservoir rocks should have been considered up front as well as characterizations of typical fresh debris that may enter the flowing fluid and provide another pathway to interact with the tracers in a way that may not reflect the new surface area.The influence of surface topology on reactivity rates could be examined.

PI Response:

To some extent we agree with this comment. However, we were not naïve with respect to the complex mineralogy. The intent of the proposal was to evaluate our ability to characterize the reactivity of the bulk (complex) system and evaluate sensitivity of the bulk reactivity as a function of surface area, temperature and fluid composition. At that time, we did not have access to a flow through reaction cell. So we opted to use samples of very different grain sizes to provide the needed wide range in geometric surface area. For comparison, we also conducted a bulk reactivity test using a slab cut from the core sample. The grain size fraction approach proved to be problematic. Not because of the complex mineralogy, but

because of a perceived sample "bias" introduced during the crushing and seiving that provided the different grain size fractions. It appeared that we were losing fine grained reactive phases (e.g. calcite, clays, etc) during sample prep. A different approach was applied in which a constant grain size fraction was run at different water/rock ratios to simulate changing surface area. This approach worked extremely well, clearly demonstrating the strong relationship between reactivity and surface area.

Reviewer 23450

Score: 3.0

Comment: The bulk rock reactivity laboratory experiments utilized specialized equipment to collect high quality data under a range of temperatures. This data was interesting but is complicated by the presence of larger quantities of clays than anticipated in bulk rock. Reactive transport modeling is used to develop techniques to estimate fracture spacing and surface area using bulk reactivity rock/fluid exchange. The lab data is compared with reactive transport model for analysis robustness. This approach seems solid and incorporates the physics of fluid transport in a fractured media with chemical transport and reaction with other chemical species. One critical issue may be the theoretical sensitivity of different tracer and reservoir parameters on tracer response that with the current field sampling and laboratory analytic error that data quality may be insufficient to provide a unique solution to a already non-unique data inversion problem.

PI Response:

The sensitivity ("signal strength") is to be investigated during Task 1.3 (proposed for the 3rd year of funding) by running repeat reactivity eperiemnts using different initial fluid compositions ranging from distilled water to the expected equilibrium composition for the reservoir lithology. Hopefully, we will get a chance to complete this task as it is very important for evaluating anticipated chemical/isotopic responses in real world EGS.

Reviewer 23572

Score: 3.0

Comment: The approach of using dissolution and precipitation of "natural" tracers is very sound and well motivated (I put natural in quotes because the "natural" system would likely be perturbed by injection of nonequilibrium brines). The discussion on grain size and rock composition seems far less sophisticated than the reaction rate analyses. Indeed, to say that finer sieve fractions are "biased" by mineral type is contrary to how most petrologists would think --- almost all fine fractions (< 2 microns) are --- by definition --- clays sensu grain size. I would interpret this not as bias, but as separation or differential sampling; something to be understood and exploited. That said, it does complicate relating reactions, surface area, etc. Finally, of course clays affect reactions disproportionately, and the investigators should have known this a priority. The slab geometry seems most likely to be representative. Specific surface area could be varied by considering multiple parallel gaps between slabs, or varying gap aperture. In my opinion, the slab approach would be more sensible than the "well-stirred tank" approach used in this project. For this approach to be reasonable, the availability of solid reactants must be presumed to be the limiting factor in the reservoir as well as the laboratory. I didn't find any justification for this small-Damkohler assumption; it's probably unreasonable if there is any reaction outside of the fracture face itself. The "equivalence" of changing fluid volume with changing specific area seems suspect to me, given that their experiments appear to have aqueous fractions what would be expected in a reservoir. Can we extrapolate meaninfully to porosities of a few percent? I can find no attempt to compute estimates of volume changes, associated with permeability.

PI Response:

As reported last year, early in the project we ran a reactivity test on a slab cut from the core. In comparing those results with our grain size fraction experiments, it appeared we were losing fine grained reactive phases (e.g. clay sized particles of calcite, etc) during sample prep (crushing and sieving) - resulting in a sampling "bias". We agree that the slab approach is likely to be more realistic, but it limits the range in surface area. Using the grain size fraction approach, we were able to run experiments with a factor of ten range in estimated geometric surface area, improving the sensitivity in our evaluation of the surface area impact on bulk reactivity.

Typically, clay minerals do not complicate the release rates of major elements, because the clay minerals are highly nonreactive compared to the primary rock-forming minerals. Clay minerals are already secondary phases, representing the result of water-rock interaction. Whereas, the primary minerals, which are much further out of equilibrium with the water, are replaced by clays which are thermodynamically stable (near equilibrium) with thee reacting water, by definition.

We are hoping to use natural tracers to evaluate observed changes in permeability (e.g. an increase in well head pressure at a constant injection rate). First by determining if the permeabilty change is being primarily driven by chemistry (e.g. dissolution of asperity minerals) and if so, what minerals are involved and what the long term impact may be on reservoir performance. This work is in progress.

Reviewer 23401

Score: 4.0

Comment: Ambitious research goals but they complement each other and can achieve important synergies if reached.

PI Response:

We appreciate the comment.

Reviewer 23577

Score: 2.0

Comment: This project should have looked at a number of different host rocks and ambient water geochemistries. It is not clear to me how representative the selected rock and water chemistries are. Not sure why this was not done because it would have helped to evaluate if there is any hope that this approach will work. There is a need to look more carefully at path lengths, time of travel and mixing volumes. A static system is fairly unrealistic especially when the contact time needs to be tens of day to come to equilibrium. Under field conditions, it seems like the measured signal will not be significant to rise above the background noise.

PI Response:

The core from Desert Peak was selected because of availability and it represents the lithology in the Desert Peak EGS stimulation zone. Should other systems be evaluated? Yes, ultimately.

Now that we have access to a flow through reaction cell, we are running dynamic reactivity experiments. However, these chemical systems almost never come to true "equilibrium". Instead they approach a dynamic chemical steady-state, where release rates are balanced, more or less, by growth rates of new minerals or adsorption rates on clays, etc., what ever the sinks may be.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23563

Score: 2.0

Comment: Initial effort was to characterize time-dependent sorbing behavior between these tracers and newly formed rock surfaces and connect that information to surface area. However, it was realized that the presence of clay minerals in samples may seriously bias surface areas depending on size fractions as well as reactivity results. This forced a decision to go to one size fraction and use very different rock/fluid ratios to control surface area changes. This was a misstep that could have been avoided. The work seems to be affected by lack of geochemical expertise – complex mineralogy (clays) matters in real reservoirs and needs to be assessed in proposed and planned reactivity studies to establish the feasibility of this idea. This is a gap which needs to be filled. At this point the project seems to progressing along its new track.

PI Response:

(1) We were not trying to characterize time-dependent sorbing behavior between tracers. We were trying to determine if bulk chemical reactivy (e.g. dissolution, precipitation, adsorbtion, etc) could be measured and if so, is bulk reactivity sensitive to surface area, so that it could be used to estimate water-rock-heat exchange in EGS.

(2) There appears to be a common misunderstanding about the presence of clays and their impact on our experiments. The only "problem" with the clays is that they make comparisons of "geometric" surface area estimates of the different grain size fractions with measured BET (adsorption) surface areas difficult , if not impossible. With respect to heat exchange, it is the geometric surface which is more relevant and the clays make it difficult to use BET measurements to constrain the geometric surface area. Nevertheless, our data clearly show that there is a direct relation between mass of crushed grains and the bulk reactivity or release rate of several elements. Therefore, there must be a direct relationship between bulk rectivity and surface area. The troubling question is what is that area, if it's not the geometric area. See other comments above regarding chemical reactivity of clay minerals.

Reviewer 23450

Score: 3.3

Comment: The reactivity measurements represent solid laboratory methods with the experimental data showing good consistency, but complicated by the presence of clays. A modified experimental approach was able to correct for this complication. Data collected with the modified approach should very good trend and good internal consistency. Tracer interpretation techniques developed used three increasingly rigorous methods for reactive tracer analysis. The techniques vary from simple response slope to analytic methods to numerical methods. No examples where given using numerical methods to analyze tracer reaction kinetics or show parametric sensitivity to key variables. Tracer techniques need to be tested with field data to provide researchers with access to operating conditions and concurrent issues of data noise.

PI Response:

We appreciate the constructive comments. We are currently running flow through (dynamic) reactivity experiments to assess, among otherthings, the reaction kinetics.

Reviewer 23572

Score: 2.0

Comment: This project is very near its end. It is not apparent that there will be any detailed results on reaction rates and methods to relate these to volume changes. For this late in the project, the integration with modeling tools and indeed even the proof of concept appears to be lagging.

PI Response:

Sorry, but we respectfully disagree. We have clearly demonstrated that we can get meaningful bulk reactivities, that the bulk reactivty is a strong function of surface area and that adding isotope systems will provide much needed additional constraints on the chemical processes occuring in the reservoir that may be related to changing reservoir permeability. See other comments above.

Reviewer 23401

Score: 3.0

Comment: See other remarks.

PI Response:

Ok.

Reviewer 23577

Score: 3.0

Comment: I am not sure what the ultimate project deliverable will be perhaps a scientific paper or a final report. A great number of experiments have been accomplished along with some modeling. I believe more experiments are required to fully eliminate this approach as not being viable in all geothermal environments. I think that the project might indicate that the use of natural tracers may not work, but the researchers resist saying so.

PI Response:

We agree that more experiments need to be completed to fully evaluate the viability of this approach. Final product will be represented in a number of ways. So far we have one paper published, two in post review revision and three papers presented at scientific conferences, including the annual GRC meeting. The ultimate deliverable, aside from determining viability, will be a field scale demonstration.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23563

Score: 2.0

Comment: Initial effort could have benefited from additional peer review which may have identified the clay issue much earlier and saved time and effort.

PI Response:

No response -- see earlier comments re the "clay problem".

Reviewer 23450

Score: 3.3

Comment: Project should good integration of laboratory testing with numerical modeling/code development. Project metrics showed good management and allocation of project resources.

PI Response:

We thank the reviewer for the positive comment.

Reviewer 23572

Score: 2.0

Comment: It appears very unlikely that the project will deliver detailed reaction data or integrative tools in a few months. The PIs failed to engage with clay geochemists who could have helped them anticipate and correct this problem. The decision to go to varible-liquid formulation of experiments is not well explained and is open to question.

PI Response:

No comment

Reviewer 23401

Score: 3.0

Comment: See other remarks.

PI Response:

Ok

Reviewer 23577

Score: 2.0

Comment: Seems appropriate for project, but it was difficult to tell. My one complaint is that by this time in the project a draft final report(s) should be complete.

PI Response:

See publication list at the end of the Peer Review Summary Report. When we are finished a final report will be written and data, interpretations, and recommendations will be submitted to DOEand the GDR.

STRENGTHS

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23450

Comment: Project benefits from the high caliber of the project personnel and facilities, results clearly demonstrate this.

PI Response:

Thank you!!

Reviewer 23572

Comment: Natural isotopes are an interesting approach, and the Sr/Rb system investigated in this project is widely used in isotope hydrogeology with frequent success. The investigators appear to be highly competent in benchtop reaction experiments.

PI Response:

We agree, thank you.

Reviewer 23401

Comment: Emphasis on quality research is tempered with awareness of practical application. Thoughtful adaptation to research surprises.

PI Response:

We agree, the pratcicallity of this approach is part of Task 1.3, where reactivity is evaluated as a function of initial fluid composition.

Reviewer 23577

Comment: Good approach for EGS in that it relies on tracers generated by fracing to serve as diagnostic of the fracture network. Good fundamental data set.

PI Response:

Thank you.

WEAKNESSES

Reviewer 23563

Comment: Geochemical expertise should be added.

PI Response:

Seriously?

Reviewer 23450

Comment: While the TOUGH family of codes are excellent research tools, the project lacks an aspect of technology transfer and implementation into commercial numerical codes used by the domestic industry. The project's relevance to industry would be greatly enhanced by some effort for numerical simulation technology (the mathematics and implementation) to commercial geothermal simulators.

PI Response:

TOUGH2 family of codes has been used at more than 500 organizations world wide. The code, including its source code, is available from technology transfer sites at both DOE and LBNL. The code with the added developments generated by this project will also be made available from the same sites. Furthermore, the analytical solutions used in this project were documented and published as a journal article.

Reviewer 23572

Comment: The complex Desert Peaks lithologies appear to have confounded the experiments, making them difficult to interpret. The team appears to lack petrologic expertise, especially with respect to clay mineralogy. No composition data are reported. The experiments with varied aqueous fraction may be too far from reservoir aq-solid ratios to be meaningful.

PI Response:

(1) Yes Desert Peak, like all potential EGS sites, has a very complex lithology - furthermore at a real EGS site the lithology may be a variable along the stimulated flow path, adding further complications.
(2) See earlier comments re the "clay problem".
(3) There is no room in the presentation or summary report to provide the large chemical data set that has been obtained over the course of this project.
(4) See slide 8: Task 1.3 was designed to address this issue. But Task 1.3 is a third year project.

Reviewer 23401

Comment: More emphasis on making computer codes accessible and documenting their limitations is needed for maximum utility of that work.

PI Response:

See response to Reviewer 23450 above.

Reviewer 23577

Comment: Not sure how broadly applicable this approach is. How does source concentration become established if geometry of fracture is not known? Clay is an apparent contaminant in lab experiments, drilling fluids contain large quantities of clay, how will this affect results? If the approach can't be proven in batch lab experiments, how can it possibly work in a field situation? Basic problem is too many unknowns.

PI Response:

Clay is not a contaminant. Also see all earlier responses regarding the "clay problem". Whether or not this approach will work in the field is what we're trrying to determine. There are definitley too many unknowns - this is not a one-dimension physics problem, but that does not mean we should through up our hands and go home.

IMPROVEMENTS

Reviewer 23563

Comment: Add geochemical expertise.

PI Response:

Seriously?

Reviewer 23450

Comment: See Weaknesses.

PI Response:

Ok

Reviewer 23572

Comment: Engage a clay mineralogist and/or isotope hydrogeologist for future work --- someone who works with field isotope data, not just experimental data (and "real" rocks). Consider mineralogy-specific tests for key components. Use multiple fractures or apertures rather than crushing to vary specific area.

PI Response:

Among us we have more than 80 years of combined field and laboratory experience with chemical and isotope data. Not sure what is meant by mineralogy-specific tests for key components. We are evalauting the isotopic and chemical data for mineral-water equilibration to identify the key minerals involved in the bulk reactivity of the system. The disadvantage in using multiple fractures instead of multilple grain size fractions is a reduced range in surface area that can be evaluated quickly. Using the flow through reactors, we will be focusing on a "multiple fracture" approach, to gain a better understanding of the kinetics and associated limitations to the approach.

Reviewer 23401

Comment: An one-day LBL workshop for tracer specialists would be worthwhile.

PI Response:

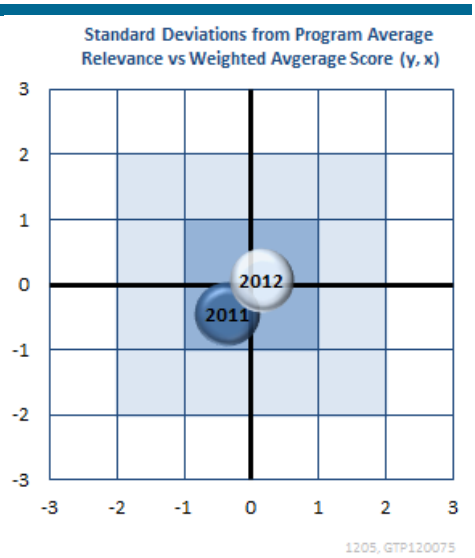
Sounds like a good idea, we would be happy to serve as hosts.

Reviewer 23577

Comment: There needs to me more thought and study put into actually trying to represent a field test through modeling and more realistic lab experiments. This would probably help to eliminate this approach as a viable alternative to introduced tracers.

PI Response:

This is not meant to be a viable alternative to introduced tracers. Instead, as pointed out in the Summary report, this project is meant to compliment introduced tracers. As far as we know, as of yet, there is not a viable alternative tracer, introduced or otherwise, available for measuring water-rock-heat exchange along a reservoir flow path. Hopefully, some day we will get to that point, but not without trying and testing many alternatives. What do you suppose will be the impact of the "clay problem" on introduced sorbing tracers?



Review: 2012 Geothermal Technologies Office Peer Review
ID: 1205
Project: Advancing Reactive Tracer Methods for Measuring Thermal Evolution in CO2- and Water-Based Geothermal Reservoirs
Principal Investigator: Hull, Laurence
Organization: Idaho National Laboratory
Panel: Tracers and Tracer Interpretation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23563

Score: 2.0

Comment: This project is about development of reactive tracers to characterize thermal evolution. This is a long sought goal, however, and incremental progress seems to be the norm. This project (near completion) has added some progress by systematically exposing the range of simple kinetics parameters which reactive tracers must have to provide some value for characterizing reservoir cooling.

PI Response:

Reviewer 23450

Score: 3.8

Comment: As many domestic fields mature, the importance of managing injection and minimizing thermal drawdown is a key operational concern. the research project addresses the theoretical and practical utility of using reactive tracers to interrogate the fracture area between an injection and production well. the development of new tracers is a pressing need, as tracers are used in field tests, after sufficient time they establish a background level, complicating using the same tracer again. The field test at Raft River is very relevant, as it tests a tracer in a dynamic, field operating context with fully developed flow paths between the sources and sinks. The software developed to estimate flow capacity vs. flow storage is very relevant, providing a tool for basic interpretation of tracer data using current models and analytic methods.

PI Response:

Reviewer 23572

Score: 2.0

Comment: The project is clearly relevant to the fracture characterization task, and its use of field data (test "coordinated") with industry increases its impact. However, there is little innovation apparent to this reviewer. No novel tracers or tracer combinations were used. The analytical solutions are not advanced, although providing a software package to industry is useful and may help lower barriers to use of tracer tests for fracture characterization.

PI Response:

Reviewer 23401

Score: 4.0

Comment: See other remarks.

PI Response:

Reviewer 23577

Score: 4.0

Comment: Piping and cooling of the reservoir due to preferential flow and other factors is a significant problem for managing many geothermal reservoirs. This project used an approach that coupled laboratory data and modeling to design and test a live demonstration at an active geothermal field of innovative tracers. The results look promising and relevant. This approach needs more testing by industry on different geothermal fields in order to have a significant impact on industry.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23563

Score: 2.0

Comment: The overall approach is modeling centric to uncover basic tracer parameters (dealing with reactivity) that might usefully be used to monitor thermal drawdown. The window of tracer parameters seems limited from a pure kinetics point of view from using a first order kinetics with an effective temperature along the fracture path. Claim is made that reduced models (e.g., single fractures) are good enough to illuminate issues. While this is correct for some basic screening, real world 3-D models (which now exist) with fracture network representations and realistic histories should be considered as well to test ranges of kinetics parameters in situations with more complex pathways (residence times) and temperature distributions. This may not be a case where if it does not work in a simple model it won't work in a more complex situation. This should be at least checked.

PI Response:

Reviewer 23450

Score: 3.5

Comment: The project plan included the numerical scoping of tracer parameters for test design and tracer selection. This effort avoided field testing that would not have provided meaningful results. the question of fracture area between a source and sink well doublet is of great practical importance to field operators. It will be critical to proper egs stimulation design, execution, flow back, and test analysis. It is unclear from the work completed to date if tracers alone can resolve a network of fractures. The field test at Raft River collected an excellent and internally consistent data set. This data set would benefit by a reservoir engineering analysis mass/energy balance to estimate the minimum fracture area required between a well doublet to match the observed production temperature using the collected tracer data. The software developed to analyze tracer return data is strongly supported. Industry is in need of robust, standard tools to analyze field tracer data. Continued updates and the incorporation of new analysis methods to this software is encouraged.

PI Response:

Reviewer 23572

Score: 2.0

Comment: Although the approach is sound, the technology is more or less off-the-shelf. The analytic solutions that were coded in MATLAB are well known (at least as far as I can tell from the papers and the materials provided). It would be better to use public license software (like FreeMat or SAGE) and provide source code rather than a precompiled package based on proprietary software. From available papers, it appears that much of the interpretation is qualitative. Where quantitative results are presented (e.g., temperatures in the peer review presentation), the match appears to be "by eye" rather than a formal inverse. It is not clear if or how data from various tracers are integrated in a consistent way.

PI Response:

Reviewer 23401

Score: 3.0

Comment: See other remarks.

PI Response:

Reviewer 23577

Score: 3.0

Comment: Very nice approach that was well thought out. It involved cost sharing with an industrial client that greatly improved the usefulness of the testing. Pre-modeling and post analysis of the data is a very useful way of focusing the test design and helping to ensure that the results ended up being useful. This was a well designed and implemented project.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23563

Score: 2.0

Comment: Project has produced a collection of useful computational tools and results to screen tracer kinetic parameters against two end point ideal models: a single fracture and a collection of interacting planar fractures (more like a porous medium). The assumption these two end points bracket real world models (although a reasonable starting point) should be challenged. Only a simple reactive first order kinetics model has been considered in the latest study. Some recent work by the same group suggests a tracer that degrades in consecutive steps may be interesting. Also more complicated (realistic) fracture earth models might be considered where a multiplicity of heterogeneous flow paths are modeled as well as a fuller treatment of the coupled processes of fluid transport, heat flow and even fracture alteration are included. These treatments are already seen being used in the oil industry and they are part of the DOE Geothermal portfolio. It is worthwhile considering if this more sophisticated approach could be undertaken to study thermal drawdown for a mature geothermal field model where there is reasonable characterization (or more could be done) and a long production history. Or even try a sophisticated test bed model as discussed by Becker etal.

PI Response:

Reviewer 23450

Score: 3.7

Comment: The project had accomplished its goals, demonstrated good project planning and execution, and achieved good progress. A successful field test with a reactive tracer showed very good agreement with theoretical models and observed field temperatures. The web based software to conduct basic tracer return analysis is strongly encouraged and also is keeping this software updated with new analysis techniques, flow regimes, fracture network descriptions, etc.

PI Response:

Reviewer 23572

Score: 3.0

Comment: The project appears to be delivering the desired projects, allowing for retracted funds.

PI Response:

Reviewer 23401

Score: 4.0

Comment: See other remarks.

PI Response:

Reviewer 23577

Score: 3.0

Comment: Very useful results and a nice story for the GTO. The progress was timely and appropriate. The results almost look too good. Another test at a different site would have helped define the robustness of this approach.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23563

Score: 3.0

Comment: Complete – all money spent. Followed schedule.

PI Response:

Reviewer 23450

Score: 3.6

Comment: The project management seemed effective, was able to collect a high quality data set from the Raft River field tests, coordinate the lab development of new tracers, and develop web-based software to analyze tracer return data. Goals were meet, scheduled kept, and budgets burn rates closely managed.

PI Response:

Reviewer 23572

Score: 4.0

Comment: Excellent handling of funding changes and coordination with a field testing program.

PI Response:

Reviewer 23401

Score: 3.0

Comment: See other remarks.

PI Response:

Reviewer 23577

Score: 4.0

Comment: Very nice management job. On time and on budget. Cost effective use of dollars for products received. Able to get through the lab and field phases in a timely manner.

PI Response:

STRENGTHS

Reviewer 23563

Comment: None in particular - study could have been done long ago.

PI Response:

Reviewer 23450

Comment: The project addressed several interrelated but distinct problems related to tracer research and was able to do so effectively. It is unfortunate the project scope and funding was reprogrammed. Lab based development of new tracers with some level of customization shows promise and demonstrates cutting edge activities. The successful field test at Raft River demonstrates excellent organizational and planning. The software development required close coordination between the scientists and programmers and is a process that requires attention. The ability to coordinate and manage an interdisciplinary team is one clear strength.

PI Response:

Reviewer 23572

Comment: 1. Promulgation of an analysis method as a software package.

2. Demonstration with a field test.

3. Demonstrated competence.

PI Response:

Reviewer 23401

Comment: Addressed high-priority need, well thought-out approach.
PI Response:

Reviewer 23577

Comment: Applied approach helping to solve a real world problem at an actual geothermal field. Seems like industry will welcome this approach for field management of thermal break through.

PI Response:

WEAKNESSES

Reviewer 23563

Comment: Consider more complex scenarios with effects of realistic temperature profiles.

PI Response:

Reviewer 23450

Comment: No indication of project weakness was noted.

PI Response:

Reviewer 23572

Comment: 1. No advance in analytical solutions per se.

2. Continued use of very simple fracture geometry models; did not consider alternative lumped models e.g. with shape factors for nonslab matrix geometries.

3. No new tracers.

4. Distribution of compiled, proprietary-platform (MATLAB) code.

PI Response:

Reviewer 23401

Comment: Accessibility and dissemination of tools resulting from work (outreach) is less than ideal.

PI Response:

Reviewer 23577

Comment: It would be nice if a second field demo could have been run to look at thermal drawdown. A summary report with all software is needed, this may be planned but it was not clear if this was the case or not.

PI Response:

IMPROVEMENTS

Reviewer 23563

Comment: Add studies of more complex models and other possible kinetics.

PI Response:

Reviewer 23450

Comment: The project would benefit by the inclusion of reservoir engineering. A reservoir engineer would provide an understanding of Darcy and fracture flow principles and how the tracer return data can be interpreted in a fashion consistent with reservoir engineering.

PI Response:

Reviewer 23572

Comment: 1. Consider more flexible, lumped parameter heat and mass transport models.

2. Distribute source code for an open source analysis tool.

Probably not relevant at this late time.

PI Response:

Reviewer 23401

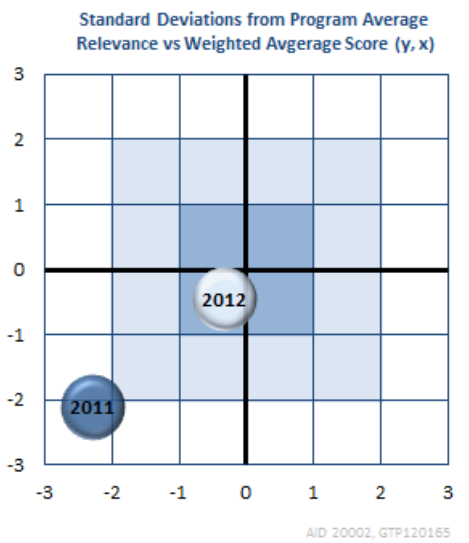
Comment: Project complete, but a follow-on to bring DOE-funded tracer developments would be useful.

PI Response:

Reviewer 23577

Comment: Involve a user interface in software development. Application of the approach at another site would be useful. The results need to be published in a peer reviewed journal.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: AID 20002
Project: Using Thermally Degrading, Partitioning and Nonreactive Tracers to Determine Temperature Distribution and Fracture/Heat Transfer Surface Area in Geothermal Reservoirs
Principal Investigator: Vermuel, Vince
Organization: Pacific Northwest National Laboratory
Panel: Tracers and Tracer Interpretation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23563

Score: 2.0

Comment: The project originally had a well intended goal to study perfluorinated cyclic compounds as thermally degrading tracers. This effort did not work and was subsequently stopped and redirected to interpretive tools testing, validation and documentation. This new effort is useful, but it does not seem to match well with the overriding technical barriers for Geothermal Energy except perhaps for new tracer methodology which has to embrace modeling. However, this modeling already goes on to some degree in most tracer projects. The impact here may be a consolidation of the tools and efforts of others with the addition of a higher degree of testing including actual field studies.

PI Response:

We are focused on developing tools to estimate fracture surface area from reactive tracers and temperature distributions from thermally-degrading tracers. Most previous tracer applications have focused on swept volume and interwell connectivity (sweep efficiency) from conservative tracers. The interpretation of reactive tracer responses relative to conservative tracer responses to extract surface area and temperature distribution information is where we believe we are making an impact.

Reviewer 23450

Score: 3.5

Comment: This project is tasked with developing interpretive tools for evaluating reactive and thermally degrading tracers and to use this test data to estimate the fracture area, fracture spacing and the resulting temperature distribution in the reservoir. The project examined analytic and numerical methods to extract information from the tracer data for single well inject/produce tests and injection-production well doublet. These are important questions for domestic geothermal operators and the requisite tools to analyze field tracer data. It is unclear if the tools and software developed from this project will be available to the industry?

PI Response:

Any tools we develop will be available to the industry, but it is important to point out that we do not have significant resources to devote to development of user-friendly interfaces or model documentation. Thus, we are using existing platforms to the extent possible.

Reviewer 23572

Score: 3.0

Comment: Improved analysis methods (using a suite of sorbing, decaying, and "ideal" compounds) can help to delineate reservoir stimulation, productivity, and temperature. This project focuses on modeling and interpretation rather than experiments or field projects. The impact would be increased if they were available in a freely available, open-licensed software package. The DOE policy of continuing to charge for TOUGH licenses (along with that simulator's horrible interface) decreases the value of extensions based on TOUGH.

PI Response:

Tough2 and ToughReact were developed at LBNL and are available from DOE's Energy Science and Technology Software Center for a one-time license fee and have discounted / nominal pricing for government and non-commercial / partner use. The source code is also available along with the executables with the license (unlike some proprietary codes) and was selected for its capabilities and wide spread use in published geothermal reservoir research. These codes are supported by LBNL with workshops, planned updates, and utility programs (some are free). Third party applications are also available for more user-friendly simulator input file preparation (e.g. PetraSim for ToughReact has a GUI interface).

Reviewer 23401

Score: 2.0

Comment: Impact mitigated by slow progress on original plan, but a strong finish can raise this project's impact several notches.

PI Response:

No response

Reviewer 23577

Score: 3.0

Comment: The work had a major redirect after last years review. One year is not sufficient to make a lot of progress on a high impact project. Nevertheless in this short time the project has pulled together a good collaboration with partners having field tracer data.

PI Response:

No response.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23563

Score: 3.0

Comment: The project has assembled numerous interpretive tools for both inter-well and single well applications and is pursuing systematic testing, validation and documentation using known data, including actual field studies. Under the new project re-direction, this seems an appropriate approach which will accomplish the stated goals.

PI Response:

No response

Reviewer 23450

Score: 3.3

Comment: The project approach seems very through, well thought out, and follows a logical progression. The 'Refined 2-D and 3-D numerical modeling' is on target to use such tools to infer complex fracture geometry and coupled heat/mass/reactive/flow modeling. Some of the slides used acronyms without a key, resulting in less than complete understanding.

The field test at Soda Lake is interesting and this research group was the only one that was able to make an estimate of the fracture area observed from the reactive tracer data. More estimates of observed fracture area is needed to gather some sense of the magnitude and distribution observed in developed reservoirs.

The mathematical outlines provided have a great deal in common with reservoir engineering pressure transient analysis. There is a great deal to be gained from reducing a complex family of theoretical reactive tracer response curves to a dimensionless set. Reduction of complex analytic relationships to type curves is extremely power and useful to practicing engineers.

PI Response:

We apologize for the use of acronyms without definitions. We will continue to pursue field opportunities to use reactive tracers.

Reviewer 23572

Score: 3.0

Comment: The investigators have a record of accomplishment and competence in this area. The use of nonfractured models for EGS systems --- not even evaluating them -- is surprising to me (of course, dual porosity does not treat discrete fractures, with their much different Peclet, Damkohler, and Nusselt numbers). The approach seems perfectly reasonable, but not especially innovative. Inverse methods (or analysis) are not very well described in materials at my disposal.

PI Response:

We are not sure what the reviewer means by "nonfractured models". Our models treat the system as a fractured domain, and we estimate average fracture network parameters such as surface area to volume ratio and fracture spacing. Perhaps the issue is that we are not using a discrete fracture network model, which we do not consider appropriate because the information to support such a model is generally lacking. Also we do not believe our model parameter estimates would be significantly improved by the use of a discrete fracture model. We agree that our inverse methods should be better documented, and we intend to do this in our final project report.

Reviewer 23401

Score: 3.0

Comment: See other remarks.

PI Response:

No response

Reviewer 23577

Score: 2.0

Comment: The objective to develop interpretive tools that can be used to evaluate reactive tracer test data sets and provide improved understand temp, fracture spacing, etc. The slide describing the scientific/Technical Approach was very busy, it is unclear. How will the results of this approach will be made available in a meaningful manner?

PI Response:

We plan to document the approach in a final report and hopefully in a set of peer-reviewed journal articles.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23563

Score: 3.0

Comment: Original scope of project was to address fracture surface area using perflourinated cyclic hydrocarbons that thermally degrade. This was not successfully demonstrated and the project shifted to interpretive tools development, testing and validation against various data sets including field data. This task has importance for capturing numerous tools being developed by many groups, testing and validating them against data and providing documentation. The work is systematic and covers all levels of modeling from purely analytical to sophisticated 3-D models . However, the effort needs an endpoint for completion including inclusion into the repository and that seems to be in 2012.

PI Response:

We agree - no response

Reviewer 23450

Score: 3.4

Comment: Project shows good progress to stated objectives and goals with the collection of data set from Soda Lake. Review of the semi-analytic interpretation of the Soda Lake test raises the issue of solution uniqueness. Field data has several sources of noise which has sufficient data scatter to compound the problem of solution uniqueness. It would seem prudent to develop methods to filter field data to reduce noise and improve solution matches.

One key accomplishment was the estimate of the fracture area observed from the reactive tracer data at Soda Lake. The concept of surface area to volume ratio is useful for a semi-quantitative measure of hydraulically effective fracture intensity. More estimates of these kinds are needed in more diverse settings to better understand fracture properties in real reservoirs.

Good project accomplishments for the budget.

PI Response:

We agree that solution uniqueness and the influence of data noise/scatter are important, and we made some cursory efforts to address (or at least identify) these issues. However, filtering of data goes beyond the scope of this project. We agree that more field reactive tracer data and more estimates of surface area to volume ratio are needed.

Reviewer 23572

Score: 3.0

Comment: The program has been well-designed and run (see management), but overall the goals are relatively modest, given resources. They have accomplished modest but meaningful extensions to existing DOE modeling infrastructure. The preliminary conclusions on cation selection are interesting.

PI Response:

The project redirection from an original high-risk effort has resulted in an apparent lack of accomplishments for a three-year project. We are focused on developing tools to estimate fracture surface area from reactive tracers and temperature distributions from thermally-degrading tracers.

Reviewer 23401

Score: 3.0

Comment: See other remarks.

PI Response:

No response.

Reviewer 23577

Score: 2.0

Comment: Taken on a one year basis the accomplishments look reasonable. However, for a three project the accomplishments and results are lacking. It is not clear to me why another geothermal model is required? RLAP is not really a model and seems to be a bit over sold.

PI Response:

The project redirection from an original high-risk effort has resulted in an apparent lack of accomplishments for a three-year project. We are focused on developing tools to estimate fracture surface area from reactive tracers and temperature distributions from thermally-degrading tracers, which we believe are gaps that exists in current geothermal models. Our models are not intended to displace current models, but rather to supplement them to satisfy these focused objectives, and we encourage the incorporation of our methods into existing, more comprehensive modeling frameworks. RELAP is, in fact, a semi-analytical model that we consider appropriate to obtain estimates of fracture parameters from tracer responses in many situations (but certainly not all; for example, it is not useful for single-well tracer tests). Perhaps the reviewer is commenting that it is not a numerical model?

PROJECT MANAGEMENT/COORDINATION

Reviewer 23563

Score: 3.0

Comment: No discernable problems.

PI Response:

No response

Reviewer 23450

Score: 3.0

Comment: Project was reprogrammed and refocused interpretative tools and methods. This seems prudent given other researchers are developing new tracers. The successful collection of an internally consistent data set at Soda Lake requires the coordination of a number of personnel. Project metrics showed good management and allocation of project resources.

PI Response:

No response

Reviewer 23572

Score: 4.0

Comment: Very well coordinated; no comments.

PI Response:

No response

Reviewer 23401

Score: 2.0

Comment: Project management could have been more aggressive in finding a field test partner to move the project forward faster. Presentation left the impression of a degree of passivity that is reflected in the slow spend.

PI Response:

We thought we were quite successful in this area. The Soda Lake test was the first-ever demonstration of the use of a reactive tracer to estimate fracture surface area in a geothermal system. We have also pursued involvement in the Newberry Crater demonstration project, which is resulting in the planned deployment of cation-exchanging tracers in single-well tracer tests to estimate fracture surface area.

Reviewer 23577

Score: 2.0

Comment: Not sure about project management aspects. Looks like a reasonable job trying to pull the project together at the end. Good incorporation of field data sets into the modeling effort. However, this is a three year project and the accomplishments are not up to par for a 3 year project.

PI Response:

The project redirection from an original high-risk effort has resulted in an apparent lack of accomplishments for a three-year project.

STRENGTHS

Reviewer 23563

Comment: It is a strong team.

PI Response:

No response

Reviewer 23450

Comment: Project benefits from a focus on tracer interpretive tools and methods.

PI Response:

No response

Reviewer 23572

Comment: Expertise. Extensions to existing modeling infrastructure. Well-chosen modeling techniques

PI Response:

No respone

Reviewer 23401

Comment: Redirected focus is on important tools.

PI Response:

No response

Reviewer 23577

Comment: Always nice to compare different modeling approaches.

PI Response:

No response

WEAKNESSES

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response

Reviewer 23450

Comment: The TOUGH family of codes is an excellent research tool; the project lacks an important element of technology transfer and implementation into commercial software for use by the domestic industry. One of the projects stated objectives is the development of tracer interpretive tools, it would clearly benefit by an aspect of technology transfer to the industry. The project's relevance, utility, and adoption by the domestic industry would be greatly enhanced by technology transfer (numerical simulation mathematics, implementation and enhancements of tracer behavior) to commercial geothermal simulators and other software.

PI Response:

We agree, but we do not have the resources to make all of these things happen seamlessly. We will document our efforts to the best of our ability with available resources.

Reviewer 23572

Comment: Continuum approach; no consideration of discrete fractures. Reliance on licensed software rather than free or stand-alone software. Analysis/inversion method not clearly described.

PI Response:

Our models treat the system as a fractured continuum, and we estimate average fracture network parameters such as surface area to volume ratio and fracture spacing. We do not believe our model parameter estimates would be significantly improved by the use of a discrete fracture model, given that the site characterization data needed to develop a discrete fracture network model are generally lacking. ToughReact was selected as one of the numerical simulators based on the simulation requirements developed for this project (see 2010 Project Report - Williams, et al., 2010, Development of Models to Simulate Tracer Behavior in Enhanced Geothermal Systems, PNNL-19523), eventhough it required a one-time license fee. Relatively few numerical simulators have the required capabilities for transient multiphase fluid flow, energy and reactive tracer transport with dual permeability/porosity or multiple interacting continua features. We did use STOMP (a free simulator available from PNNL, see FY2010 report listed above and in backup slides to the review) in this project for certain types of problems. We agree that our inverse methods should be better documented, and we intend to do this in our final project report.

Reviewer 23401

Comment: See other remarks.

PI Response:

No response

Reviewer 23577

Comment: A quantified or side by side comparison of results of models to multiple data sets is needed to better evaluate various models.

PI Response:

We agree, but reactive tracer data sets are very rare (the Soda Lake data set is the only one we are aware of in a true geothermal system). Hopefully, reactive tracers will also be used in the Newberry Crater demonstration project.

IMPROVEMENTS

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response

Reviewer 23450

Comment: Address weaknesses.

PI Response:

No response

Reviewer 23572

Comment: Include discrete fractures. Decouple from licensed software. Implement/describe analysis/inverse method. I endorse using Becker's site for further experiments, if possible.

PI Response:

Our models treat the system as a fractured continuum, and we estimate average fracture network parameters such as surface area to volume ratio and fracture spacing. We do not believe our model parameter estimates would be significantly improved by the use of a discrete fracture model, given that the site characterization data needed to develop a discrete fracture network model are generally lacking. We agree that our inverse methods should be better documented, and we intend to do this in our final project report. We are pursuing collaboration with Matt Becker at his research site.

Reviewer 23401

Comment: See other remarks.

PI Response:

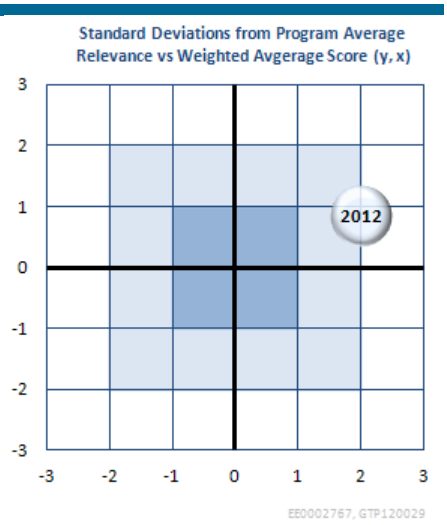
No response

Reviewer 23577

Comment: More modeling runs of different geothermal systems are required to evaluate robustness of modeling approaches.

PI Response:

We agree, and we are pursuing/promoting the use of reactive tracers in more geothermal systems.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002767
Project: Verification of Geothermal Tracer Methods in Highly Constrained Field Experiments
Principal Investigator: Becker, Matthew
Organization: California State University - Long Beach
Panel: Tracers and Tracer Interpretation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23563

Score: 4.0

Comment: This project has exposed the value of an experimental test bed (beyond lab scale) to study and validate geothermal characterization techniques. The concept of such test beds is not new having appeared in other applications. However, the versatility of this facility reminds us such facilities could have enormous value to many projects developing geothermal tracer methods to study critical behaviors including connectivity, sorption, reactivity, heat transport, thermal drawdown, etc. Overall, this project has high value to the Geothermal mission and should be propagated.

PI Response:

No response entered.

Reviewer 23450

Score: 3.8

Comment: The project relevance and impact is impressive for collecting a internally consistent geoscience data set, fund three graduate students all for under $600k. the rich data set, easy field access, small test site, characterized fracture provides a well constrained problem for additional numerical modeling.

PI Response:

No response entered.

Reviewer 23572

Score: 4.0

Comment: The project addresses essential needs in fracture sensing and characterization. The meter-scale experiment spans scales that are not commonly addressed. Laboratory scale is about 100 times smaller, and while it is better constrained than this project the lab scale is too small and "unnatural"; the field scale is 10-100 higher, and while it is therefore more representative it is typically very poorly constrained. The project addresses both heat and mass transport. Whereas many of the particular sensing methods may be inappropriate at the field scale (e.g., multiple observation wells, GPR, and [possibly] periodic rates/pressures), they are somewhat to very innovative and thought provoking --- as well as

being appropriate to the particular project. This project could provide important calibration or checks for other experiments at the lab and field scales.

PI Response:

No response entered.

Reviewer 23401

Score: 4.0

Comment: See other remarks.

PI Response:

No response entered.

Reviewer 23577

Score: 3.0

Comment: This project hosts/develops a characterized field site of a single fracture for conducting tracer tests. Intermediate scale field tests of well defined fractures are critically important for advancing understanding the movement of tracers, this is especially true when coupled with geophysics as it is in this project. The impact of this project could be improved if the site was utilized as a user facility. The use of downhole geophysics would make the knowledge gained more transferable to the geothermal industry.

PI Response:

We agree borehole geophysics would be beneficial, but was not included to constrain the scope of the project.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23563

Score: 4.0

Comment: Constructed an experimental testbed with a five spot pattern with roughly 10 m spacings and a buried horizontal fracture intersecting the wells. In this known setting multiple experiments are being conducted: Periodic hydraulic tests for better connectivity information than std pump tests, GPR studies to image water and saline tracers through the fracture as well as reactive tracers, thermal tests with injection of hot water through the fracture and temperature monitoring outside the matrix using fiber optic distributed temperature sensing. All thermal and tracer transport tests are being subjected to modeling studies for interpretation. In addition a special apparatus has been constructed which allows studies of GPR transmission and reflection behaviors from fractures under known conditions. This type of experimental setup with its flexibility to simulate many interesting scenarios for verification of tracer methods is extremely valuable and should be made available to other groups as well or replicated.

PI Response:

We are working with other PIs in the program (e.g. Reimus, Tang) to test tracers at Altona Flat Rock as funding allows.

Reviewer 23450

Score: 3.6

Comment: The project is organized in a logical progression to test and collect data on the tracer and thermal response of a well instrumented, sub-horizontal fracture. The project was able to collect an impressive amount of pressure transient data, diffusive and reactive tracer responses, and thermal response to hot water injection. These co-located data sets comprise a well documented geoscience dataset for numerical modeling. Effective testing and characterization of the fracture requires an interdisciplinary approach which was utilized in this project. the diverse data sets provide a rich data set to conduct numerical modeling to better understand the interrelated hydraulic and thermal processes occurring. The failure of the reactive and diffusive tracer to work as the matrix porosity was too low could have been mitigated if the Task 5 Modeling and Interpretation had occurred sooner as a subtask of Task 1 Hydraulic Tests. This may have provided indications to modify the tracer test design.

PI Response:

Preliminary modeling indicated that diffusive tracers would work and these models were presented at a prior peer review meeting. However, the matrix porosity was underestimated in the model due to lack of field data (no cores).

Reviewer 23572

Score: 4.0

Comment: The investigators use appropriate instruments, forward models and (largely) interpretive models. The combination of hydraulic, thermal, and radar sensing is well-integrated, innovative, and convincing. The results on periodic hydraulic testing are intriguing. However, they would be more convincing if a little more detail was provided; unfortunately, the materials presented (and publications to date; see management criteria) are not adequate to fully assess this. Classical solutions in e.g. Carslaw and Jaeger give the solution for a homogeneous isotropic solid in terms of ker and kei (of course these are readily adapted using the standard diffus. eqn. permeability--length transforms) -- these give a clear understanding of relations among mobility, storativity, frequency, and investigation distance. The presented materials refer to Monte Carlos inversion. It seems to me a Bayesian inversion makes more sense in this data integration problem. Possibilities include Markov Chain Monte Carlo (if the models are very fast), Ensemble Kalman Filters (if many data must be integrated), or Ensemble Kalmam smoother (if there are not too many data, and the priors are excellent); or perhaps randomized max likelihood (if the models are fairly fast, and adjoint data are available). Of course these are all "Monte Carlo" methods, but in my opinion it is their Bayesian character that is most important.

PI Response:

No response entered.

Reviewer 23401

Score: 4.0

Comment: See other remarks.

PI Response:

No response entered.

Reviewer 23577

Score: 3.0

Comment: Approach is very sound based on an industry approach for site characterization. Hydraulic tests, tracer tests, thermal, Geophysics GPR and modeling all combine to make a nice story. The project is nicely laid out and the results are interesting. Of course it would be nice to have run more tests, particularly downhole geophysics. Improvement to the approach could also be achieved by comparing these results from an intermediate scale test to field work at a geothermal field, i.e. solve an applied problem. Overall, nicely done.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23563

Score: 4.0

Comment: Numerous experiments already accomplished and analyzed. Testing new methods (and even old ones) against ground truth at an interesting scale (well beyond lab bench) has enormous value. Other groups are asking for access to this kind of facility (a sign of success) and this should be followed up.

PI Response:

We are making the facility availble to other users as funding allows.

Reviewer 23450

Score: 3.4

Comment: The project has accomplished many of the stated goals, with the failure of the tracer tests to work in a low porosity system perhaps the greatest disappointment. The work with the ground penetrating radar is interesting, but its relevance is weak as a field tool. It's relevance to better characterize the fracture rugosity as an additional data set provides a needed constraint on the fracture properties in such a small test site. Task 5 Modeling and Interpretation and final project report has yet to be completed. The results, progress, and use of three graduate students for a nominal budget is impressive.

PI Response:

No response entered.

Reviewer 23572

Score: 3.0

Comment: The current results appear to be very good but not completely integrated. Hopefully, this will be done in the remaining project time. The goal is clearly to have a "geomodel" (or better yet, an ensemble of plausible geomodels) that approximately match all observations. This is a highly skilled task, and the researcher should have been identified years ago to train adequately in inverse methods. See scientific approach and management. The results have not been reported in articles, appearing in conference proceedings (some of which are impossible to find with my University's resources). It is to be hoped that this will be corrected.

PI Response:

The results have been presented at conferences and articles are in preparation.

Reviewer 23401

Score: 3.0

Comment: See other remarks.

PI Response:

No response entered.

Reviewer 23577

Score: 3.0

Comment: Field work is logically laid out and performed. Excellent integration of field methods at site. Modeling of the system should not have waited for the very end, pre-modeling may have been very helpful for test design. The model inversion should be very informative. The conclusions of the work seems a little weak. What is the "so what?" factor for the work? Overall, the accomplishments, results and progress represent a good value for the geothermal program.

PI Response:

No response entered.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23563

Score: 4.0

Comment: Project is well thought out and systematically executed.

PI Response:

No response entered.

Reviewer 23450

Score: 3.0

Comment: Project management has a small staff with collaboration with several national labs and universities. The project management did not appear to suffer from the geographically spread out nature of project participants.

PI Response:

No response entered.

Reviewer 23572

Score: 3.0

Comment: This is a small project, and thus easier to manage and it appears to be largely effective. Variances are adequately handled. However, publications appear to be lagging and impact of presentations is good but not outstanding. In addition, inadequate preparation for tackling the inverse problem was a significant oversight.

PI Response:

We disagree that publications are lagging. Publications are typicaly produced toward the end of the project. We are preparing articles for submission now.

Reviewer 23401

Score: 4.0

Comment: See other remarks.

PI Response:

No response entered.

Reviewer 23577

Score: 3.0

Comment: Project management appears to be good. Lots of results and the project appears to be on schedule and budget.

PI Response:

No response entered.

STRENGTHS

Reviewer 23563

Comment: This kind of experimental/modeling validation facility should be very helpful to the Geothermal community especially for developing and assessing new tracers

PI Response:

No response entered.

Reviewer 23450

Comment: The project strengths are the straight forward, logical manner in which a rich geoscience data set was collected using an interdisciplinary approach. the data set has allowed detailed chacterization of a shallow, easily accessible fracture in a well constrained well field. this approach allows detailed data collection of the hydraulic, tracer response (busted), and thermal response of the fracture. The ground penetrating radar to allow detailed fracture characterization of this shallow feature is very interesting. the larger amount of effort by the project staff to work with this data set attests to the importance attached. the detailed characterization will provide needed constraints on numerical modeling activities.

PI Response:

No response entered.

Reviewer 23572

Comment: The strengths have largely been addressed in the relevance and approach section, and will not be repeated in detail here, but merely quickly enumerated:

1. A significant, relevant, mid scale experiment.

2. Multiple, related measurements on a sufficiently dense spatial and temporal scale.

3. Well designed instruments and experiments.

4. Investigators are clearly competent.

5. Pushing hard towards an integrated model.

PI Response:

No response entered.

Reviewer 23401

Comment: Creative approach to up-scaling lab tests to a miniature field scale is a great idea to get at "ground truth."

PI Response:

No response entered.

Reviewer 23577

Comment: The cross over between various data sets is important and may lead to advanced understanding of fracture flow in geothermal systems. Shallow system allows for inexpensive access to subsurface. The site allows the cross over of surface geophysics to subsurface well problems. This is nicely done in this project.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23563

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23450

Comment: The major weakness in this project is not using modeling sooner and more often in the study, examples are: (1) the reactive/diffusive tracer test which did not work due to the matrix porosity being too low. Modeling during the tracer test design may have provided indications to consider alternative tracer tracers, tracer test design before a field test. (2) waiting until Task 5 to conduct Modeling and Interpretation, earlier integration of modeling in the test design, data collection, and data interpretation would provide a tool to use throughout the project.

PI Response:

Modeling was performed early in the project. However, transport parameters were not correctly estimated for lack of field data so some results were not anticipated.

Reviewer 23572

Comment: There are very few weaknesses, and these have been described in relevance and science sections, and to a lesser degree in accomplishments and management. Briefly,

1. From the materials presented, it is not clear that the best current inversion methods are being used.

2. Discussion of the periodic hydraulic testing could be clearer.

3. Publication record is not outstanding.

4. Training for inversion work was not planned for adequately.

PI Response:

No response entered.

Reviewer 23401

Comment: See other remarks.

PI Response:

No response entered.

Reviewer 23577

Comment: Need to integrate the data sets more completely. Pre-modeling would have been very informative and would have added greatly to the story.

PI Response:

Pre modeling was performed and presented at a prior peer-review meeting.

IMPROVEMENTS

Reviewer 23563

Comment: Only to document the facility design and construction for others to follow.

PI Response:

No response entered.

Reviewer 23450

Comment: The only major improvement would be earlier integration of modeling in the project for test design, data interpretation, and as a tool during the project.

PI Response:

Pre modeling was performed and presented at a prior peer-review meeting.

Reviewer 23572

Comment: 1. Consider interacting with GTO researchers at adjacent scales. Could some of the new tracer compounds be tested here? Could we do a "pre-test" for a field demonstration here?

2. In a next phase, could high-frequency seismic be considered here?

3. Use a Bayesian method to get a posteriori model sets -- it is suggested in the material provided, but not explicit.

4. Publish in widely accessible journals.

5. Share data in journal data sections as well as NGDS. GRL would be a great venue.

PI Response:

Discussions with other GTO tracer PIs have been ongoing. The relevance of this site is limited but the near-surface temperature and pressures, however.

Reviewer 23401

Comment: See other remarks.

PI Response:

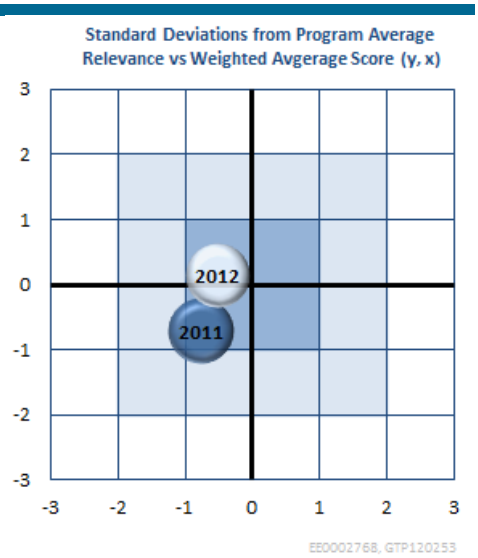
No response entered.

Reviewer 23577

Comment: Peer reviewed publications are critically important. This work needs to get out into the open literature. Its too late for this project, but the use of downhole geophysics for fracture imaging would be useful (not sure if the holes are still open).

PI Response:

We are working on getting pubs out and borehole geophysics is planned for the future, if funding is available.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002768
Project: Quantum Dot Tracers for Use in Engineered Geothermal Systems
Principal Investigator: Rose, Peter
Organization: University of Utah
Panel: Tracers and Tracer Interpretation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23563

Score: 3.0

Comment: Fits need for new/novel tracers based on quantum dots that can withstand geothermal reservoir conditions, potentially supply information beyond connectivity and could be combined in novel ways with other tracers.

PI Response:

No response entered.

Reviewer 23450

Score: 3.8

Comment: This project is very interesting and shows a great deal of promise in several areas. The development of nanoparticles with florescence in the visible spectra allows very low detection limits and the use of a continuous monitoring equipment. Additional properties can be designed into the quantum dots for additional ‘smart’ characteristics. This is potentially a very high impact project and should be closely monitored by GTO for additional support to accelerate commercialization.

PI Response:

I agree.

Reviewer 23572

Score: 3.0

Comment: Quantum dots could help characterize fracture networks because of their ease of detection, and the possibility of tailoring diffusion by size exclusion and sorption by selected ligands.

PI Response:

No response entered.

Reviewer 23577

Score: 3.0

Comment: These quantum dot tracers as advertised offer great promise for characterizing fracture flow in geothermal reservoirs. These particles are exotic and have properties useful for geothermal. The fluorescing in the visible range can result in real time analysis of results. Plus a common wavelength offers great flexibility. Different diameters could be used to evaluate fracture apertures. Reversible sorption would be very useful.

PI Response:

No response entered.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23563

Score: 3.0

Comment: The attraction of quantum dots is their highly tailorable temperature dependent photoluminescence which varies with particle type and size. Program is following a sensible systematic characterization and optimization of material properties relevant for Geothermal Applications (the project team has a strong participation with chemistry expertise). Size dependent photoluminescence (in the visible) and variability with temperature are getting strong consideration which is appropriate. Conservative and reactive species are being explored - again appropriate. Synthesis of kg quantities is a big challenge and they are involved with scaling - again appropriate as this is a big risk factor. Want to go to 100 um sizes via a core-shell structure with maybe several qdots in the core with different functionality. This is an interesting idea for fractures. Injection/ backflow testing in a flow reactor has started as they foresee first tests are single well. I would not jump on field tests too soon. Need new models for QDot transport in fractured media – this is a big problem since QDots are colloidal particles which can agglomerate and stick to rocks. The team's strength in this area is less clear.

PI Response:

I agree that synthesis of kg quantities of quantum dots is a challenge. However, just recently a company was formed based on the patented high-throughput synthesis method developed in the lab of one of the team members (Bartl). The goal of this company (Navillum Nanotechnologies, LLC) is to address this very challenge and produce high-quality quantum dots in large quantities and inexpensively. In June, 2012, Navillum was awarded a DOE Clean Technology Award and our geothermal quantum dot project will greatly benefit from collaborating with Navillum.

Reviewer 23450

Score: 3.4

Comment: The project sequence is well thought out and proceeds logically. The project synthesis of lab quantities of quantum dots, there is a logical progression of standard testing of the physical, chemical and thermal stability of the quantum dots. Additional modifications have been identified in the liqands allowing further development of reactive tracers. Laboratory studies and numerical modeling have been performed to better understand the tracer behavior at reservoir scales with field testing planned. Can the price to manufacture quantum dots be reduced by an order of magnitude or more?

PI Response:

This last question is an important one for anyone working with the commercialization and/or large-scale use of colloidal nanoparticles. Our low cost/high volume methods offer the best approach for cost reduction.

Reviewer 23572

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23577

Score: 3.0

Comment: Good control over quantum dot manufacture, appears that custom dots is feasible. Study of heat effects is important for geothermal applications.

PI Response:

No response entered.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23563

Score: 3.0

Comment: This project is appropriately focusing on the materials science properties of qdots relevant to geothermal applications. The major issues will be synthesis in large enough quantities with well controlled properties and flow in fractured media. They are pursuing scaling ideas for manufacture that could yield kg quantities that appear promising.This is an unsolved problem for many others as well and the DOE effort could provide unique results of general interest. Ligand coating chemistries to control interactions with rocks are underway - the project should carefully monitor similar work in universities and work in another Geothermal Project (Tang). This effort needs to be systematically linked to the development of models to predict transport in porous media. Overall a good start with the team well aware of the key issues, but there is still much to do.

PI Response:

I agree.

Reviewer 23450

Score: 3.8

Comment: Accomplishments have been very encouraging. Project results are well documented and presented. This project shows promise for rapid commercialization and consideration should be given for additional support to accelerate field testing, reduce the cost of quantum dot synthesis, accelerate development of a continuous downhole and surface tracer monitoring in a production environment.

PI Response:

No response entered.

Reviewer 23572

Score: 2.0

Comment: The stability of the dots was demonstrated last year, and was an impressive result. This year only modeling results and limited "flow reactor" results are presented, with no movement toward design or implementation of a field test. The pace of work seems to be slowing significantly.

PI Response:

Admittedly, the rate of progress has slowed. However, the tasks that remain are all in the 'achievable' realm now that the very significant challenge of synthesizing the first aqueous-phase, thermally stable quantum dots has been achieved.

Reviewer 23577

Score: 2.0

Comment: Progress seems OK to reasonable. Lots of time spent on Q D manufacture and testing. More accomplishments and progress is needed on testing of these tracers. Overall the results look very good, just need more effort to get this concept to the next level.

PI Response:

Agreed.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23563

Score: 3.0

Comment: No discernable problems.

PI Response:

No response entered.

Reviewer 23450

Score: 3.0

Comment: Project should good integration of laboratory testing with numerical modeling/code development. Project metrics showed good management and allocation of project resources.

PI Response:

No response entered.

Reviewer 23572

Score: 2.0

Comment: A large group of excellent investigators appears to be cooperating effectively. However, it seems unlikely that the behavior of the dots will be assessed as the project originally proposed.

PI Response:

Admittedly, the objectives have evolved as our experience with the synthesis and testing of the quantum dots has progressed. But, I suspect that there are very few projects wherein the objectives, as originally proposed, were realized.

Reviewer 23577

Score: 2.0

Comment: Seems like project management could be improved. Project planning and execution would have lead to more accomplishments.

PI Response:

No response entered.

STRENGTHS

Reviewer 23563

Comment: Good materials/chemistry expertise.

PI Response:

No response entered.

Reviewer 23450

Comment: Very innovative project with a great deal of promise for addressing the need for new tracers with 'smart' properties, lower detections limits and readily amenable to field continuous tracer monitoring. These are highly desirable properties and should not have to wait for EGS to occur.

PI Response:

The quantum dot tracers will be as useful in conventional geothermal energy as they will be for EGS.

Reviewer 23572

Comment: Promising approach for fracture characterization. Good collaboration.

PI Response:

No response entered.

Reviewer 23577

Comment: This is a novel and new application and it has exciting possibilities for diagnosing geothermal reservoir characteristics. Project team is very capable and well trained. Overall this is a very good project.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23563

Comment: Scaling of materials production is understood as a risk, but maybe not enough.

PI Response:

If this was not expressed then it is felt. The PIs recognize the considerable challenges in up-scaling the synthesis.

Reviewer 23450

Comment: The project is very complex and involves a number of skill sets for one PI and collaboration.

PI Response:

No response entered.

Reviewer 23572

Comment: Which ligands? Will they work? These critical issues appear not to have been addressed in this almost-over project. No flow experiments with dots (just polystrene proxies). The field demonstration appears to be a long way off.

PI Response:

I think that we offered our suggestions for the best ligand candidates at this point. But, this remains a challenge.

Reviewer 23577

Comment: Need to run a field test. A field test of the quantum dots is need to better ascertain their viability under field conditions.

PI Response:

We intend to run a field test, but we first need to complete the laboratory batch and flow experiments and then we need to up-scale the synthesis for the optimum quantum dot.

IMPROVEMENTS

Reviewer 23563

Comment: Materials scaling and validation of properties may need more attention.

PI Response:

No response entered.

Reviewer 23450

Comment: Project would benefit by splitting research elements into separate projects. One focus should be methods and techniques to build custom or ‘smart’ tracers at much lower costs and may benefit by a industrial partner. The PI should continue with fundamental research into quantum dot properties and reactive behavior.

PI Response:

Good suggestion.

Reviewer 23572

Comment: Reviewer did not provide comments for this criterion.

PI Response:

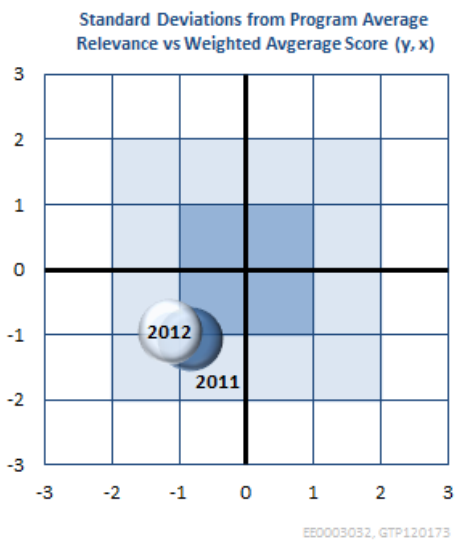
No response entered.

Reviewer 23577

Comment: A practical way of counting needs to be described/discussed. How will the data be collected in the field? Need to be compared side by side to conventional tracers.

PI Response:

Agreed.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0003032
Project: Novel Multidimensional Tracers for Geothermal Inter-Well Diagnostics
Principal Investigator: Tang, Yongchun
Organization: Power, Environmental and Energy Research Institute
Panel: Tracers and Tracer Interpretation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23563

Score: 2.0

Comment: The stated goal is an inclusive approach to uncovering and characterizing new tracer materials using first principles tools such as molecular modeling tools up to and including field testing. New materials are a stated goal of the Geothermal Program, making this part of the program quite relevant. However, the rest of the scope, especially flow testing and field testing, needlessly expands the scope so as to negate the basic materials effort , which to their credit has uncovered some interesting candidates. However, much more can and should be done on basic materials, leaving other tasks to other groups. The score of 2 reflects this overextended scope which will sacrifice overall impact. For the materials effort alone the score would be 3.

PI Response:

There are many conventional tracer systems that have been tested and used in the oil/gas exploration. One of the main questions in developing the geothermal tracer is whether these conventional tracer systems can be extended into the high-temperature geothermal reservoirs. Another key question is how the geothermal tracer system can be applied to generate in-depth subsurface information beyond the well-to-well connectivity. Therefore, our initial approach is to examine existed tracer materials to establish relationships of subsurface information with tracer behavoir using conventional tracer systems. Through this project, we have indeed identified a set of carboxylic tarcers (mono- and di-acidic forms) which have the potentials to become the "smart" tracer to reflect more subsurface information such as surface areas, porosity, etc. Molcular modeling tools are being used to provide fundamental understandings of interaction mechanism of carboxylic tracer with solid surface. Once more detailed tracer-rock interaction schemes can be obtained, we expect to have a better theory which could guide us to material designs of new tracer systems.

Reviewer 23450

Score: 3.2

Comment: The project is to develop, test and screen ‘smart’ geothermal tracers to interrogate reservoir inter-well connectivity for porosity, fracture spacing, migration path distance and develop the user-friendly interpretation tools for application in the field. The development of ‘smart’ tracers represents the next evolution in tracer design and is highly relevant as repeated field tests begin to exhaust the toolbox of conservative and other tracers. Thus new tracers are needed in the pipeline for future tests and to augment test already performed. User-friendly software interpretation tools are needed by geothermal reservoir engineers as another tool for reservoir characterization. A field test is always helpful to verify, validate observations made in the lab, analytically, and numerically. Unfortunately, this project’s identified test site has delays for access.

PI Response:

One of the important findings from our project is the potential of using carboxylic acids (mono- and di-acidic forms) as one of the "smart" tracer systems. Our laboratory works have established theoretical bases to connect the tracer test to the reservoir subsurface conditions. We agree with Reviewer 23450's comment that a field test is helpful to verify, validate observations made in the lab. We are currently identifying an alternated field test site to conduct the field test as proposed.

Reviewer 23572

Score: 3.0

Comment: The formulation of new tracers, and methods to concentrate effluent, can aid in fracture network characterization for EGS or other fracture-dominated systems. The large range of tracers selected (4 classes; 29 compounds) may prove especially useful for systems with many wells or in which repeated testing is needed. The concentration techniques may allow use of smaller doses of tracer, which would tend to decrease background signal in reservoirs where repeated tests are done. Like all tracer techniques, this can give only volume and area of (possibly multiple) fracture(s). Any inference of fracture interconnectivity would have to use more advanced flow models than those presented in this work. Similarly, temperature or pressure transients (if k_matrix > 0 and test time allows) would be needed to estimate spacing in situ. Thus, those claims to impact do not seem very credible to this reviewer.

PI Response:

We agree with Reviewer 23572's comment that more advanced flow models will be needed to obtain detailed fracture interconnectivity, and we are currently testing more interaction patterns of the selected tracers with different rock surfaces to improve the interpretation model. The temperature and pressure profiles of the selected tracers will also be established.

Reviewer 23401

Score: 2.0

Comment: See other remarks.

PI Response:

No response entered.

Reviewer 23577

Score: 2.0

Comment: As laid out the project objectives and relevance is a bit difficult to understand. Are new smart tracers really needed, if so, what are the advantages? It seems like some of the tracers selected may not be useful at high temperatures. The laboratory tests may not be appropriate, especially short term thermal decay tests of benzoic acid.

PI Response:

The selected tracers short term thermal decay are included in the tracer array list to reflect the temperature profile of reservoir. The advantages of using an array of tracer are that we can get more geologic conditions through the tracer test,

if interpretation models to connect the tracer behavoirs with geologic conditions. The purpose of this project is to establish theoretical interpretation tools for these connections, and we believe that we are on-track on doing so.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23563

Score: 2.0

Comment: Adopting the use of first principles computational tools along with experimental validations to gain fundamental understanding of new tracer interactions with rock and fluids is a suitable strategy to help fulfil a key geothermal gap. The project has identified carboxylic tracers as potential new candidates and studied a novel, highly sensitive detection method (hollow fibers) to find them in low concentrations of produced fluids. However, this effort is diluted by intended studies of flow behavior and even planning for a field test. This project is more valuable if it focuses on basic materials science issues having to do with expanding the class of suitable tracers. If the focus were just materials the score would be a 3.

PI Response:

We value our program of a multidisiplinary effort including theoretical studies, laboratory tests and field validation to develop interpretation models for an array of tracers, suitable for the Enhanced Geothermal Program. Expanding the class of new suitable tracer candidates rely on our better understandings of the reaction mechanism of selected tracers with the rock surfaces.

Reviewer 23450

Score: 3.4

Comment: The approach appears solid with the standard investigative suite of experimental, analytical and numerical approaches. Integration of these approaches has identified characteristics of tracers that are favorable to estimating the pore volume, porosity, fracture surface area and fracture spacing. While theoretical models provide guidance that ‘smart’ tracers can provide information of these reservoir variables, there is still the practical difficulties. Primary among these are collecting tracer data with sufficient temporal resolution to provide a rich enough data set to allow advanced analysis methods to use derivative methods. Perhaps concurrent with ‘smart’ tracer development is the development of continuous monitoring equipment that can be installed in a production environment. The development of the hollow-fiber liquid-liquid microextraction technique is innovate and will allow the use of smaller slugs of tracer and increased detection limits.

PI Response:

We fully agree with Reviewer 23450's comment that the developmnet of continuous monitoring devices and/or methods that can be installed in a production environment will be tremendously useful for the tracer tests. At the current stage, our tracer calibration will have to rely on the on-site sample collection with off-site GC/ECD laboratorial sample analyses. A skid-mounted analytic device coupling with our HF-LLME pre-concentration tracer technique will be of great interests to the geothermal program.

Reviewer 23572

Score: 3.0

Comment: The score in this segment mainly reflects the tracer formulation and concentration methods -- not analysis or the field project. The analysis is not novel. The field project is far behind schedule, and might be considered for defunding. However, the tracer formulation is interesting enough to warrant a good score. The approach of screening and measurement of adsorption seem sound. There are a variety of basic shapes (e.g., carboxylic and benzoic) which one might expect to have different sorption behavior. This could provide high contrasts in retardation, perhaps improving estimates of A_v. The concentration method appears useful, but I have little expertise in the chemistry or analytical precision required. It might be wise to consider minerals other than quartz in some experiments.

PI Response:

We are currently investigate the interaction of our selected carboxylic tracers with the carbonated surface, which is another one of major subsurface structures. It is anticipated the interation between tracer-carbonate will be even stronger than that with the silica surface, such that the retardation difference could be enhanced. Comparison of the interaction patterns on different mineral surface should provide us more information as suggested by the Reviewer 23572. We have also identified an alternative field test site to test our developing tracer system. The expected starting date for the field test is on September 2012.

Reviewer 23401

Score: 2.0

Comment: See other remarks.

PI Response:

No response entered.

Reviewer 23577

Score: 2.0

Comment: An aggressive scope is laid out, that includes:
1. Novel tracer detection and analysis tools.
2. Fundamental understandings between tracers and subsurface.
3. Laboratory protocol to define tracer systems.
4. Integrated multiple tracer system.

It does not appear that the PI has strong enough background in conducting field tests. Good integration with industry. However, the laboratory strength needs to be coupled with a more realistic look at field conditions and the duration and harshness of thermal/aqueous environments in geothermal field. The utility of the smart tracer approach was not demonstrated. What will it do that conventional tracers cannot do?

PI Response:

Most of the conventional tracers are conservative, which are mainly used to determine the well-to-well connectivity. Our developing "smart" tracers, if they work, should be able to predict more reservoir information.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23563

Score: 2.0

Comment: Exploring use of first principles computational tools to gain fundamental understanding of tracer interactions with rock and fluids and identify new materials, a key geothermal gap. This is a key contribution from this project. However, the project scope includes many other tasks, including field testing. Strongly suggest this project should concentrate on understanding novel tracer properties related to sorption, reactions, partitioning, etc. and not be diverted into taking a fully integrated approach covering synthesis, materials characterizations, flow testing, modeling and field testing which other groups are better prepared to take on. In fact this project is ill-prepared to assume field testing.

PI Response:

Indeed, fundamental understandings about the tracer properties related to sorption, reaction, and partitioning in the subsurfae are crucial for the molecular designs of novel tracers. We are currently carring our more computational simulation studies to obtain better understandings about interaction patterns of selected tracer condidates with different rock surfaces. Nevertheless, we believe that laboratorial and field validations of our developing interpretation models for novel tracer designs are also improtant.

Reviewer 23450

Score: 2.8

Comment: Laboratory accomplishments have identified select tracers with properties that can selectively react with a fracture surface mineralogy. Molecular modeling has confirmed this and allowed understanding of the chemical-physical processes involved. This information has been combined with analytical models to develop physical constants for use with the selected tracers. One very interesting result is the insight that smaller slugs can provide more detailed information if coupled with improved detection limits.

PI Response:

Potentials of using less concentrated tracer to reflecting multiple-paths of the subsurface structures is one of important findings from our studies. This could have both economic and environmental beneficials for the large-scale tracer tests in the field operations. Our developing HF-LLME pre-concentration method and established multiple-path theoretical models could have important impacts on reducing the amount of tracers.

Reviewer 23572

Score: 2.0

Comment: The progress on tracer formulation and characterization appears good. The concentration work appears adequate. Flow experiments convincingly validate retardation experiments, although the interpretation of multiple paths is not wholly convincing (expression on two tracers is too different; hard to explain for such coarse particles with relatively homogeneous mineralogy and size). It is simply not possible that the field test will be be completed, which is the main reason for the score of only fair. It should have at least been permitted and designed by now.

PI Response:

We have identified an alternated site to complete the required field tests on time. Preliminary engineering design and environmental promit for the field test are in progress. We believe we can meet the deadline to complete this project, once we complete all preparation works for the field trial.

Reviewer 23401

Score: 2.0

Comment: See other remarks.

PI Response:

No response entered.

Reviewer 23577

Score: 2.0

Comment: Developed a class of carboxylic tracers, enhancing tracer detections 1000x. Historical application of benzoic acid has not been successful in field trials at other sites. It may not be useful in a field environment. It may not be useful for this work. This project was difficult to appraise as far as accomplishments go. Some detailed information was presented on the experimental work conducted was presented, but it is difficult to understand why this is an improvement. The 1000x improvement in detections would be a plus but there was not a discussion of how the improvement was achieved. Has not gone to the field yet and is behind schedule. It doesn't seem like this PI has the background necessary for a field test.

PI Response:

Carboxylic acids (mono- and di-acids) are used in this study to demonstrate and develop theoretical models for the "smart" tracers (sorptive). Our laboratories studies did show different retardation patterns of the mono- and di-carboxylic acids on the silica surface, which enables us to developing interpretation models. The 1000x preconcentration using the HF-LLME technique had been discussed in our first-year reviewing meeting, so we do not provide more details. A field trial in an alternative site has been scheduled and the administrative and engineering preparations for the field test are in progress.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23563

Score: 2.0

Comment: This project is handicapped from an original scope that included field tests, which they are not equipped to do. This has had a negative effect on the real strength of this project which is the identification and characterization of new tracers at the materials science level. The scope should be refactored to emphasize the new materials science and leave field testing to others.

PI Response:

The field test at the alternative site is being preparing. We are planning to work closely with a Professor from the Department of Geologic Science and his teams who has extensive tracer field test experiences to complete this task.

Reviewer 23450

Score: 2.8

Comment: Project showed good integration of laboratory testing with modeling. Project metrics showed good management and allocation of project resources. Future planning should consider alternative test sites.

PI Response:

Thanks for very helpful comments, we are taking action to complete the field test in the alternative test site.

Reviewer 23572

Score: 2.0

Comment: The field project is unlikely to be completed, and the PI still seems to be in denial about this.

PI Response:

We have identified and will complete the field test in an alternative site.

Reviewer 23401

Score: 1.0

Comment: See other remarks.

PI Response:

No response entered.

Reviewer 23577

Score: 1.0

Comment: Project management is behind schedule. Mentioned may need for a no cost time extension. Delays of this of magnitude are significant and should be incorporated into the project plan. NEPA documentation is a problem, why? Perhaps they should forego the field work in lieu of finalizing the lab experiments at high temperatures for a longer period of time.

PI Response:

We are currently working on the high-temperature studies to test the thermal stability of seleted tracer candidates. We are making progress to complete the field test at the alternative site.

STRENGTHS

Reviewer 23563

Comment: Materials science approach is good and should be the focus.

PI Response:

We will continously work on finding more novel tracer candidates based on our established theoretical models.

Reviewer 23450

Comment: Good integration of laboratory, analytical, and molecular modeling. A industrial partner like BJ Hughes adds credibility to the research that there is commercial potential, enhancing the project relevance.

PI Response:

It is our intension to bring out academic/industrial and theoretical/experimental efforts to development novel tracer systems for Enhanced Geothermal Program.

Reviewer 23572

Comment: Investigated many chemicals. Investigated different families of chemicals. Considered (although not perhaps sufficiently) thermal stability. Good relation of geochemical and flow tests.

PI Response:

We are in progress to examine the thermal stability of selected tracer candidates using a special sealed gold-tube designs to mimic the geologic conditions (temperature/pressure).

Reviewer 23401

Comment: Proponents advance an attractive thesis which could have a major impact if fully realized: noninvasive diagnostics of key resource parameters.

PI Response:

We believe our developing tracer systems, if fully understood and utilized, should have important impacts to exploration of geothermal resources, as well as to other energy resources.

Reviewer 23577

Comment: Integrated approach appears to have good laboratory components and modeling components. The laboratory portion of this work appears to be much stronger than the other parts.

PI Response:

The laboratorial development is one of the most important aspect of our project, and theoretical studies also play important role to assist our laboratorial programs.

WEAKNESSES

Reviewer 23563

Comment: Project is overextended in its cope - eliminate field testing at least.

PI Response:

The field test will be carried out at an alternative site, which should be easier than the originally proposed one.

Reviewer 23450

Comment: Unfortunately, the reliance on the Mt. Princeton project development and schedule did not allow a field test.

PI Response:

We have identified an alternative field site which will be more readily for the field test than the originally proposed Mt. Princeton's site.

Reviewer 23572

Comment: Only considered quartz. Possibly overselling and over-interpreting tracer tests (fracture spacing, pattern; multiple flow paths). Massive delays in arranging field test.

PI Response:

We are working the interaction of selected tracer compounds with carbonate surface, which is another common subsurface in reservoirs. We have just demonstrated the possibility of using multiple tracer systems to obtain more subsurface information. Much of work (rationalizing more tracer compounds, development robust interpretation model, field test validation, etc) will be needed.

Reviewer 23401

Comment: The presentation repeats decades-old knowledge about tracers as though this was an accomplishment and with no credit given to the original workers. The presentation of future plans borders on fraudulent, as the presenter admitted when challenged by a reviewer. The presenter as much as said there are NO plans for field validation and the project managers have known for a long time that the plan was doomed.

PI Response:

There have been decades of developments and field applications of the tracer tests. When we publish our results on public journals, we will definitely credit all previous accomplishments from original workers. The field test on an alternative site has been estalished.

Reviewer 23577

Comment: Poor planning and unfortunate scheduling of field components. The field component is definitely the weakest part of this project.

PI Response:

We are working on the field test at an alternative site.

IMPROVEMENTS

Reviewer 23563

Comment: Reduce overall scope and in favor of the materials science components.

PI Response:

We will continously work on more tracer materials both theoretically and experimentally.

Reviewer 23450

Comment: In general, for all GTO funded projects that propose a field test site, a backup test site should also be identified.

PI Response:

Agree. And the idea of using an alternative testing site is very helpful for us to complete this project.

Reviewer 23572

Comment: Delete field test; retract or re-allocate funds. Consider clay, calcite, feldspar ... or at least something besides quartz. Do a plausible statistical test of the multiple flow paths models (like AIC or BIC). I'm not certain the noisy data support the complex model, especially because ideal tracers don't show the same effects.

PI Response:

We are working on different surfaces, and trying to establish more robust interpretation models. Since the interaction between the carboxylic acids with the carbonated surface is expected to be stronger than with the silica surface, we expect to eliminate possible background noisy, to validate the multiple-flow path model.

Reviewer 23401

Comment: A peer review of research already conducted to audit reported results and to compare differences between this project's lab results and those already in the literature would improve the utility and credibility of the results. There do

appear to be competent researchers at work, but the presentation failed to place any of this work in context. Since no field test will be forthcoming the remaining money can be best spent making the best data available in the national database.

PI Response:

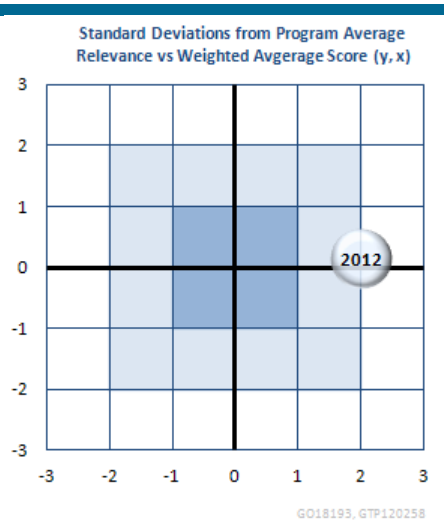
To our best knowledge, most of the early tracer tests on the database are for the conventional conservative tracer tests. There are, however, certain numbers of literature papers discussing about the unconventional tracer system (reactive, sorptive, partitional, etc), we should conduct more detailed literature survey when we are going to develop a more comprehensive interpretation model).

Reviewer 23577

Comment: Focus on more realistic lab experiments at high temperatures for a longer period of time. The project would benefit from leadership of a person that has significant field experience.

PI Response:

The high-temperature and high-pressure behavoirs of our selected tracer compounds are being studied using our special sealed gold-tube experiments.



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO18193
Project: Use of Tracers to Characterize Fractures in Engineered Geothermal Systems
Principal Investigator: Rose, Peter
Organization: University of Utah
Panel: Tracers and Tracer Interpretation

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23563

Score: 3.0

Comment: This project focuses on the need for new tracers which will provide more information than just connectivity patterns. In particular novel reactive tracers which will provide additional information on fracture surface areas when used in conjunction with other tracers are considered very useful. This fits a key a key technical objective of the Geothermal Program.

PI Response:

I agree.

Reviewer 23450

Score: 3.0

Comment: This project is tasked with developing interpretive tools for evaluating reactive and thermally degrading tracers and to use this test data to estimate the fracture area, fracture spacing and the resulting temperature distribution in the testing of an EGS reservoir. The development of a downhole fluorimeter is very relevant in the operating environment. As injection continues in maturing reservoirs, preferential pathways may develop that result in thermal breakthrough. Downhole tools that can measure tracer entry along a long wellbore interval has high diagnostic value identify potential intervals for treatment to delay fluid breakthrough.

PI Response:

I agree.

Reviewer 23572

Score: 4.0

Comment: The borehole fluorimeter and cation tracers may help to infer fracture properties. It is the combination of these two quite different subprojects that makes the potential impact outstanding. However, it seems a field version of the tool may be a long way off.

PI Response:

I agree.

Reviewer 23577

Score: 3.0

Comment: This work addresses some of the most pressing problems facing the geothermal industry, including determining fracture surface area and defining in borehole flow. The project team has made good use of collaborations and has reached out to other researchers funded by other GTO projects to leverage funds. Progress although not fabulous is promising.

PI Response:

I agree.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23563

Score: 3.0

Comment: The approach followed is:

1.) Conduct a laboratory program to screen candidate tracers for sorption behavior and survivability under geothermal reservoir conditions.
2.) Use analytical and numerical modeling to study candidate tracer transport/retardation behavior under known geothermal conditions.
3.) Demonstrate suitable tracer candidates in actual field experiments.

This strategy is logical and systematic overall. However, it was difficult to judge how extensive the search for new materials was. Also, while I am in favor of field experiments, I sometimes wonder if field experimentation is done prematurely in the geothermal community and whether highly controlled test bed scale experiments as done by Becker might be a useful intermediary.

PI Response:

Opportunities to test tracers under real-world conditions are few and far between. I never like to pass up the opportunity, especially since temperature is such an important variable. Becker's test field is excellent for groundwater or very low temperature testing, but is not very useful for high-temperature conditions.

Reviewer 23450

Score: 3.3

Comment: The approach uses a standard investigative suite of experimental, analytical and numerical approaches to characterize tracer behavior. Theoretical models provide guidance for ideal tracer properties, there is still the practical

difficulties. Primary among these are collecting tracer data with sufficient temporal resolution to provide a rich enough data set to allow advanced analysis methods to use derivative methods. A prototype down hole fluorimeter is under development to measure downhole concentrations in the wellbore and hence infer discrete tracer entry intervals. This effort should be accelerated with perhaps additional industrial support from a major wireline company.

PI Response:

Good suggestions.

Reviewer 23572

Score: 4.0

Comment: The team's experience with instrumentation, laboratory experiments, and field experiments seems very good, and they have developed a sound approach. Election to do a single well test is sound.

PI Response:

Thank you.

Reviewer 23577

Score: 3.0

Comment: Straight forward approach of lab work, modeling and field work. The proof will be in the Newberry demonstration this summer.

PI Response:

Good point.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23563

Score: 3.0

Comment: 1. After some screening a novel tracer Safranin T was selected which is both sorptive and subject to thermal decay.
2.) Amino G (sorbing, fluorescent) and its decay product (non adsorbing, fluorescent) was also considered as an interesting combination for single well injection/flowback studies.
3.) Cation exchange tracers were also shown to exhibit retardation and temperature insensitive sorption – also potentially useful for single well experiments

Safranin T plus a conservative tracer studied in the lab and used in a field experiment (Soda Lake) which served as a first field test to get after fracture surface area. However, lab preparation was suboptimal for the field test (and the thermal decay was a confounding factor). A claim was made that they could calculate the surface area, but none was reported. Suggest better preparations for field tests. Other ideas need more study beyond prelim lab studies. Amino-G plus decay

product (fluorescence) - being considered for single well test. Sorption and thermal decay kinetics as a fct of temperature are underway. Cation exchange work is still in progress. Li, Rb and Cs are being considered, and so far Li retardation has been demonstrated in column studies against a conservative tracer. No lab data for Rb and Cs. These cations are already in line to be used in a field test.
Lab work is incomplete for these tracers, yet field testing is already planned. The race for field testing seems to subsume lab testing to the point where one can ask legitimately whether enough lab study precedes field testing to derived proper value from the field test effort.

PI Response:

Again, opportunities to test tracers in the field are quite rare. I never like to pass one up because I never know if I will get another chance. Even if the preparation is less than optimal, it is important to take a risk and an opportunity.

Reviewer 23450

Score: 3.4

Comment: This project shows promise for rapid commercialization of a downhole fluorimeter and consideration should be given for additional support to accelerate design, bench and field testing and become a tool available for downhole tracer detection and zonal identification. Field testing at Soda Lake demonstrated the ability of tracers to estimate an interwell temperature in very good agreement with measured.

PI Response:

I agree.

Reviewer 23572

Score: 3.0

Comment: The single well test has not yet been conducted or analyzed (task 2), and it will be challenging to get the field prototype deployed by Aug 2012 as prognosticated (task 3). There has been good progress on characterization of sorbing tracers.

PI Response:

Good points.

Reviewer 23577

Score: 2.0

Comment: Accomplishments seem to be reasonable. Interwell fracture surface area determination for Ottawa sand, column experiments by LANL, etc. Seems like the project is running late. Dowhole fluorimeter would be very useful, does it work is the big question? With a few more accomplishments this project would have ranked higher in this area.

PI Response:

Understood.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23563

Score: 3.0

Comment: No discernable problems.

PI Response:

No response entered.

Reviewer 23450

Score: 3.0

Comment: Project should good integration of laboratory testing with modeling. Project metrics showed good management and allocation of project resources.

PI Response:

No response entered.

Reviewer 23572

Score: Not scored

Comment: Reviewer did not provide comments for this criterion.

PI Response:

No response entered.

Reviewer 23577

Score: 3.0

Comment: Quite a bit of coordination required and the project seems to be behind schedule, however, if the planned field work is pulled off without a problem then the project can be classified as a success.

PI Response:

No response entered.

STRENGTHS

Reviewer 23563

Comment: Some new tracer candidates identified, but still wonder if the search was exhaustive.

PI Response:

It was as exhaustive as time and resources allowed. We examined maybe two dozen candidates, but I agree that it would have been useful to find more and better candidates. This stuff is harder than it looks.

Reviewer 23450

Comment: The potential utility of a downhole tool to measure tracer concentrations using a fluorimeter is project plus.

PI Response:

I agree.

Reviewer 23572

Comment: Well-conceived field experiment. Exploitation of thermal decay. Interesting new "profiling" instrument in the wellbore fluorimeter.

PI Response:

No response entered.

Reviewer 23577

Comment: The coupling of tracer analysis and development of a downhole tool seems like a very useful and interesting combination. Some pre-modeling of the well to well tracer test would be helpful to understand the viability of the approach for identifying or characterizing fractures, e.g. what kind of dilution can be resolved with the downhole tool.

PI Response:

No response entered.

WEAKNESSES

Reviewer 23563

Comment: Field studies may be premature.

PI Response:

See my responses above.

Reviewer 23450

Comment: A sense of commercialization potential and urgency as a working tool for operators is lacking.

PI Response:

No response entered.

Reviewer 23572

Comment: Only Ottawa sand. Running a bit behind. Two disparate aspects of project (tasks 1&2 vs 3) not well integrated.

PI Response:

Agreed.

Reviewer 23577

Comment: Other than being behind schedule the technical foundations for the approach need to better validated.

PI Response:

Agreed.

IMPROVEMENTS

Reviewer 23563

Comment: Doing some of these studies in scaled models a la Becker might be very valuable.

PI Response:

I don't like the Becker approach for the reasons given above.

Reviewer 23450

Comment: A second focus should be on continuous tracer monitoring equipment for both surface and subsurface environment; perhaps further national laboratory collaboration will be helpful with an industrial partner to accelerate downhole tool development.

PI Response:

No response entered.

Reviewer 23572

Comment: Consider minerals other than quartz.

PI Response:

We were also studying rhyolite and illite, but the results were not ready for the report.

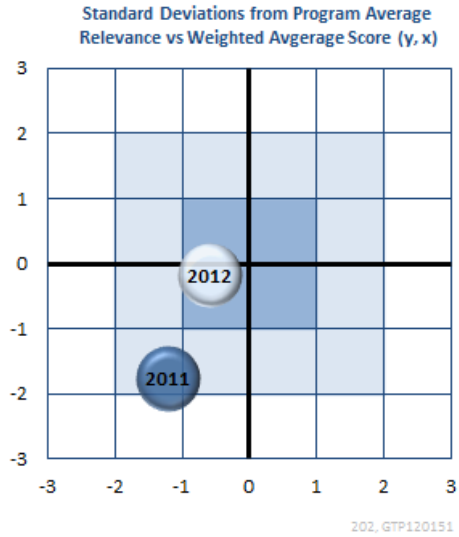
Reviewer 23577

Comment: I would like to see some validation of the approach in a synthetic fracture network, i.e. a meso-scale experiment. Something where the dimensions and connectivity are known and then this approach used to characterize the network. I know this is outside the scope of this project but something along these lines is needed to take the project to the next level.

PI Response:

If such a place exists that has the constraint of geothermal temperatures, then I agree that it would make a good field laboratory.

WORKING FLUIDS



Review: 2012 Geothermal Technologies Office Peer Review
ID: 202
Project: Working Fluids and Their Effect on Geothermal Turbines
Principal Investigator: Sabau, Adrian
Organization: Oak Ridge National Laboratory
Panel: Working Fluids

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23414

Score: 4.0

Comment: The presenter was a no show, so my comments here and elsewhere are based on my read of the electronic material that was provided. This work looks highly relevant and well thought out.

PI Response:

The PI presentation was rescheduled an hour later than the original time due to flight delays. We thank the reviewer for the taking the time to review the electronic material submitted.

Reviewer 23463

Score: 2.0

Comment: The project objective is to identify and test new cycle fluids to improve binary power plant efficiencies. It would have been better if the aim were set as maximizing the brine effectiveness. Otherwise, this is a high-impact objective and is pursued by two other projects in this group. However, the project team had chosen to focus on supercritical CO2+SF6 early in the project and this limited their ability to achieve a significant impact.

PI Response:

The main concern raised is that our team focused on the CO2+SF6 binary mixture. The early focus on the CO2+SF6 binary mixture was made based on preliminary data that was available from Sandia's supercritical loop. Thus, the team rightly took the decision to investigate this new mixture, CO2+SF6, which looked promising but was not investigated before as a geothermal working fluid. Our ability to achieve a significant impact was limited much more by the budget cut (approx. 1/3 - not for poor performance; which the reviewer may have not been aware of) rather than by our decision to investigate a new working fluid, so other efforts such as investigating additional fluids, which were envisioned in the original proposal, were not possible.

Reviewer 23489

Score: 4.0

Comment: Impact is limited only by type of turbine - this was a good project with otherwise significant impact.

PI Response:

No response entered.

Reviewer 23445

Score: 2.0

Comment: the goal of this project is to examine new working fluids, and mixtures of working fluids for use in geothermal power cycles. Costs are to be a major consideration, not only the cost of the fluids, but the power cycle equipment. Fluids were ranked based on performance (cycle power), and costs. The presenter started his talk stating that they spent more time investigating mixtures of refrigerants due to comments from the previous peer review. It was also stated that mixtures that are not available from REFPROP would be examined for non-ideal mixture properties. However, this change in direction was not evident in the presentation. As in the previous year, the mixture studies were all performed at the University of South Florida, and they relied completely upon properties from the REFPROP database. No experimental investigation into properties was discussed.

Experimental data on SF6/CO2 mixtures are to be shared with REFPROP.

PI Response:

The change in direction was not that evident since the format of the presentation does not allow the inclusion of too many results (approx. 50-60% of slides can contain technical data, other slides were required to generate non-technical management type data, which are very much needed for the program as a whole). In the original proposal, before the budget cuts, the thermophysical property measurements, which were conducted for CO2-SF6 mixtures using a vibrating tube densitometer, were envisioned to be conducted for two working fluids. Unfortunately, due to the budget cuts, the VTD measurements could be conducted for only one mixture. Based on the simulation data obtained at USF we can now justify the consideration of other fluids for further property measurements.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23414

Score: 4.0

Comment: Excellent mix of experimental and theoretical analysis.

PI Response:

No response entered.

Reviewer 23463

Score: 1.0

Comment: A thermodynamic analysis at the beginning of the project should have identified the fact that CO2 + SF6 cannot match the cycle efficiencies offered by conventional refrigerants in the geothermal fluid temperature ranges. The calculation of brine effectiveness would be slightly more favorable for CO2+SF6 but this comparison does not seem to have been made and even then the refrigerants would still come as the better ones. The project team tries to justify the

emphasis on the CO2+SF6 by the smaller turbines (and hence lower plant cost) but firstly, the lower turbine cost may be cancelled by the more expensive heat exchangers due to higher pressures and, secondly, while the binary plant cost is important it is more important to maximize the brine utilization. The project team, after the review last year, extended their scope to other refrigerants but they may not have been analyzed with the same rigor since no testing seems to have been performed for the thermodynamic properties of the new fluid mixtures considered and the team has had to rely on existing published data.

PI Response:

We agree with the reviewer that the brine effectiveness has to be reported and included in the evaluation criteria. Last year we contacted several companies involved heat exchangers and found that nowadays the high-pressure operation would add very little to the cost. In order to be more relevant to the industry, we considered the evaluation of heat exchanger areas, which is seldom reported in the literature for the geothermal cycles. However, it was not possible to quickly screen the fluids right at the onset of the project. In fact this was one of the main task in the project. The preliminary data obtained very early in the program, which were based on experiments that were conducted on the supercritical loop at Sandia, indicated that the cycle efficiencies for the CO2+SF6 mixture were promising. We believe that the CO2+SF6 mixture is well matched for low temperature brines. The investigation of refrigerants at USF was not meant to be exhaustive and as rigorous as the investigations at ORNL (for example, the capability for the estimation of the heat exchanger areas is not available at USF). The team undertook the additional effort of directly investigating other refrigerants for the sake of completeness, i.e., in order to insure a direct comparison between the CO2+SF6 for the the same conditions, instead of relying on data obtained for different operating parameters of a geothermal cycle.

Reviewer 23489

Score: 4.0

Comment: Investigation approach is v. good. Looking for new working fluids in a systematic manner. The development of tasks and delivery of information is good, particularly with thought process in ranking fluids and overall risk control. Sorting working fluids with filters and criteria barriers.

PI Response:

No response entered.

Reviewer 23445

Score: 3.0

Comment: The approach as stated seemed very sound. However, it was not apparent that the investigations followed the approach as outlined.

PI Response:

The approach as stated was followed, but the fact that the PIs were allowed basically only several slides with actual data (in the current format, more than 60% of slides had mandatory format for managerial type data - data that is very useful to the DOE geothermal program - but not useful to technical presentation). However, the project was originally conceived as a three year effort, with the final year being devoted to optimization of the working fluid for a particular set of conditions relevant to engineered geothermal systems. The duration of the project was 18 months, and so besides the optimization, only minimal attention could be paid to materials interactions, another key focus of the original project.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23414

Score: 4.0

Comment: Lots of data measured, data transmitted, and published papers.

PI Response:

No response entered.

Reviewer 23463

Score: 1.0

Comment: It is not clear to identify a significant achievement towards the objectives said at the beginning. Most of the effort were spent on a cycle that is not relevant and the analysis of the other candidates were limited to computer simulations using existing data with no additional insight and new information.

PI Response:

In terms of significant achievements, we have to mention: (1) measurement of thermophysical property data for the CO2-SF6 mixture (analyzing 181 measurements is quite an endeavor), (2) obtaining optimum composition of CO2-SF6 mixture for efficiency and size of heat exchangers, and (3) obtaining data for cycle efficiency and exergy efficiency of most promising refrigerants.

Reviewer 23489

Score: 3.0

Comment: Excellent ranking of fluids on environmental as well as efficiency, turbo size, HE size, cost etc. Realization that even high GWP fluids may be used because of high efficiency if leak potential is very low.

PI Response:

No response entered.

Reviewer 23445

Score: 1.0

Comment: Little results were presented. It was stated that a wide variety of fluids would be investigated, and yet the majority of the work seemed to be centered on CO2/SF6 mixtures that were being developed for other applications. It was stated that properties would be measured, and yet very little experimental property measurements were presented. It was stated that models for non-ideal mixtures of fluids would be developed, and yet no models were discussed.

Some qualitative rankings of refrigerants were provided (low or high in a variety of categories), but this seemed to not justify the dollars spent. Much of the ranking chart was blank.

PI Response:

It is hard to understand the reviewer's comment that "little results were presented" and "very little experimental property measurements were presented". Our presentation included significant amount of experimental data, measurement of thermophyiscal property data for the CO2-SF6 mixture involve 181 measurements (results presented in slides 8 and 9 out of 15 slides, meaning approx. 13% of the presentation. Thus, we respectfully disagree with this reviewer's comments, which are not supported by any facts.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23414

Score: 3.0

Comment: Judging from the project progress and output, and the successful experimental-theoretical work coordination, this project was well managed.

PI Response:

No response entered.

Reviewer 23463

Score: 1.0

Comment: The project is complete and it failed to deliver its original objectives as already mentioned under the previous heading.

PI Response:

We respectfully disagree with this reviewer. As a matter of fact, we believe that this comment is misplaced, as this is the "project management and coordination" section. We have successfully met our original objective of identifying working fluids candidates through: (1) thermophysical property measurement, (2) obtaining optimum composition of CO2-SF6 mixture for efficiency and size of heat exchangers, and (3) obtaining data for cycle efficiency and exergy efficiency of most promising refrigerants.

Reviewer 23489

Score: 4.0

Comment: Very well coordinated and supported within the leveraged knowledge base.

PI Response:

No response entered.

Reviewer 23445

Score: 1.0

Comment: I was pleased to see the collaboration between two national laboratories and a university. However, it seemed that each group performed research that was not coordinated. ORNL measured properties of SF6/CO2 mixtures, USF performed some cycle calculations, and SNL provided an experimental facility that did not seem to be used.

PI Response:

The effort between ORNL and USF was coordinated through bi-monthly conference calls. As a result of our coordination, the data at ORNL and USF was obtained for the same geothermal conditions in order to allow direct side-by-side comparison. As a matter of fact several papers were written jointly, as shown on slide 13. The effort at SNL was described in the last year presentation. It involved experiments with CO2-SF6 and CO2-nbutane. As SNL effort was completed last year and significant data was obtained at ORNL and USF, the SNL data was not presented in this year.

STRENGTHS

Reviewer 23414

Comment: Coordination of theoretical analysis with experimental measurements.

PI Response:

No response entered.

Reviewer 23463

Comment: The team claimed to have developed an inexpensive method of measuring the thermodynamic properties. It is a shame that this method was not used on fluid mixtures that mattered.

PI Response:

The vibrating tube densitometer is indeed inexpensive in comparison with other methods of measuring PVTx properties of mixtures in wide ranges of temperature, pressure, and composition. However, developing equations of state for binary mixtures is a quite a considerable task. Our approach can also be used to investigate working fluids for EGS conditions. Knowing what those working fluids "that mattered" is the Holy Grail in this area. Our work unraveled a systematic way to screen these fluids. As the presentations made at the FY10 DOE annual review meeting, at the onset of the three working fluids projects, suprisingly show, none of the teams pointed to any fluid in particular but rather different approaches were presented to identify these new fluids.

Reviewer 23489

Comment: The approach is possibly the strongest part - solved many challenges that would have stalled other projects.

PI Response:

No response entered.

Reviewer 23445

Comment: This project obtained mixture properties for SF6/CO2 mixtures. If this combination is to be used in geothermal applications, there is some justification for this project.

PI Response:

No reponse entered.

WEAKNESSES

Reviewer 23414

Comment: None.

PI Response:

No response entered.

Reviewer 23463

Comment: It seems like the project team lacked a clear focus on geothermal power generation.

PI Response:

We took significant steps to be relevant to the geothermal industry. First, we considered the evaluation of heat exchanger areas, which is seldom reported in the literature for the geothermal cycles. Second, we worked with Prof. Goswami at USF, who is a well accomplished in the geothermal power generation. Third, we investigated cycles under conditions specific to low temperature reservoirs, from 100 to 200 C, as most the existent wells in US are within this range.

Reviewer 23489

Comment: Has not gone far enough yet. Needs to be extended to focus on specific uses.

PI Response:

We believe that a collaboration with a geothermal power company would be bring us to the next stage.

Reviewer 23445

Comment: This project seemed disorganized. They have measured properties of a mixture that does not seem to be of importance due to the potential of SF6 release. A chart was created to rank potential fluids that had more blank cells than entries (and the entries were a simple choice of "high" or "low").

PI Response:

We wanted to present the impact of our project in terms easy to follow. Hence the chart to rank potential working fluids according to different criteria. We believed that this would illustrate the project vision and its impact. We will re-evaluate the chart presentation and quantify the heat exchanger sizes and remove the investment cost as a thermoeconomic analysis was beyond the scope of this project.

IMPROVEMENTS

Reviewer 23414

Comment: None.

PI Response:

No response entered.

Reviewer 23463

Comment: The project is complete.

PI Response:

No response entered.

Reviewer 23489

Comment: Extend and link with a specific application.

PI Response:

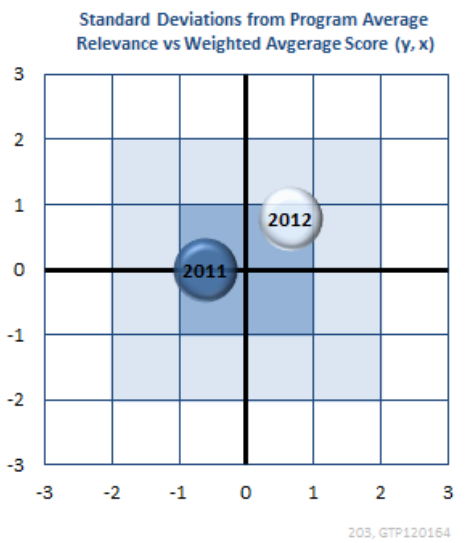
Yes. We believe that a collaboration with a geothermal power company would be bring us to the next stage.

Reviewer 23445

Comment: This program is completed, but if it were to be continued, there are many opportunities for improvement. The study should have spent more time measuring properties of other fluid mixtures, and developing a model for non-ideal mixture properties. Even a model that would only allow interpolation of mixture properties to other concentrations would have been useful.

PI Response:

We agree that there are many opportunities for improvement. It is impossible to develop a model for non-ideal mixture properties, as it can be seen from numerous papers on non-ideal mixture properties. It would very nice, indeed. Models are easy to develop, but they have to be grounded on sound experimental data, otherwise, large errors in property data would be propagated elsewhere.



Review: 2012 Geothermal Technologies Office Peer Review
ID: 203
Project: Development of New Biphasic Metal Organic Working Fluids for Subcritical Geothermal Systems
Principal Investigator: McGrail, Peter
Organization: Pacific Northwest National Laboratory
Panel: Working Fluids

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23414

Score: 4.0

Comment: Excellent analysis of metal organic working fluids. Fundamental science was combined with a thorough engineering analysis.

PI Response:

Reviewer 23463

Score: 4.0

Comment: The objective is to develop a new fluid concept that will improve the efficiency and increase brine utilization. The impact on geothermal power conversion is significant but the impact goes beyond geothermal industry and should have application in other renewable power generation applications.

PI Response:

Reviewer 23489

Score: 4.0

Comment: Development of fluids and the behavior models of working fluids will have a high impact if inexpensive working fluids with properties focused on specifics can be developed.

PI Response:

Reviewer 23445

Score: 3.0

Comment: Last year it seemed that the presenter was considering using nanofluids in a heat transfer fluid injected underground. This seemed like a non-starter to me. Loss of fluid issues would result in excessive costs, and pollution. This year other projects seem to indicate that they are still considering injection of nano-fluids underground (Greenfire in Arizona), but PNL did not seem to promote this. This made me much more receptive to this idea.

Little work had been done in the intervening year due to budget constraints. However, PNL presented a much better case by including some preliminary cost figures to demonstrate that the process is economical. A chart showed that the conversion of a simple ORC to use of a nanofluid could make a significant impact on the power output of the plant. The payback period seemed very reasonable. By designing a plant from the start to use a nano-fluid further savings could be obtained by designing smaller heat exchangers, etc.

This project seemed to be historically tied to EGS. However, I think that the impact of this research could be even greater for lower temperature reservoirs.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23414

Score: 4.0

Comment: The technical approach involved a very strong combination of experimental synthesis and theoretical analysis that considered several candidates and tested one. The candidate synthesis and selection analysis were excellent.

PI Response:

Reviewer 23463

Score: 4.0

Comment: The project team seems to be following a rigorous approach, The characterization of the Metal-organic heat carriers (MOHCs) is complete and the justification for their expected high performance is convincing. Their higher heat transfer capability has been proven by capillary flow testing and in micro heat exchangers. There is no experimental evidence yet whether the extra heat retained by the MOHC particles will be converted to mechanical power in the expander, The PI is aware of this point and has a plausible explanation for the mechanism of such conversing but this needs to be tested.

PI Response:

Reviewer 23489

Score: 4.0

Comment: The approach using metal-organic nanofluids was intriguing. These fluids can improve efficiency of the ORC (organic Rankin cycle), with advantages of being chemically passive while increasing heat transfer coefficient. A good update was provided by covering prior work - helped connect past and present work. Approach was technical and very well explained. Proved that they can create fluids on nano scale and tracked interactions on nano scale. Described tasks and techno-economic performance.

PI Response:

Reviewer 23445

Score: 3.0

Comment: I think the modeling work was a great way to investigate this subject. However, I would liked to have seen more experimental validation of the model results.

The presenter correlated the lack of deposition of the nanoparticles to a Reynolds number of the liquid flow. This scaling was not justified, and probably not correct. The Reynolds number of the liquid flow does not include any of the important physics such as: the vapor velocity to sweep away the particles, the particle size and density, the particle uptake of the host fluid, etc.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23414

Score: 4.0

Comment: The accomplishments of this project are made more impressive by the fact that they were achieved despite the elimination of the last year's funding.

PI Response:

Reviewer 23463

Score: 3.0

Comment: The project had four tasks identified:
•Task 1 – MOHC Synthesis

•Task 2 – Thermophysical Property Characterization
•Task 3 – Cycle Performance Testing
•Task 4 – Techno-Economic Performance Analysis

All were completed bar Task 3. This task had two subtasks: heat transfer performance and cycle efficiency testing. The first testing was done but the second was not. The project funding received was less than the proposed budget for these four tasks and this could be the reason for failure to complete Task 3,

It is important to finalize this project by confirming that cycle efficiency is increased and it is recommended that the project is extended to accomplish this.

PI Response:

Reviewer 23489

Score: 3.0

Comment: Usable results with solid technical base for continuing the project. Described tasks and techno-economic performance.

PI Response:

Reviewer 23445

Score: 3.0

Comment: The project completed all milestones. I think it was a success. The PI desires to continue with a study of nanoparticles traveling through a turbine to demonstrate the energy extraction and the lack of deposition of the turbine blade. This program could also study the erosion of the turbine. However, I feel that this is too limited a step. The next step should demonstrate a complete cycle.

The dollar cost numbers presented for this review were very preliminary, and the assumptions vague. It would have been nicer to have more details provided for this portion.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23414

Score: 3.0

Comment: Not a whole lot of external coordination required.
PI Response:

Reviewer 23463

Score: 3.0

Comment: It was not clear to this reviewer whether the reduced budget meant a reduction of the scope or whether the cycle testing remained in the scope but could not be done. It is disappointing that we do not have experimental evidence of increased cycle efficiency. The PI is expecting significant improvements in the cycle efficiency and this needed to be tested. A score of 3 is given because of the lack of clarity whether the turbine testing was included in the funded project scope or not.

PI Response:

Reviewer 23489

Score: 3.0

Comment: Adequate for the project needs. Talked about some examples and early work.

PI Response:

Reviewer 23445

Score: 2.0

Comment: This project seemed to be a one man show. Odd interactions were highlighted, but these seemed to be un-funded collaborations. It seemed odd that Greenfire desired to use the fluid within the geologic media and PNL seemed to have given up on that idea.

PI Response:

STRENGTHS

Reviewer 23414

Comment: Experimental analysis of metal organic working fluids.

PI Response:

Reviewer 23463

Comment: A novel idea and a PI with a clear focus, specialist knowledge and a good understanding of the application domain.

PI Response:

Reviewer 23489

Comment: Solid chemical developments and general work.

PI Response:

Reviewer 23445

Comment: The PI seems to have great enthusiasm for this project, and is very knowledgeable in the required fields of science to continue this work. The PR department at PNL has been able to attract significant attention to this project. I have seen PNNL nanofluids highlighted in a number of publications.

PI Response:

WEAKNESSES

Reviewer 23414

Comment: None.

PI Response:

Reviewer 23463

Comment: Failure to do the cycle testing.

PI Response:

Reviewer 23489

Comment: not focused to specific technologies in the detail that would be usable without significant work.

PI Response:

Reviewer 23445

Comment: Despite the great publicity that this project has received, and the numerous industry inquiries, this project needs a successful application to continue to the next level. The PI failed to identify any potential pitfalls of this process except the possibility of deposition of the particles on the system piping, One would like to know the chemical stability of the particles, the potential consequences of the chemical or physical breakdown, particle agglomeration with time, etc.

PI Response:

IMPROVEMENTS

Reviewer 23414

Comment: Give them the last year's funding.

PI Response:

Reviewer 23463

Comment: It is recommended that the project is extended, probably by making the original funding cut available, to enable the PI carry out the cycle testing.

PI Response:

Reviewer 23489

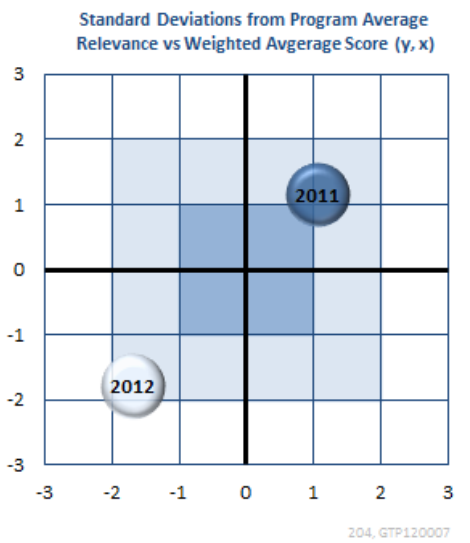
Comment: Mone considered.

PI Response:

Reviewer 23445

Comment: I had a poor understanding of the project last year, and the presentation assumed I had a better knowledge. However, I was greatly intrigued, and therefore read a number of the papers by PNNL. This year I came into the review with a better background, and could follow the presentation with greater understanding. However, the presenter still did not give a sufficient background for many in the audience. With the limited time available for the presentation, it will be difficult to get all to a good level of understanding, but I feel that the presenter could have devoted one slide to a tutorial.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: 204
Project: Chemical Energy Carriers (CEC) for the Utilization of Geothermal Energy
Principal Investigator: Jody, Bassam
Organization: Argonne National Laboratory
Panel: Working Fluids

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23489

Score: 2.0

Comment: Geothermal application may be significantly heightened by using transfer chemicals that improve delivery or heat and power and/or reduce problems with scale, deposits, etc. This is a good topic but substantial progress was limited. The primary output is identification of carrier fluids – but I did not understand how a useful ranking could be established.

PI Response:

We thank the reviewers for their thoughtful comments. The PI was not able to attend because of a family situation and our colleague Richard Doctor who was attending as a reviewer had to make the presentation on a short notice.

The objective of the project was to identify chemically reacting fluids that can be used to extract heat from deep Enhanced geothermal Systems (EGS) or high temperature geothermal energy, for increasing the power generation output using the extracted heat. EGS present unque conditions not only in terms of the high temperatures and exceptionally high pressures that the fluids can attain but also design challenges to prevent contamination of the underground, losing of the working fluid and introduction of catalysts. We evaluated over 45 different potential chemically reacting materials that may help achieving the objective. The ranking was primarily based on the "exergy" or ideal work that can be produced using the extracted heat and the actual work that can be potentially produced when the output hot fluid is utilized for driving different configurations of power cycles. We identified steam methanol reforming, thermal decomposition of ammonia and thermal decomposition of dinitrogen tetroxide as potential candidates. The analysis proceeded in 3 basic steps: (1) determination of the enthalpy and exergy gain by the working fluid in order to establish the ideal work that can be generated by the working fluid, (2) integration of the hot fluid with different power cycle configurations in order to determien the the actual work that can be expected and (3) compared the performance with non reacting working fluids (water and CO2).

After identifying materials and reactions the focus was shifted to developing designs that can accommodate the reactions in an EGS environment without direct contact with the rocks and without having to fracture the rocks in order to eliminate potential contamination and loss of the working fluid.

Reviewer 23463

Score: 1.0

Comment: While the idea of a magic energy carrier is enticing, it is unfortunate that this project was funded without some preliminary work to support the existence of such a magic substance available at a cost to make it feasible for the purpose.

PI Response:

We thank the reviewers for their thoughtful comments. The PI was not able to attend because of a family situation and our colleague Richard Doctor who was attending as a reviewer had to make the presentation on a short notice.

Chemically reacting working fluids were considered long time ago for the capture, storage and transport of high temperature solar energy. We identified steam methanol reforming, thermal decomposition of ammonia and thermal decomposition of dinitrogen tetroxide as potential candidates. These materials were looked at before for solar applications and/or for power generation. Their reactions are well known at normal conditions. The analysis was extended to the conditions in the deep EGS.

After identifying materials and reactions the focus was shifted to developing designs that can accommodate the reactions in an EGS environment without direct contact with the rocks and without having to fracture the rocks in order to eliminate potential contamination and loss of the working fluid.

Another benefit is where water is scarce using such working fluids without fluid loss will conserve water.

Reviewer 23414

Score: 2.0

Comment: This project was truncated with a funding cut making it hard to fully establish its potential impact or relevance. The overall impact does not seem high though.

PI Response:

We thank the reviewers for their thoughtful comments. The PI was not able to attend because of a family situation and our colleague Richard Doctor who was attending as a reviewer had to make the presentation on a short notice.

Utilization of deep EGS heat presents special challenges. For example, high EGS temperatures may make it difficult if not impossible to fracture the rocks as the rocks start to creep. Reactions between minerals and the working fluids also present challenges. Therefore, special closed system designs such as the ones we evaluated may be necessary. In such designs reacting fluids that could increase the overall power output from a fixed system size, compared to water should have high impact.

Reviewer 23445

Score: 2.0

Comment: This project tried to investigate alternative ways of extracting energy from a geothermal reservoir other than simple sensible (or latent) heat. Simply by adding another free parameter to the problem, they were guaranteed to find an optimum solution were additional energy could be extracted (at a minimum they would have arrived at the same optimum solution as current designs). Due to funding constraints, this program simply considered modeling studies, and did not perform any experimental demonstrations.

The investigators were obviously very bright, and had a free rein to enable them to consider a wide variety of systems. However, the program will have limited impact due to the lack of a cost model. The presenter could not provide any indication if any of the proposed systems were viable. One can always improve on any system, but there becomes a level

of system maturity where improvements become smaller and smaller, at the same time the increased costs become larger and larger.

PI Response:

We thank the reviewers for their thoughtful comments. The PI was not able to attend because of a family situation and our colleague Richard Doctor who was attending as a reviewer had to make the presentation on a short notice.

It was not part of the scope of the work to develop an economic model. We agree that without reliable experimental data to valiadate the quantitative performance of the selected fluids compared to water, detailed economic analysis will be pre-mature.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23489

Score: 2.0

Comment: Approach seemed limited and narrow. Dual fluids in series, downhole equipments (out of the scope in reality) and consideration or other approaches were missing.

PI Response:

The approach that was followed was consistent with the proposed project. After a number of potential fluids were identified and screeded to determine a short list the following procedure was followed: (1) determination of the enthalpy and exergy gain by the different working fluid in order to establish the ideal work that can be generated by the working fluid, (2) integration of the hot fluid with different power cycle configurations in order to determine the the actual work that can be expected, and (3) compared the performance with the leading non-reacting working fluids (water and CO2).

Designs were developed and evaluated to facilitate the extraction of the high temperature EGS heat. Some of these designs will also enable using water as a working fluid where circulation of the working fluid through the rocks is not feasible or will result in large loss of the working fluid.

Reviewer 23463

Score: 1.0

Comment: 71% of the budget was spent to execute less than half of the proposed work. The achievements are not enough to justify the expenditure. Since there are no publications beyond what is presented during the review, it is difficult to assess the quality of the work that was done in this project. The charts in the presentation probably depend on some simple reservoir models but it is not clear what is in the so-called "thermodynamic and process engineering simulation" as referred to in the project summary.

PI Response:

The proposed work was completed within the funding profile. The work resulted in 3 invention disclosures. A paper "Capture of Geothermal Heat as Chemical Energy" has been submitted to Energy Sources Journal for publication. A

second paper "Enhanced Geothermal Systems —The Chemical Reactors of the Future" will be submitted to a journal soon.

Reviewer 23414

Score: 2.0

Comment: The technical approach seems appropriate but, since it was fairly straightforward reaction-path calculations that weren't fully compared to experimental work, the overall result was not large.

PI Response:

Experimental data is available on some of these systems such as steam reforming of methanol and thermal decomposition of ammonia but not under pressure conditions that will be encountered in deep EGS reservoirs. The known information was used to select the appropriate equation of state for the analysis and extrapolated to the higher pressures. For some the analysis was done with more than one equation of state before selecting one for extrapolation.

Because chemically reacting fluids produce species that can be utilized in advanced power generation systems such as using the H2 from the steam reforming process in a fuel cell results in a large number of integrated working fluid/power generation system that had to be analyzed before optimum power could be determined.

Reviewer 23445

Score: 2.0

Comment: The authors claimed to eliminate processes that they deemed a safety concern. However, how this was defined was not presented. The authors also eliminated a number of other potential systems due to other vague criteria such as they were unwilling to require a down-hole catalyst that had to be replaced. These type of decisions are required in an optimization process for it is difficult to quantify every cost and benefit. However, the arbitrariness of the process requires one to accept expert judgment without gaining insight of the expert. Hopefully, the final report will have more information to allow the reader to understand all the decisions.

The project seemed to ignore pollution concerns. The majority of the proposed projects involved injecting toxic materials into a geothermal reservoir. Current public concerns about chemicals used in fracking should not be ignored.

PI Response:

Pollution concerns were considered. That was a primary reason why we recommended closed system designs. Safety issues were also considered. Materials that contain chlorine were rated low because of the potential generation of irreversible chlorinated side products which will require treatment or special disposal.

The selected materials (methanol, ammonia and dinitrogen tetroxide) are also hazardoes materials. However, ammonia and methanol are used commercially and closed systems can be designed to accommodate them. Hydrogen which is a product also has hazards associated with it but there is plenty of data that can enble the design of safe systems. Dinitrogen tetroxide is a hazardous material. It was looked at long time ago as a potential "dissociating" working fluid for power cycles. However, we recognize that it is not a prime candidate even though it can result in high power generation.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23489

Score: 2.0

Comment: The accomplishments were limited in my unlearned estimation since it referred to some fluids that would not be used and lacked a meaningful base line - I may be off here, but just was expecting arrival at a list of high use fluids.

PI Response:

We used water and CO2, the two leading geothermal working fluids, as baselines for comparing the different working fluids. We presented a list of candidate reacting working fluids.

Reviewer 23463

Score: 1.0

Comment: It is difficult to identify the accomplishments in the project because the presentation has limited information; the PI did not attend the review; and there are no publications that this reviewer could check to get extra information.

PI Response:

My apology that I (PI) was not able to attend because of a family situation and our colleague Richard Doctor who was attending as a reviewer had to make the presentation on a short notice.

The work resulted in three invention disclosures. A paper "Capture of Geothermal Heat as Chemical Energy" has been submitted to Energy Sources Journal for publication. A second paper "Enhanced Geothermal Systems — The Chemical Reactors of the Future" will be submitted to a journal soon.

Reviewer 23414

Score: 3.0

Comment: Again, the funding truncation may have obscured the overall impact. The fact that 3 patent disclosures were filed suggests tangible accomplishments.

PI Response:

The lab equipment, test matrix and experimental procedures were defined.

Reviewer 23445

Score: 2.0

Comment: The project examined quite a number of systems and determined that some are fit for further consideration. These recommendations depend upon only modeling, and no experimental confirmation. Vague rules were established such as all fluids and chemicals are to be returned underground so that waste streams would not be created. The investigators did not seem to be concerned with pollution of underground environments, or the public acceptance of the

process. Some fluid loss would be expected. In the current public environment, injection of fluids underground without concern about water table pollution seems naive. The economic costs of any fluid loss was also not considered.

PI Response:

What is meant is that the working fluids will be contained in a closed system and will be re-circulated after they are regenerated. Closed systems are used to avoid contamination.

Pollution concerns were considered. That was a primary reason why we recommended closed system designs. Safety issues were also considered. Materials that contain chlorine where rated low because of the potential generation of irreversible chlorinated side products which will require treatment or special disposal.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23489

Score: 3.0

Comment: Reasonable collaboration and coordination although somewhat limited - would like to see industry links and input more than what was here.

PI Response:

No response entered.

Reviewer 23463

Score: 1.0

Comment: 71% of the budget was spent on paper-and-pen studies and the experimental evaluation/validation tasks were cancelled. One would think that the paper-and-pen studies would consume a relatively small part of the budget since it is typically the experimental work that is expensive. Based on these observations, one cannot call this a particularly well-managed project.

PI Response:

We followed the proposed work plan. In is well know in chemical engineering that detailed thermodynamic analyses require rigorous mathematics to avoid spurious results. We focused on the evaluation of as many working fluid/power system integrated designs in order to provide guidelines for future researchers in this area. We were hopeful that funds will be available for the continuation of the project.

Reviewer 23414

Score: 3.0

Comment: These folks get points for wrapping up a project whose final year of funding was unexpectedly eliminated.

PI Response:

No response entered.

Reviewer 23445

Score: 2.0

Comment: The project seemed to examine a wide variety of potential systems to extract energy from a geothermal resource. This obviously required investigating a large number of possible systems. The project was completed within budget. However, the project seemed to be very informally organized with vague criteria for including or excluding a potential system. Obviously collaboration with external experts would be an important part of such a project, if only to invite others to offer suggested chemical systems. However, the presentation only provided a single bullet that stated "Collaborated with experts in the field". It was unclear if this was actually accomplished, or if it was, how it was implemented.

PI Response:

We agree that more collaboration whould have been good for the project. Without resources to conduct the experimental validation of our ideas, it was difficult to attract collaborators. Collaboration would have been important during the experimental part of the project and in developing the plan for field testing. It was in the plan to do so. Our collaboration with Dr. Mark Reed was to investigate potential interaction between the working fluids and the rock formations if the fluids are to be circulated through the rocks.

STRENGTHS

Reviewer 23489

Comment: A reasonable look at fluids - the topic will have significant impact.

PI Response:

Agree

Reviewer 23463

Comment: Strengths are difficult to identify.

PI Response:

The objectives were accomplished. We identified chemically reacting fluids for recovering the EGS heat and developed designs to implement them.

Reviewer 23414

Comment: Reaction-path modeling.

PI Response:

The objectives were accomplished. We identified chemically reacting fluids for recovering the EGS heat and developed designs to implement them.

Reviewer 23445

Comment: The participants were obviously well qualified to perform this work. They had expertise to include a wide variety of factors in the evaluation of potential systems. These included chemical reactions as a function of large variations in pressure and temperature, the potential for permeability reductions, the ability of systems to operate with a reducing geothermal temperature, etc.

PI Response:

Agree

WEAKNESSES

Reviewer 23489

Comment: The project results did not help get us closer to optimum fluids for a specific task - too wide a look without specific guidance as to what is really needed.

PI Response:

At the start of the project, tt was preliminary to conduct a downselect without conducting the thermodynamic analysis. One of our conclusions is that no one single fluid is the best for all EGS reservoirs. Selection of the fluid should be done based on analysis that takes in consideration the EGS parameters and design specifics.

Reviewer 23463

Comment: Other than the fact that the work presented is disappointingly limited for the size of the budget spent, no specific weakness can be identified.

PI Response:

Over 45 different fluids were evaluated.

Reviewer 23414

Comment: Dearth of experimental data.

PI Response:

No experiments were performed. The lab equipment, test matrix and test procedures were determined.

Reviewer 23445

Comment: The program did not develop a formal program to invite input from other laboratories. I am sure that many individuals would have been able to spend a few minutes to suggest their own pet ideas on how to get energy from a geothermal system. Geothermal systems include a large elevation change, and large salinity differences when compared to surface conditions. I am sure others can identify other systems to extract energy from these energy differences. These, along with the temperature difference, can all be exploited to obtain power.

PI Response:

To the best of our knowledge this is the first study to evaluate the potential of using chemically reacting fluids for the extraction of EGS heat for power generation. I agree with the reviewer that there may be others that were well beyond the scope of the current project. However, the results obtained from this study are valuable for the evaluation and comparison of others that may be developed.

IMPROVEMENTS

Reviewer 23489

Comment: Need to select specific systems and focus on fluids for those systems (geothermal source and conversion techniques). I don't wish to be negative, but this projects really needs some help to deliver a useful product.

PI Response:

One of our conclusions is that no one single fluid is the best for all EGS reservoirs. Selection of the fluid should be done based on analysis that takes in consideration the EGS parameters and design specifics.

Reviewer 23463

Comment: It is too late to recommend improvements since the project is complete. For the future, it is important to require the proposers to have done some preliminary work to provide support that their objectives can be achieved.

PI Response:

The objectives of the funded work as per the proposed work plan were achieved.

Reviewer 23414

Comment: They should have front-ended more experimental work.

PI Response:

Good comment.

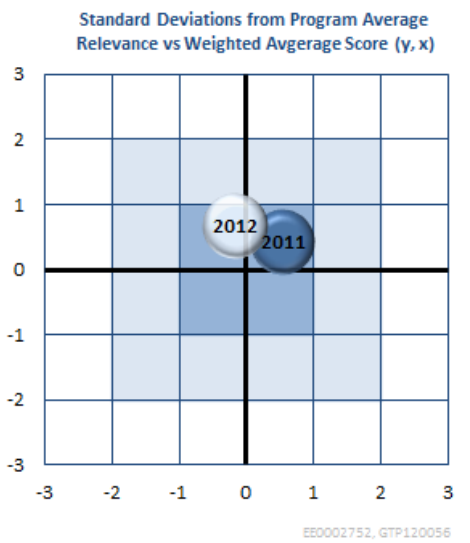
Reviewer 23445

Comment: The project should have validated their property extrapolations and their chemical systems with experiments. However, I understand that funding limitations prevented this. It is interesting that the experiments were completely

eliminated, and the modeling continued unaltered. I might have reduced both to allow some experiments to continue. However, this may not have been possible due to the timing of the funding cut.

PI Response:

Good suggestion



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002752
Project: High-Temperature-High-Volume Lifting For Enhanced Geothermal Systems
Principal Investigator: Turnquist, Norman
Organization: GE Global Research
Panel: Working Fluids

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23463

Score: 4.0

Comment: The project is addressing a real need. Deeper geothermal resources are being pursued and lifting the fluid to the surface without flashing becomes an issue unless the reservoir pressure is sufficiently high. This is especially important for EGS but may also be relevant to some deep hydrothermal resources. There is no question about the expected impact if the project is successful. This is however a very high risk project but this will be addressed in other headings.

PI Response:

No comment.

Reviewer 23489

Score: 4.0

Comment: High impact because of the potential to accelerate movement of fluids from geothermal wells. The work on downhole equipment can help other efforts if the data can be shared in a reasonably fast manner.

PI Response:

No Comment.

Reviewer 23445

Score: 3.0

Comment: This program is to develop a high volume high temperature high pressure geothermal lift pump. The program examined a wide variety of designs and selected an electrical submersible design that meets all criteria. This design will enable geothermal projects to consider deeper and hotter resources. It is unclear how many such resources can be developed. Current EGS research is still trying to determine if hotter and deeper resources can be exploited profitably. However, this pump will have other applications for GE. Its modular design allows it to be used in a variety of high temperature applications.

PI Response:

No comment.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23463

Score: 1.0

Comment: The project team is correct that the design of the motor is a critical task. They chose a hollow (to offer fluid passage) permanent-magnet (PM) motor. The review documents did not specify whether the choice is an AC or a DC motor. During the discussion a preference for an AC motor was pronounced by the presenter. This reviewer finds this preference very odd. This is explained in the following paragraph.

A serious concern not addressed anywhere in the review documents is the power transmission cable. The pump specs call for a capability of lifting 80 kg/s of brine through 300 bars of pressure difference. This requires a 3-MWe motor (assuming 78% pump efficiency). A cable carrying this much power is going to be of significant outside diameter (OD) and there will be a limit on the OD to minimise the additional flow resistance. The cable will be in hot water carrying 3-MWe power. The transmission losses will be very high and they will be even higher for AC transmission. These losses mean extra heat that needs to be dissipated. Being in a hot stream will make this job harder. The hot cable means of course higher resistance and higher losses.

The proposed test set-up does not address the cable transmission issue. No mention is made anywhere in the document that this issue has received attention.

PI Response:

The issue of power transmission to the ESP system is by no means being ignored. Steps have been taken to minimize potential losses, including maximizing the motor voltage. Additionally, the primary reason for placing the motor on the top of the ESP is to provide adequate space for electrical cabling while still having enough flow area to pass 80 kg/s of process water. The reveiwer is correct in assessing the overall power need of several MW's, and the motor is indeed an AC motor utilizing high-temperature permanent magnets. This choice provides the highest possible power density and efficiency, thus minimizing the cable power as magnetizing current is not required. Additioanlly, selecting a higher voltage reduces the current the cables have to carry and thus reduce their losses. Also, the total drive train is designed to be modular with multiple tandem motors, each fed by its own three-phase cables. Each of these three-phase cable set would only need to provide power per motor enabling the space allocation in the well for the process water and the cables to be optimized. Having multiple sets of three-phase cables makes it possible for their location to be around the outermost circumference, with larger surface area for more efficient heat transfer.

Additionally, the subject program has chosen to focus on the artificial lift aspect of the problem. A separate DOE grant of $3.2M was awarded to Draka Cableteq to focus on high temperature cable technology. Rather than duplicate efforts, the GE team has chosen to leverage the Draka work to the fullest extent possible, as mentioned on slide 13 of the presentation.

Reviewer 23489

Score: 4.0

Comment: Starting with a blank piece of paper for the design, with linkage to pump specialists, gave this project a unique perspective and opportunity for project delivery. Great approach.

PI Response:

No comment.

Reviewer 23445

Score: 3.0

Comment: I feel that this modular design provides great flexibility and will allow this pump to be used in a variety of applications. I feel that an experimental validation will enable the design to be optimized. The experimental test will examine only the pump motor, and a standard pump will be included to provide a load. This obviously will test the motor. And by making the load a pump, the motor cooling design can be evaluated. However, the pump will not be tested. I understand that the pump is not novel, and thus requires little testing. However, the experimental design as proposed misses the opportunity to evaluate pump seal operation with brines, material compatibilities, sealing operation at temperature, etc.

PI Response:

This is a valid concern. However, the "standard" pump will indeed be modified somewhat for the higher temperature operation, including material substitutions where necessary. The pump will also be instrumented so that the CFD models used to analyze it (and to design the actual geothermal pump) can be validated.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23463

Score: 1.0

Comment: There appears to be good progress with the design of the motor and the pump and the test set-up. However, the issue of transmission cable seems to have been ignored completely. This could be a showstopper and it is worrying that no mention of this was made in the presentation. This issue occurred to the reviewer after the presentation (after learning during the presentation that the motor choice was AC) therefore it was not raised as a question with the presenter. Lack of attention to this crucial issue is the reason for the low score for otherwise very good progress in other areas. The project would have scored a 3 or 4 otherwise.

PI Response:

Again as stated above, the issue of power transmission to the ESP system is by no means being ignored. The choice of an AC motor provides the highest possible power density and efficiency, thus minimizing the cable power as magnetizing current is not required. Selecting a higher voltage reduces the current the cables have to carry and thus reduce their losses. Also, the total drive train is designed to be modular with multiple tandem motors, each fed by its own three-phase cables. Each of these three-phase cable set would only need to provide power per motor enabling the space allocation in the well for the process water and the cables to be optimal. Having multiple sets of three-phase cables makes it possible for their location to be around the outermost circumference, with larger surface area for more efficient heat transfer.

Also as stated above, the GE team has chosen to leverage another DOE-funded cable development program to the fullest extent possible. This is specifically stated on slide 13 of the presentation.

Reviewer 23489

Score: 4.0

Comment: The possibility of delivering a useable product is high, given the approach, resources and importance of this product to other geothermal efforts.

PI Response:

No comment.

Reviewer 23445

Score: 3.0

Comment: To date the program has achieved all goals. It seems to be making the required progress to assure successful completion. Much of the design was deemed proprietary, and thus it is difficult to fully evaluate. By not sharing all details about the design GE misses the opportunity to gain valuable experience from some in the review. Potentially some design problem could have been identified at the peer review.

PI Response:

No comment.

PROJECT MANAGEMENT/COORDINATION

Reviewer 23463

Score: 2.0

Comment: The budget and the project schedule seems to be on track. Proving the feasibility of transmitting 3-MWe power over a 3-kilometer cable should have been included as a GO/NO GO decision point. It is disconcerting that it appears that this issue is being ignored. Lack of attention to this crucial issue is the reason for the low score for otherwise very good progress in other areas. The score would have been a 4 otherwise.

PI Response:

Again as stated above, the issue of power transmission to the ESP system is by no means being ignored. The choice of an AC motor provides the highest possible power density and efficiency, thus minimizing the cable power as magnetizing current is not required. Selecting a higher voltage reduces the current the cables have to carry and thus reduce their losses. Also, the total drive train is designed to be modular with multiple tandem motors, each fed by its own three-phase cables. Each of these three-phase cable set would only need to provide power per motor enabling the space allocation in the well for the process water and the cables to be optimal. Having multiple sets of three-phase cables makes it possible for their location to be around the outermost circumference, with larger surface area for more efficient heat transfer.

Additionally the GE team has chosen to leverage a DOE-funded cable development program rather than duplicate efforts. This is specifically stated on slide 13 of the presentation.
Reviewer 23489

Score: 4.0

Comment: The management and coordination is typical of a dedicated team in the industrial setting of a successful company that goes further and uses collaboration and involves multiple resources. It is very clear that even small details were attended to in the approach and in this paper design component. Kudos!

PI Response:

No comment.

Reviewer 23445

Score: 3.0

Comment: The project seems to be well managed, and on schedule for a successful completion. However, it seemed to me that the project seemed to not directly incorporate expertise from Wood Group. I would have thought that the GE purchase of Wood Group would have yielded a significant influx of talent into this project. I was pleased to see that GE consulted with AltaRock on what are the requirements of such a pump. Even though the potential of EGS is not well defined at this point, AltaRock should be able to guide GE on what performance parameters are of importance for this application.

PI Response:

The presenter should have made clear that Wood Group has been renamed "GE Artificial Lift", and they are cited as one of the key collaborators on slide 15 of the presentation. All aspects of the program have been, and continue to be, reviewed by experts at GE Artifical Lift. The project team realizes that their success depends on the involvement of the GE AL (formerly Wood Group) experts.

STRENGTHS

Reviewer 23463

Comment: Strong company although the expertise of the team assigned to the project is questionable.

PI Response:

The presenter should have made clear that Wood Group, an industry leader in the design, fabrication, and operation of electric submersible pumps, has been renamed "GE Artificial Lift", and they are cited as one of the key collaborators on slide 15 of the presentation. All aspects of the program have been, and continue to be, reviewed by experts at GE Artifical Lift. The project team realizes that their success depends on the involvement of the GE AL (formerly Wood Group) experts.

Reviewer 23489

Comment: Large company resources and vision for a needed items that will ultimately impact many geothermal projects.

PI Response:

No comment.

Reviewer 23445

Comment: I feel that this project is well centered on the goal of producing a high temperature high lift high volume pump. All efforts are directed to this application.

PI Response:

No comment.

WEAKNESSES

Reviewer 23463

Comment: The expertise of the team is questionable because it seems to have failed to identify power transmission as a critical component.

PI Response:

Again, the issue of power transmission to the ESP system was identified very early in the program, steps have been taken to minimize cable power losses and provide adequate space within the well to transmit power to the motor, and all aspects of the program have been, and continue to be, reviewed by experts at GE Artifical Lift (formerly Wood Group).

Reviewer 23489

Comment: None detected.

PI Response:

No comment.

Reviewer 23445

Comment: I think the proprietary nature of this project may prove to be a weakness. By not presenting the insulation selected, the oil selected, design details, the team cannot receive feedback on their choices. It is possible that other companies or government researchers may have experience with making these choices, and experiences with their actual choice.

PI Response:

This is true, and information would be shared more freely except that with GE's entry to the electric submersible pump market via its acquisition of Wood Group in 2011, disclosure of technical details may directly impact the business.

IMPROVEMENTS

Reviewer 23463

Comment: Choice of a DC motor would help the cable design although it is not known if this would be enough to make transmission feasible. The test should include testing of the cable. The pressure is not an issue and water does not need to flow therefore testing should be a lot easier although still not trivial because it would have to be tested in full length being immersed in hot brine.

PI Response:

The team will continue to focus on the motor/pump lifting system design and testing while leveraging other DOE-funded efforts on cable development to the greatest extent possible.

Reviewer 23489

Comment: None.

PI Response:

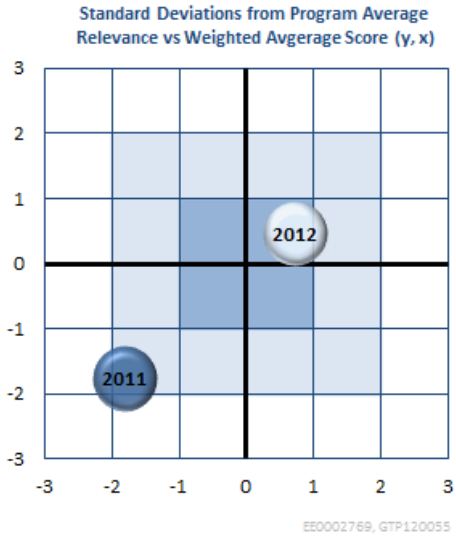
No comment.

Reviewer 23445

Comment: I think the project should have included Wood Group personnel directly into the project.

PI Response:

As stated on slide 15 of the presentation GE Artificial Lift (formerly Wood Group) are key collaborators. Since May 2011 when GE purchased Wood Group, experts at GE Artifical Lift have been actively involved in guiding the program. The project team realizes that their success depends on the involvement of the GE AL (formerly Wood Group) experts.



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002769
Project: High-Potential Working Fluids for Next Generation Binary Cycle Geothermal Power Plants
Principal Investigator: Zia, Jalal
Organization: GE Global Research
Panel: Working Fluids

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23414

Score: 4.0

Comment: I was very impressed with Zia's presentation of this work and with GE's commitment to succeed with this project. The relevance off the technical work was quite high and spoke of extensive effort by the project partners.

PI Response:

Reviewer 23463

Score: 4.0

Comment: The objectives are highly relevant to the search for higher efficiency geothermal power conversion. The supercritical cycle has the potential to deliver such improvements by offering a better match between brine cooling curve and working fluid heating curve. Compared to a single-fluid subcritical cycle, this leads to better utilization of the geothermal resource. Similar potential benefits apply also to the mixed-fluid cycles. Mixed-fluid cycles are said to be excluded from the scope of this project but it is good to know that they are covered in another GTO project by a competing manufacturer.

PI Response:

Reviewer 23489

Score: 3.0

Comment: This late stage work has high significance in a focused area of geothermal power generation. The problem is release on specific information that could help other projects.

PI Response:

Reviewer 23445

Score: 3.0

Comment: I think that this was an excellent program. It is well organized, and examined a lot of material. However, I am concerned that essentially none of the results are available to the geothermal community. If the goal of the DOE is to assist GE in their marketing of geothermal systems, this project can be considered a success. If the goal is to promote geothermal energy, it is only a partial success in that the project helped only one company. Also, by not providing details, GE limits the amount of feedback at the peer review and other forums. It is possible that the audience has experience with a particular fluid that would be of value to GE.

The only result that was presented is that if one has a higher resource temperature, one should choose a fluid with a higher critical temperature. I learned this fact within my first month of working in the field in 1980. This will not be news to many in the field.

This last year of this project was concentrated in developing a cost model for geothermal systems so that one could pick an optimum system for any resource (defined by its depth and temperature). The costs considered not only the cost of the fluid, but the costs of the energy conversion equipment and well system. Also the equipment costs were adjusted by the material compatibility of the fluid.

Some "costs" were difficult to quantify and thus evaluated via a separate process. Such as some fluids were not considered due to flammability concerns, ozone depletion concerns, global warming concerns, fluid stability concerns and a lack of good physical data. All of this is very reasonable.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23414

Score: 4.0

Comment: The technical approach was well thought out and executed.

PI Response:

Reviewer 23463

Score: 3.0

Comment: The analysis appears to be rigorous but it is difficult to be sure because very little information has been made available in the review documents. This reviewer also read the paper by the project team submitted to the last Stanford workshop and that paper also does not include information beyond generalities that have been for a long time. One issue is the assertion in the Stanford paper that Shell-and-Tube heat exchangers were selected to be used in the supercritical

ORC plant being designed. The brine is in the tubes and the cycle fluid is in the shell. Since the supercritical cycle means the heating of the cycle fluid occurs at a pressure above the critical pressure, these cycles are expected to operate at a significantly higher pressure compared to subcritical cycles. Not knowing the fluids considered by the PI, I cannot say how higher the pressure is for their cycles. Nevertheless, the difference is expected to be high enough to make the design of the shell expensive. A different heat exchanger design, e.g. plate-shell, may be more suitable.

PI Response:

Reviewer 23489

Score: 4.0

Comment: Very good technical approach that made use of talent from a wide variety of sources. Coordination with business side is good – regular meetings, Collaboration appears good. Two possible business outlets for developments .

PI Response:

Reviewer 23445

Score: 3.0

Comment: The technical approach in general seemed excellent. However, since this was only presented in general terms, it was difficult to evaluate in detail. The project considered a wide variety of costs. The project also considered a wide variety of cycles to be used at various resource temperatures. The project will be validated with a small scale experimental rig.

One of the identified risks was a lack of property data for fluids. This led to the elimination of mixed working fluids. This is a reasonable conclusion, but may yield reduced performance for some applications.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23414

Score: 4.0

Comment: I believe the project results will be of high interest. The project appears on schedule as it heads into the important pilot phase.

PI Response:

Reviewer 23463

Score: 3.0

Comment: If we accept the summary of achievements on trust, the project seems to be progressing well. It is commendable that fluid property formulae are to be verified because it is known that the existing property relations are not very reliable near the critical point. The interest in the properties near the critical point suggests that they are considering expansion through a region near the critical point. In fact, this is supported by the interest in the mention of the search for multiphase expansion e.g. for trilateral flash cycles. It is is not clear why because according to the charts presented trilateral flash cycles offer the worst performance. We did not get any impression that the heat exchanger design has been receiving the attention it deserves. In a supercritical cycle, the heat exchangers are of critical importance and will offer a greater challenge than the expander design. The score of 3 is given because we have no way of assessing the real progress due to lack of information given.

PI Response:

Reviewer 23489

Score: 4.0

Comment: Very good accomplishments and linkage to other projects. Improvement in power plant efficiency was also important. Technology approach and environmental approach is suitable – individual assessments helped eliminate some paths that would have proved troublesome later. Separation of the cycles and pricing on the chart was understandable. Presented examples and identified technology gaps and next actions.

PI Response:

Reviewer 23445

Score: 3.0

Comment: The project seems to be progressing very well. They plan to validate their modeling with an experimental program. Success of the validation will be a great addition to the program. However, this evaluation is based only on general comments made by the presenter since no concrete details were presented.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23414

Score: 4.0

Comment: The fact that GE is deploying a Senior Engineer for the critical pilot testing phase bespeaks a high degree of project management and coordination. Several instances in the preceding work were cited where strong coordination was required and delivered.

PI Response:

Reviewer 23463

Score: 3.0

Comment: 45% of the budget has been spent but the project is just starting the expensive stage where equipment is to be designed and built. No mention is made of how large the test plant is going to be. The value of the experience from a very small lab-scale test plant could be limited. But this can be forced if the project runs out of money. Otherwise, the decision points so far have been followed up and the project has been progressing well. A score of 3 is given because of having to make these assessment with little information.

PI Response:

Reviewer 23489

Score: 4.0

Comment: Very good coordination within an industry perspective - very highly focused into development of a specific technology. I was impressed with the amount of resource tie-in and the rapid pace of the project because of this.

PI Response:

Reviewer 23445

Score: 3.0

Comment: The study seemed to rely upon internal GE expertise. A couple of examples were provided where they obtained information from Energent and AltaRock. I wonder if these companies obtained any proprietary information from GE in return for this cooperation. GE was not providing much information within this review. Nor have they provided any information in their presentations at other forums.

PI Response:

STRENGTHS

Reviewer 23414

Comment: Coordination, science, engineering analysis.

PI Response:

Reviewer 23463

Comment: A strength is the fact that the PI is a manufacturer. This means a successful outcome will be quickly transferred to the market and be enjoyed by the geothermal industry.

PI Response:

Reviewer 23489

Comment: Tight work focus, Highly leveraged resource base and great results. The future from this work is outstanding. It showcases the geothermal potential and how industry and government can coordinate and deliver a success story.

PI Response:

Reviewer 23445

Comment: GE seems well qualified to perform this study. Their results seem to be excellent.

PI Response:

WEAKNESSES

Reviewer 23414

Comment: None.

PI Response:

Reviewer 23463

Comment: A weakness is the fact that the PI is a manufacturer. The IP protection concerns meant that very little real content was presented during the review (and also in the presentation to the last Stanford Workshop). Therefore, we have to take it on trust that real progress has been achieved in the project. We have no way of assessing the progress.

PI Response:

Reviewer 23489

Comment: It may be quite a while before all the data available from this project will be shared with the rest of the Geothermal researchers.

PI Response:

Reviewer 23445

Comment: From the presentation the program seems to have no weaknesses. However, little details were presented to allow me to identify any. I think they overestimated their improvements on LCOE since they used a single system for the baseline. Isobutane cannot be the optimal system for all temperatures.

PI Response:

IMPROVEMENTS

Reviewer 23414

Comment: None.

PI Response:

Reviewer 23463

Comment: Different heat exchanger options may be considered depending on the cycle fluid selection and the design expander inlet pressure values. A shell-and-tube heat exchanger where the shell is subjected to high pressures may not be the most optimum choice. We did not get any impression that the heat exchanger design has been receiving the attention

it deserves. In a supercritical cycle, the heat exchangers are of critical importance and will offer a greater challenge than the expander design.

PI Response**:**

Reviewer 23489

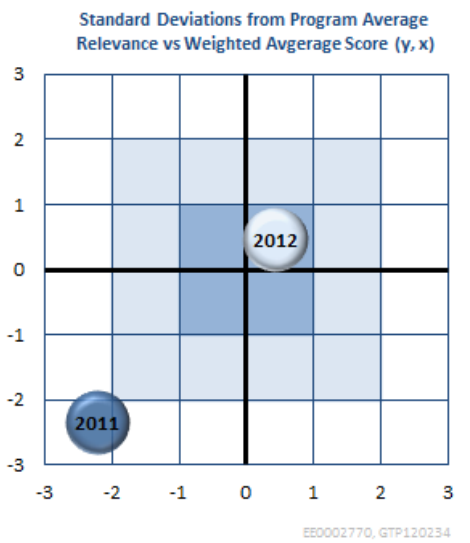
Comment: None.

PI Response:

Reviewer 23445

Comment: They did not present enough information to enable me to suggest any improvements. Maybe this is one way their secrecy may cost them. Without any feedback from outside, it is possible that they are missing something. It is unclear why GE needs DOE funding since they are such a large corporation that seems to pay no taxes.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002770
Project: Tailored Working Fluids for Enhanced Binary Geothermal Power Plants
Principal Investigator: Mahmoud, Ahmad
Organization: United Technologies Research Center
Panel: Working Fluids

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23414

Score: 4.0

Comment: This was a very well thought out theoretical and lab analysis of potential working fluids. I was quite impressed by Mahmoud's presentation of the approach and the results and believe this work will have high relevance.

PI Response:

Reviewer 23463

Score: 4.0

Comment: The objective is similar to a few other projects in the "Working Fluids" groups of project: Increased brine utilization through clever cycle design, In this project, the cleverness is designing new mixture fluids using mixtures of standard fluids. The presentation claims that a successful outcome in this project would increase the overall energy conversion efficiency of binary geothermal power plants by at least 40%. This claim may be ambitious and over-optimistic but it is certain that optimizing fluids for each individual application has significant potential benefits. The project objectives are very relevant to the broader geothermal program mission.

PI Response:

Reviewer 23489

Score: 3.0

Comment: This project is a good examination of the lower temperature working fluids with introductory work into efficiency improvements possible with classes of fluids. For this project to have sufficient impact, the project needs to have a secondary part on generating thermodynamic properties of the higher ranking fluids.

PI Response:

Reviewer 23445

Score: 3.0

Comment: This presentation is greatly improved over what was provided last year. Last year no results were presented due to proprietary concerns. This year the optimum fluids were not presented, but the study methods and concepts were presented, along with results for less than optimal fluid mixtures. The presenter claimed that performance improvements over 30% can be achieved by using mixtures of fluids for the working fluid. This is likely exaggerated since the base case considered using R245fa, which is not an optimal choice of a single fluid for many applications.

The speaker stated that use of a fluid mixture allows one to extract more heat from the brine, and allows elimination of pinch points. However, due to scaling concerns it may not be possible to further lower the brine temperature. This would limit the potential improvement due to fluid mixtures at such sites.

I was also pleased to see that the presenter now presents the improvements in energy per pound of brine instead of an increase in the cycle efficiency. Cycle efficiency is only an indicator of cost, but does not determine costs. Typically greater reduction in the heat removed from the brine will result in a lower efficiency, but a greater power. The greater power is often desired. It would be even better to present improvements in terms of LCOE, so that the operation and maintenance costs can be included in the analysis.

It is possible that if UTC would release more of its results it would gain more insight from the peer review process. It is possible that the audience has experience with some of the fluids that is not captured in the property database.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23414

Score: 4.0

Comment: The collaboration between UTRC, Georgia Tech, and NIST is well thought out and produced clear "winners" for further testing while adding to our technical understanding of the behavior of the various fluids.

PI Response:

Reviewer 23463

Score: 4.0

Comment: We were told that the Project Team evaluated Kalina cycles, bi-phase systems, and supercritical cycles before deciding that non-azeotropic mixed working fluids offer the best potential to achieve the desired improvement. It is interesting that the other manufacturing PI project arrived at exactly the opposite conclusion and decided on supercritical

cycles. This is good for the robustness of the GTO by making sure that all possibilities are explored. The team also identified a limitation that shell-and-tube heat exchangers will not work with mixed fluids and settled on a counter-flow design. There is no good data to cover different mixed fluid ratios and therefore a thermophysical property determination task was sponsored with NIST and Georgia Tech. These results were published and are probably going to be made accessible through future REFPROP editions. Overall, the project seems to be following a sufficiently rigorous path.

PI Response:

Reviewer 23489

Score: 3.0

Comment: Approach was decent but needed more detail. Rigor was sufficient and staffing was good. Specifics on these fluids was a little sketchy but appropriate for a short presentation. Good job pointing out glide profile differences and general differences for the few examples mentioned. Economics are not highly supported in the presentation but appear to be reasonable.

PI Response:

Reviewer 23445

Score: 3.0

Comment: Paper studies on optimal working fluids provide some insight. However, typically the fluid mixture properties are approximate. Therefore, this project's emphasis on experimentally determining fluid mixture properties makes it superior to the many studies that have already been completed.

The speaker indicated that environmental impacts, pressure limits, mach number limits, fluid degradation, material incompatibility, and many other considerations were used to eliminate a potential fluid. These items are difficult to quantitatively evaluate, but are proper inputs into the study.

Mixed working fluids are difficult to use due to the poor property values that are available. It was unclear how much of the mixture property values used in this study were based on ideal mixtures, and how much were based on actual measurements. This could impact some of the conclusions on which is the optimal fluid for a particular study. Since the optimal fluids were not presented, it is unclear if this is a concern.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23414

Score: 3.0

Comment: Despite a lot of this being proprietary there seems to be a substantial amount of data publication and sharing going on. The overall progress of the project is excellent.

PI Response:

Reviewer 23463

Score: 3.0

Comment: We were told that the project achieved all its initial objectives. It is easy to see that new data were generated in terms of new thermodynamic property relations and fluid selection methodologies. It is not possible for us to check whether a 40% improvement has really been achieved and under what conditions. We understand the IP concerns of the PI but it makes it difficult to check the validity of some claims. Hence the score of 3 under this heading.

PI Response:

Reviewer 23489

Score: 3.0

Comment: Accomplished a program for down-selecting working fluids, Stated aim was to get to a 40% increase in efficiency. Baseline is a cost to the customer model. Considered cost and LCOE. Profile of the temperature glide still needs work. Need equations of state for the fluids to develop heat exchangers that are optimized.

PI Response:

Reviewer 23445

Score: 3.0

Comment: From what was presented, it seems that the project was a great success to UTC. However, since the results will not be shared, it is of limited success to the industry. I assume that NIST will share the property data measurement results with the industry, and this will help other companies.

The rating of fluids based on cost and performance is good. The cost evaluation was not clearly identified. It was implied that the cost would not only include fluid costs, but cycle equipment costs. The performance evaluation has shifted from cycle efficiency to energy per pound of brine. This is an excellent shift. A further change to LCOE would enable the operation and maintenance costs to also be included.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23414

Score: 4.0

Comment: Judging from the admirable progress of the project the coordination between UTRC, NIST, and Ga. Tech has been managed well. There seems to be the real possibility that a commercially useful approach will result.

PI Response:

Reviewer 23463

Score: 4.0

Comment: The project is close to completion. It appears that the most promising candidates were selected although the review team were not told what fluids they are and in what concentrations. Equations of state will have to be developed to make cycle computations easy and heat exchanger design correlations need to be finalized. These are not onerous tasks. The project only involved fundamental testing studies to help the team generate new property data and test mixed-fluid heat exchanger behavior. These experiments were completed and no more testing is required.

PI Response:

Reviewer 23489

Score: 3.0

Comment: Adequate for the task but wasn't clear on leveraged resources.

PI Response:

Reviewer 23445

Score: 3.0

Comment: I feel that this project was managed excellently. NIST is well qualified to perform the property measurements, and Georgia Tech is well positioned to evaluate cycles. Potentially the project could have used more expertise in equipment designs since a university is typically not the best source of commercial information. The project considered a variety of cycles so that the proper cycle can be applied at each source temperature. Trilateral cycles are of current

interest, but limited experience with them introduces risks. It is hoped that these will be shown to be reliable in the near future.

PI Response:

STRENGTHS

Reviewer 23414

Comment: The fluid screening and testing approach.

PI Response:

Reviewer 23463

Comment: The collaboration between the equipment manufacturer PI and university and research institutions is a significant strength of this project. It seems that this collaboration is working well.

PI Response:

Reviewer 23489

Comment: The focus was adhered to very well, but presentation lacked sufficient detail to do more judging.

PI Response:

Reviewer 23445

Comment: This program was well balanced. Rating software was developed to rank various fluids and cycles for geothermal applications. Property measurement efforts were initiated to determine fluid properties when they were unreliable. Numerous cycles were evaluated to allow optimization for various source temperatures.

PI Response:

WEAKNESSES

Reviewer 23414

Comment: None.

PI Response:

Reviewer 23463

Comment: This is still a fundamental project and, in spite of the component-level testing done, there is still a significant amount of work that needs to be done before power generation equipment using mixed fluids become available to the geothermal developers.

PI Response:

Reviewer 23489

Comment: Linkages and collaboration - overall just needed some work.

PI Response:

Reviewer 23445

Comment: I would have hoped that the project would have been more open about their results and concerns. I understand that there are competitive concerns, and UTC would like to keep some information proprietary. However, if the industry can be more open, sharing more can be beneficial to all. Other companies can gain from the insight from this study. Also, UTC can gain if they present all of their results in detail. For example other companies might be willing to provide some insight (i.e. state that a potential fluid picks up humidity from the air, and this results in greatly reduced performance, therefore one must go to great extremes to prevent contact with air). Even if other companies do not cooperate, it is possible if more results from UTC are presented, government researchers can provide valuable inputs.

PI Response:

IMPROVEMENTS

Reviewer 23414

Comment: None.

PI Response:

Reviewer 23463

Comment: Full cycle testing would have been a big improvement on the project scope. Component level testing is valuable but full cycle testing even at a laboratory scale could identify operational difficulties that may not become apparent otherwise.

PI Response:

Reviewer 23489

Comment: Described in weaknesses.

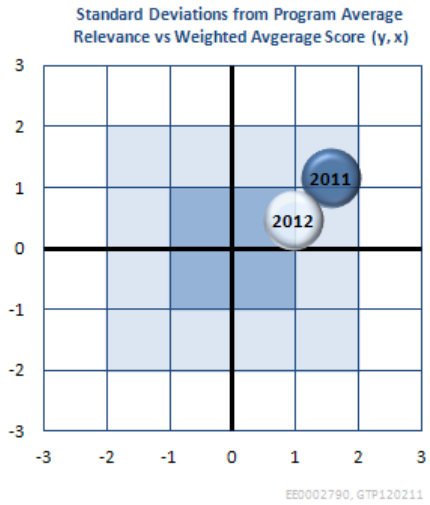
PI Response:

Reviewer 23445

Comment: I simply suggest that the project be more open with their results as stated earlier.

PI Response:

Review: 2012 Geothermal Technologies Office Peer Review
ID: EE0002790
Project: Technologies for Extracting Valuable Metals and Compounds from Geothermal Fluids
Principal Investigator: Harrison, Stephen
Organization: Simbol Materials
Panel: Working Fluids



RELEVANCE/IMPACT OF RESEARCH

Reviewer 23414

Score: 4.0

Comment: Mining valuable trace elements from geothermal brines is a novel and potentially game-changing activity in some geothermal systems. This work is of high relevance and potentially great impact.

PI Response:

Reviewer 23443

Score: 4.0

Comment: This project has made notable progress toward the Geothermal Technologies Office's goal of lowering the cost of electricity by adding an additional revenue stream to the geothermal facility operator. This additional revenue stream will only be viable with concentrated brines such as those in the Imperial Valley, California.

PI Response:

Reviewer 23489

Score: 3.0

Comment: The impact of mineral recovery is limited for rare-earth minerals focus of this project, but the knock-off information in controlling mineral removal sequence is high.

PI Response:

Reviewer 23445

Score: 3.0

Comment: This program determined a chemical process for the extraction of chemicals from a brine available from the Salton Sea. It was determined that Lithium compounds could be extracted at a profit. The company is also considering the extraction of other chemicals. Due to the unique brine available at this site, the processes developed have little or no applicability for chemical extraction at other geothermal sites. This reduces the impact of this study.

I think this is an excellent application that will make Geothermal applications more cost effective at the Salton Sea site. This company has performed well on the project. It appears to me that the project is on track to yield a very successful result.

PI Response:

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23414

Score: 4.0

Comment: This work involves the solving of a host of difficult technical problems, in particular silica removal and trace element sorption, along with all the difficulties of working with high temperature, high salinity brines. These folks seem to have a well developed understanding of the technical obstacles and a comprehensive plan for overcoming them.

PI Response:

Reviewer 23443

Score: 4.0

Comment: The technical approach was sound and has proven to be successful. The development of an ion exchange medium that is selective for the lithium ion is a significant advancement and may be useful to current lithium producers. The generation of a silica removal process (probably Ferric chloride coagulation) that produces a precipitate that can pass EPA TCLP and STLP testing is also significant.

PI Response:

Reviewer 23489

Score: 4.0

Comment: Excellent approach and focus on specific metals and the move from lab to pilot plant with a focus on the next step that leads to early equipment optimization.

PI Response:

Reviewer 23445

Score: 4.0

Comment: The project has considered a wide variety of chemical processes that may be used to extract valuable chemicals from a specific geothermal brine. The company has considered environmental consequences of its process choices in considering the toxicity of the chemicals used and the waste streams generated. The company is concerned with the waste streams and has tried to develop processes that allow for safe disposal of the wastes generated.

PI Response:

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23414

Score: 3.0

Comment: Although according to the slides, there were no papers and no presentations, this is probably because of the proprietary nature of a lot of this work. Judged on the stated technical achievements - the selectivity measurements, batch and column tests, and the 4 patents - this project has made significant accomplishments.

PI Response:

Reviewer 23443

Score: 4.0

Comment: This project has accomplished two important things. First, they have been able to recover Lithium from the geothermal solutions that is sufficiently pure for batteries. Next they have been able to remove silica in a form that is not a hazardous waste. Progress has been steady.

PI Response:

Reviewer 23489

Score: 4.0

Comment: The progress from early testing to pilot plant to testing of the end product and manufacture of a battery using the end product is excellent.

PI Response:

Reviewer 23445

Score: 3.0

Comment: The project is currently 70% complete, and is on tract to a successful conclusion. The project has developed a new cost effective process to extract lithium compounds that result in a minimum amount of waste. It seems that their processes will not conflict with the operation of the geothermal power plant. However, it may result in a colder brine temperature for re-injection. A study on the impact on the thermal source is of interest. It is also possible that the chemically altered brine may result in unwanted chemical reactions in the reservoir that may impact the chemical and/or the thermal extraction from the reservoir.

PI Response:

PROJECT MANAGEMENT/COORDINATION

Reviewer 23414

Score: 3.0

Comment: This all looks good. This program appears well planned and moving forward despite the various technical challenges.

PI Response:

Reviewer 23443

Score: 3.0

Comment: There is no indication that the project encountered schedule delays. However, there is an apparent cost over-run that will be absorbed by Simbol Materials.

PI Response:

Reviewer 23489

Score: 4.0

Comment: The coordination and collaboration was adequate to achieve the progress but not overblown to the extend that would slow a project's progress.

PI Response:

Reviewer 23445

Score: 4.0

Comment: This project seems to be well coordinated. Experimental studies compliment the process modeling. However, due to proprietary concerns, details of this project were not shared. This limits my ability to fully evaluate this project. It also limits that potential for the project gaining valuable input from the peer review audience. It is possible that they could identify a problem or improvement unknown to Simbol.

PI Response:

STRENGTHS

Reviewer 23414

Comment: Silica removal and sorbent screening and identification.

PI Response:

Reviewer 23443

Comment: This project has added an additional revenue stream to geothermal power plants in the Salton Sea area. It is also providing a source for high quality lithium that will become more important as more cars become electrified.

PI Response:

Reviewer 23489

Comment: The vison along the progress path was outstanding as was the capturing of the lessons learned that quickly optimized the project.

PI Response:

Reviewer 23445

Comment: The balance of this study is its greatest strength. It seems that all modeling is validated by an experimental program. The project is considering not only yield, but waste streams. This will all yield an efficient process.

PI Response:

WEAKNESSES

Reviewer 23414

Comment: I'm not completely sold on the relevance of the Li cathode testing. The work looks well done, but appears as a superfluous add-on of a battery development effort to the much more relevant lithium extraction work.

PI Response:

Reviewer 23443

Comment: This technology will only be applicable to the Salton Sea KGRA as other geothermal resources do not have significant lithium concentrations.

PI Response:

Reviewer 23489

Comment: None noted.

PI Response:

Reviewer 23445

Comment: The only portion that the project seems to have ignored is the impact of their process on the geothermal and chemical source. Likely, the impact on the thermal is not a direct concern of Osmol, and this may have been investigated by the power operator. However, if the power plant stops operation, the feed of brine will stop. I would be concerned how the altered brine may impact the geothermal source. Obviously the lowered brine temperature is will deplete the source quicker, but this may not be significant. A quick analysis could address this issue. The altered chemical content was stated to be easier to handle due to reduced scaling. However, the altered brine chemistry may result in chemical reactions within

the geothermal reservoir that are detrimental (reduction of permeability, fixing of lithium to the rock, etc.). This was not discussed.

PI Response:

IMPROVEMENTS

Reviewer 23414

Comment: None.

PI Response:

Reviewer 23443

Comment: Reviewer did not provide comments for this criterion.

PI Response:

Reviewer 23489

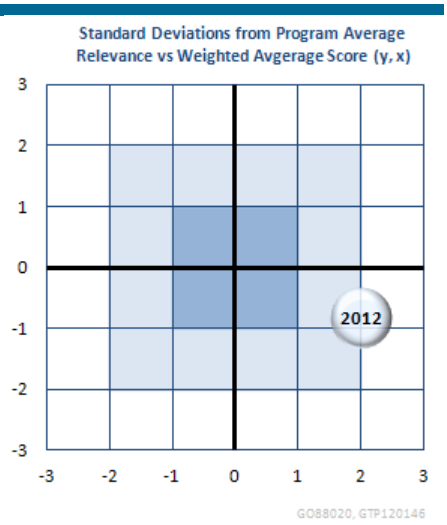
Comment: None noted.

PI Response:

Reviewer 23445

Comment: I have no chemical process background so it is difficult for me to suggest any improvement. This seems like a well run program. I am a little concerned that this program has no application to other sites, and even if it did Simbol seems unwilling to share any of the detailed results. This program will make money for Simbol, and Simbol will share some of the profits with the geothermal operator. However, it has little general application.

PI Response:



Review: 2012 Geothermal Technologies Office Peer Review
ID: GO88020
Project: Geothermal Working Fluids
Principal Investigator: Brennecke, Joan
Organization: Notre Dame University
Panel: Working Fluids

RELEVANCE/IMPACT OF RESEARCH

Reviewer 23414

Score: 2.0

Comment: I doubt ionic fluids will ever be used in geothermal matters and the presentation could not persuade me otherwise.

PI Response:

As pointed out by one of the other reviewers below, this project is perhaps a bit more fundamental than other EERE projects. As a result, we probably should have done a better job of describing the potential, although not immediate, applications. We believe that the use of ionic liquids for cooling systems using low grade geothermal heat does have significant potential, as pointed out by some of the other reviewers. We have formed a new company (Ionic Research Technologies) to advance the use of ionic liquids for cooling and heating applications. We now believe, in agreement with the reviewer, that ionic liquids are not likely to be used in down hole heat transfer applications. Fortunately, the work on ionic liquids as heat transfer fluids has much broader application than solely in geothermal systems. We believe that this research has contributed to the use of ionic liquids in other heat transfer applications.

Reviewer 23463

Score: 2.0

Comment: The objective of this project is to develop ionic liquids for two geothermal energy related applications. The first goal is to design ionic liquids as high temperature heat transfer fluids. The second is to use ionic liquids in absorption refrigeration systems driven with low temperature geothermal resources. The first objective is not expected to have a significant impact on geothermal power generation efficiencies. Since the fluids are only used as a heat transfer fluid, in other words extracting the heat from brine and passing it on to the cycle fluid in another heat exchange, the benefit is not clear. What is gained in increased heat transfer capability will be lost by having an extra heat exchanger. On the other hand, the success towards the second objective could have a very significant impact in utilizing Low Temperature geothermal resources and ground source heat pumps, and air conditioning driven by solar collectors. The project is however misplaced in this project heading since it will have no significant impact in the primary focus of this group of projects. Hence it gets a lukewarm rating from this reviewer.

PI Response:

As indicated in the previous response, we now agree that ionic liquids are not likely to see use as down hole heat transfer fluids and, therefore, not likely to have any significant impact on geothermal power generation efficiencies. We appreciate this reviewer's understanding of and enthusiasm for the use of ionic liquids for cooling with low grade

geothermal heat sources. We agree with that analysis. We agree that EERE's positioning of the presentation of our project in the 'working fluids' section may not have been the most appropriate.

Reviewer 23489

Score: 4.0

Comment: Geothermal Working Fluids is a high impact area for most geothermal projects. This project delivered significant work on ionic liquid heat transfer.

PI Response:

We appreciate the reviewer's enthusiasm for our work. We agree that we have shown ionic liquids to be excellent heat transfer fluids. However, like the reviewers above, we are not convinced that they will be useful for down hole applications, primarily because of environmental concerns.

Reviewer 23445

Score: 2.0

Comment: This project investigated the use of ionic liquids in geothermal applications. Much of the presentation seemed to compare ionic liquids to silicone oil. This seemed odd to me for silicone oil is not used in geothermal applications, nor do I see much potential for using silicone oile in geothermal applications. A "heat transfer fluid" other than water (or maybe CO2) is not considered for use in geothermal applications. The volumes of heat transfer fluid are so large, it is not possible to use anything that has any significant cost.

Some of the work considered use of ionic liquids as a working fluid in absorption refrigeration equipment. Geothermal heat to run an absorption refrigeration cycle is an excellent application. This seems to be the only relevant portion of the study.

PI Response:

We compare ionic liquids to silicone oil because this is a commonly used heat transfer fluid. As touched on above, we agree that neither ionic liquids (nor silicone oils) are likely to be used in down hole applications. However, they do have significant potential for other heat transfer fluid applications, where silicone oil would be an appropriate point of comparison. Here again, we fully appreciate the reviewer's understanding of and enthusiasm for our work demonstrating the potential of ionic liquids for utilization of low grade geothermal resources for cooling.

SCIENTIFIC/TECHNICAL APPROACH

Reviewer 23414

Score: 4.0

Comment: The technical analysis of the problem was fundamental and top-notch. I am certain that new applications for ionic fluids will be found because of this research. I just don't think they're going to be in geothermal.

PI Response:

We thank the reviewer for the comments on the high quality of our research. We agree that the use of ionic liquids as heat transfer fluids is not likely to be in the geothermal arena. However, we believe that the use of ionic liquids for cooling using low grade geothermal resources does have significant potential.

Reviewer 23463

Score: 3.0

Comment: For the use of ionic liquids (ILs) as heat transfer fluids, the target metrics are different from the use as in absorption chiller applications. The ILs as heat transfer fluids are identified in the documentation but the ILs considered for absorption chiller application are not identified. Since it is the second objective that is important about this project, hearing about progress in this area would be more interesting. These questions could not be adequately addressed in the Q&A session because the PI could not personally attend. The project team has had a commendable output in terms of scientific articles and some of these questions can probably be found in those publications. It would have been a better use of resources if the focus were limited to the second objective.

PI Response:

Yes, the details on the ionic liquids for the absorption chiller application are given in many of the presentations and publications that have resulted from this project. It is true that of the senior personnel associated with this project that I (the PI of the project - Joan Brennecke) am the most familiar with the absorption cooling work. I regret that I was not able to attend the review and present our report myself. Unfortunately, I had to make arrangements for and attend the funeral of my father, who passed away the previous week. However, I am confident that Professor McCready, the co-PI who gave the presentation, would have been able to explain the details of the ionic liquid/water absorption chiller if any of the reviewers had asked a question. Unfortunately, there were no questions about this at the end of the presentation.

Reviewer 23489

Score: 3.0

Comment: Held monthly meetings and appeared to be well leveraged with knowledge bases. Early screening with a group of Go-No/Go decisions and used outside reviews. Labor well spread among several groups.

PI Response:

Yes, we have held monthly meetings of all of the personnel from multiple research groups for the duration of this project. We think that this communication has been vital to the progress of the project.

Reviewer 23445

Score: 3.0

Comment: The program goal is to measure properties of ionic liquids to enable the determination of their potential to be used in geothermal applications. With these properties the researcher can calculate the performance of these fluids. Molecular dynamic calculations are also to be performed. This is a reasonable outline of work to be performed.

PI Response:

We agree with the reviewer's statements.

ACCOMPLISHMENTS, RESULTS, AND PROGRESS

Reviewer 23414

Score: 4.0

Comment: Lots of papers, technical accomplishments, and presentations. This was an obviously productive group.

PI Response:

Yes, given the somewhat more fundamental nature of this project, technical presentations and reviewed publications has been an extremely important component of our work. We believe this has provided an excellent learning experience for all of the graduate students working on the project.

Reviewer 23463

Score: 2.0

Comment: While higher COP is demonstrated with the chosen IL/water mixtures, it is a long way from satisfactory thermodynamic performance to a successful reliable solution. Long-term issues associated to repeated cycling of the absorption process are important and have been the reason in the past for the rejection of some of the promising absorption chiller material candidates. No evidence has been presented about even a simple experimental apparatus where these effects were tested in long-term operation. It would not have been expensive to build such a simple scaled rig of the absorption chilling process using the selected ILs. The project budget was large enough to allow for this.

PI Response:

We appreciate the reviewer's suggestion of the construction of an absorption chiller demonstration rig. This was not within the scope of the award. Unfortunately, the project concludes in just one month so I am afraid that it is not possible to modify the scope of work for the project at this point. Construction of ionic liquid - based cooling demonstration units is a goal of the company that we have formed.

Reviewer 23489

Score: 4.0

Comment: Good progress from description of tasks. Worked with Ionic liquids for heat transfer and distinguished between thermal property change and decomposition. Good work confirming vapor pressures for the working fluids. Good effort – helps to rule out false indicators of decomposition. Molecular dynamic simulations used to investigate equilibrium.

PI Response:

We thank the reviewer for these positive comments.

Reviewer 23445

Score: 2.0

Comment: The number of property measurements seemed to be small for the amount of funding received. Properties for only three liquids were presented. The properties that were measured were thermal conductivity, thermal heat capacity, viscosity, and thermal decomposition. These property values were only obtained a a few temperatures.

The molecular dynamics portion of this study was not completed. Limited results on a gold/water mixture had no relevance to geothermal applications. It was unclear if further molecular dynamics are to be attempted. However, it is unlikely since the program is 90% complete.

The analysis to determine the COP of absorption cycles are of interest. However, it is unclear how realistic these calculations are. The assumptions on the cycle characteristics were not presented. For example, what temperature differentials were assumed across heat exchangers, what pumping efficiencies were assumed, etc. Also, the equipment and fluid costs were not estimated. It is possible that the cycle is indeed optimum, but too costly. The costs of the fluid seem to be very large.

PI Response:

Given the time limitations, we only presented sample measurements in the project review presentation. We have synthesized, characterized and tested many more than three ionic liquids (on the order of about a dozen). We have even investigated the properties of a variety of ionic liquid mixtures. These results are given in the quarterly reports and the technical presentations and publications that have and will be resulting from the project.

The reviewer is correct that the molecular dynamics work provided significantly more challenges than were anticipated and progressed at a much slower rate than we would have liked. As a result, we did not achieve the planned objectives in this area. Fortunately, the work that was done (with gold nanoparticles in water) is of interest and has resulted in peer-reviewed publications. There are no plans that I know of for continuation of that work since this project concludes in one month and the graduate student graduated in May.

We are sorry that we did not put more details on the steady state and unsteady state models of the absorption refrigeration system in the presentation. These can be found in the technical presentations and publications, including some that are currently in preparations (Revelli et al. and Maces and Stadtherr).

PROJECT MANAGEMENT/COORDINATION

Reviewer 23414

Score: 4.0

Comment: Multiple tasks were being pursued simultaneously and all seemed to have mostly succeeded.

PI Response:

Thank you. We agree, except for the nanoparticle molecular dynamics work, which was not completed, as noted above.

Reviewer 23463

Score: 2.0

Comment: There is little synergy between the two objectives and it was a mistake to structure the project at the beginning with these two objectives. It would have been a lot better to focus on the second objective, which is the one with the real impact, i.e. absorption chilling. The sharper focus would have helped the team generate more convincing results beyond thermodynamic analyses and would probably start teasing out operational issues that may or may not be associated with the use of these new fluids.

PI Response:

Yes, we agree that the two objectives were mostly unrelated, except that they both involved the synthesis and characterization of ionic liquids, with which our group at the University of Notre Dame has significant expertise. After completing the research, we agree that the absorption chilling application has much more potential for geothermal applications and focus on that application may have been a better use of resources.

Reviewer 23489

Score: 4.0

Comment: Project management was highly effective - illustrated by regular reports and outside reviews.

PI Response:

Thank you.

Reviewer 23445

Score: 2.0

Comment: It is difficult to evaluate the project management of a project that yielded limited results. The lack of project management could have caused the problem, or the lack of results was simply due to poor staff performance. My impression was that each participant was given free rein to contribute in any way they desired with little coordination.

PI Response:

We strongly disagree that there has been a lack of results and lack of coordination for this project. As demonstrated by the acknowledged large number of presentations and publications, there have been a large number of results. Once again, the May 2012 presentation only included a sampling of the results due to time limitations. While each research group brought different expertise to the table, they were not given free rein. The monthly meetings served to ensure the necessary coordination. For instance, the dynamic absorption chilling model was made using the experimental data for the ionic liquid/water system that the experimental group had found to have the best properties. The physical properties simulations (i.e., not to be confused with the nanofluid simulations) were for exactly the same ionic liquids that were synthesized, characterized and tested for viscosity, density, thermal conductivity, heat capacity and thermal decomposition. Please see the quarterly reports (e.g., the quarterly report for 1/1/11-3/31/11) for a demonstration of the coordination and comparisons between the experimental and computational work.

STRENGTHS

Reviewer 23414

Comment: Good experimental work and fundamental analysis.

PI Response:

Thank you.

Reviewer 23463

Comment: The project team has strong scientific credentials.

PI Response:

Thank you.

Reviewer 23489

Comment: Helped understand mixing with the gold work and how that related to enhanced thermal conductivities. Experiments proved that this is not a large area for improvement. Identified better fluids and then looked for cheaper supply. This is important to industry usage.

PI Response:

Yes, we agree; even though the nanofluid simulations were limited to gold nanoparticles in water, they did provide new insights and understanding.

Reviewer 23445

Comment: The personnel were well qualified to execute this project.

PI Response:

Thank you.

WEAKNESSES

Reviewer 23414

Comment: Again, I think ionic liquids are quite a long shot for geothermal. This work should have been funded by DOE-BES.

PI Response:

As discussed above, we agree that this project was somewhat fundamental. Although we do not anticipate down hole geothermal applications for ionic liquids, we do think that the use of ionic liquids for cooling using low grade geothermal resources is an excellent application. The reviewer is correct that it may have been more appropriate for this project to have been funded by BES.

Reviewer 23463

Comment: The project focus is diluted by having two unrelated objectives. It was also not clear whether the project team had access to engineering expertise with conventional absorption chillers.

PI Response:

During the course of the project, the University researchers had limited access to industrial engineering expertise on absorption chillers. This would have been essential if producing a demonstration unit had been a component of the project. However, building or modifying the absorption chiller equipment was not within the scope of this project. Rather, the focus was on understanding the fundamental thermodynamics of the process and designing appropriate ionic liquids for this application.

Reviewer 23489

Comment: Silicone oil really not a useful comparison.

PI Response:

As mentioned above, we agree that neither ionic liquids nor silicone oil is likely to be used in down hole applications. However, ionic liquids are excellent heat transfer fluids for non-geothermal applications and silicone oil is used for those applications.

Reviewer 23445

Comment: The project should have been more goal oriented. Additional property measurements should have been provided. It is unclear if the project identified fluid properties that are desired to maximize the performance of an absorption refrigeration cycle. This should have been done, and the efforts of the project should have centered on developing a fluid with the desired traits.

PI Response:

The project did focus on developing an ionic liquid for the absorption chiller application with the desired traits. Based on synthesis, characterization, testing, molecular simulations, and steady-state and dynamic moldeing of the absorption refrigeration cycle, we determined that the ionic liquid with all the desired traits is [emim][TfO]. It is the one having the highest COP in the graph shown in the review presentation. As shown in our quarterly reports, it yields a reasonably sized chiller system, with reasonable circulation rates. Once again, we are sorry that all of the information and properties were not shown in the May review presentation, due to time limitations. However, all this information is in the quarterly reports, as well as the technical presentations and reviewed publications.

IMPROVEMENTS

Reviewer 23414

Comment: None.

PI Response:

N/A

Reviewer 23463

Comment: The project is almost complete and too late to suggest improvements. It has already been noted that a sharper focus would have helped.

PI Response:

As mentioned above, we agree, after having completed the research, that the absorption chiller application has more potential for geothermal projects.

Reviewer 23489

Comment: None.

PI Response:

N/A

Reviewer 23445

Comment: I think this study was a solution looking for a problem. The personnel obviously are looking for a use of ionic liquids. The did identify it as a working fluid for absorption refrigeration, and this is a potential use. Their efforts should have been concentrated in this application. They should have tried to determine what properties make it a good working fluid, and tried to develop a fluid that optimizes these properties. Use of an ionic liquid as a "heat transfer fluid" is a non-starter. The volumes required are too large, and the pumping this fluid through a geolotic medium would simply be considered pollution.

PI Response:

As mentioned above, we agree, after doing the research, that the absorption chiller application has more potential for geothermal projects.

Appendix B: Project Identification Information

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120260	EE0000215	Concept Testing and Development at the Raft River Geothermal Field, Idaho	Moore	Joseph	University of Utah	Enhanced Geothermal Systems Demonstrations
GTO120065	GO18201	Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field	Walters	Mark	Geysers Power Company, LLC	Enhanced Geothermal Systems Demonstrations
GTO120158	ID14406	Desert Peak East EGS Project	Drakos	Peter	Ormat Nevada, Inc.	Enhanced Geothermal Systems Demonstrations
GTO120157	GO18200	Feasibility of EGS Development at Bradys Hot Springs	Drakos	Peter	Ormat Nevada, Inc.	Enhanced Geothermal Systems Demonstrations
GTO120002	EE0002777	Newberry Volcano EGS Demonstration	Petty	Susan	AltaRock Energy, Inc.	Enhanced Geothermal Systems Demonstrations
GTO120162	EE0002839	Advanced Seismic data Analysis Program (The "Hot Pot Project")	Rocher	Theodore	Oski Energy, LLC	Exploration Validation
GTO120177	EE0002845	Alum Innovative Exploration Project	Miller	Clay	Ram Power Corp.	Exploration Validation
GTO120241	EE0002748	Characterizing Structural Controls of EGS-Candidate and Conventional Geothermal Reservoirs in the Great Basin: Developing Successful Exploration Strategies in Extended Terranes	Faulds	James	University of Nevada, Reno	Exploration Validation
GTO120176	EE0002842	Comprehensive Evaluation of the Geothermal Resource Potential within the Pyramid Lake Paiute Reservation	Noel	Donna	Pyramid Lake Paiute Tribe	Exploration Validation
GTO120161	EE0002838	Conducting a 3D Converted Shear Wave Project to reduce exploration risk at Wister, CA	Walsh	Patrick	Ormat Technologies Inc.	Exploration Validation

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120239	EE0002960	Detachment Faulting and Geothermal Resources - An Innovative Integrated Geological and Geophysical Investigation in Fish Lake Valley, Nevada	Stockli	Daniel	University of Kansas	Exploration Validation
GTO120003	EE0002778	Development of Exploration Methods for Engineered Geothermal Systems through Integrated Geophysical, Geologic and Geochemical Interpretation	Iovenitti	Joe	AltaRock Energy, Inc.	Exploration Validation
GTO120052	EE0002828	Direct Confirmation of Commercial Geothermal Resources in Colorado using Remote Sensing and On-Site Exploration, Testing and Analysis	Robinson	F.	Flint Geothermal LLC	Exploration Validation
GTO120180	EE0002827	El Paso County Geothermal Electric Generation Project: Innovative Research Technologies Applied to the Geothermal Resource Potential at Ft. Bliss	Lear	Jon	Ruby Mountain, Inc	Exploration Validation
GTO120144	EE0002835	High Precision Geophysics & Detailed Structural Exploration & Slim Well Drilling	Casteel	John	Nevada Geothermal Power Inc.	Exploration Validation
GTO120175	EE0002841	Innovative Exploration Techniques for Geothermal Assessment at Jemez Pueblo, New Mexico	Kaufman	Greg	Pueblo of Jemez	Exploration Validation
GTO120093	904 FY11 AOP 3	Integrated Chemical Geothermometry System for Geothermal Exploration	Spycher	Nicolas	Lawrence Berkeley National Laboratory	Exploration Validation
GTO120159	EE0002836	Merging High Resolution Geophysical and Geochemical Surveys to Reduce Exploration Risk at Glass Buttes, Oregon	Walsh	Patrick	Ormat Technologies Inc.	Exploration Validation
GTO120263	EE0002848	The Snake River Geothermal Drilling Project - Innovative Approaches to Geothermal Exploration	Shervais	John	Utah State University	Exploration Validation
GTO120237	EE0002846	Validation of Innovative Exploration Techniques at Pilgrim Hot Springs, Alaska	Holdmann	Gwen	University of Alaska Fairbanks	Exploration Validation
GTO120044	EE0002833	Validation of Innovative Exploration Technologies for Newberry Volcano	Waibel	Albert	Davenport Power, LLC	Exploration Validation

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120106	LLNL FY11 AOP 1	Application of geothermally produced silica in Reservoir Management	Hunt	Jonathan	Lawrence Livermore National Laboratory	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120201	SNL FY11 AOP3.4	Auto-Indexer for Percussive Hammers	Sugama	JiAnn	Sandia National Laboratories	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120190	717	Base Technologies and Tools for Supercritical Reservoirs	Lindblom	Scott	Sandia National Laboratories	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120045	EE0002786	Complete Fiber/Copper Cable Solution for Long-Term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells	Lowell	Mark	Draka Cableteq USA	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120016	GO18186	Detecting Fractures Using Technology at High-Temperatures and Depths	Patterson	Doug	Baker Hughes Oilfield Operation, Inc.	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120171	EE0002746	Development of a Hydrothermal Spallation Drilling System for EGS	Potter	Jared	Potter Drilling, Inc.	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120197	SNL FY11 AOP2.4	Development of a Multichip Module(MCM) to Enhance High Temperature Accelerometer Measurements	Lindblom	Scott	Sandia National Laboratories	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120206	SNL FY11 AOP3.1	Energetic Materials for EGS Well Stimulation	Blankenship	Doug	Sandia National Laboratories	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120198	SNL FY11 AOP3.1	Enhanced High Temperature/High Speed Data Link for Logging Cables	Lindblom	Scott	Sandia National Laboratories	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120154	ORNL FY11 AOP 3	Evaluation of Corrosion/Erosion of Casing Materials Under Extreme Conditions	Jy-An Wang	John	Oak Ridge National Laboratory	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120024	600	Geopolymer Sealing Materials	Sugama	Toshi	Brookhaven National Laboratory	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120238	EE0002753	Harsh Environment Silicon Carbide Sensor Technology	Pisano	Dr. Albert	University of California, Berkeley	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120015	EE0002782	High Temperature 300°C Directional Drilling System	Dick	Aaron	Baker Hughes Oilfield Operation, Inc.	High Temp Tools, Drilling Systems, Zonal Isolation

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120200	SNL FY11 AOP3.3	High Temperature Downhole Motor	Raymond	David	Sandia National Laboratories	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120041	EE0002771	High Temperature, High Pressure Devices for Zonal Isolation in Geothermal Wells	Fabian	Paul	Composite Technology Development, Inc.	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120040	EE0002751	High-Temperature Circuit Boards for use in Geothermal Well Monitoring Applications	Hooker	Matthew	Composite Technology Development, Inc.	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120079	EE0002783	Microhole Arrays Drilled With Advanced Abrasive Slurry Jet Technology To Efficiently Exploit Enhanced Geothermal Systems	Oglesby	Kenneth	Impact Technologies, LLC	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120107	LLNL FY11 AOP 2	Modeling of thermally induced spall of brittle geomaterials	Lomov	Ilya	Lawrence Livermore National Laboratory	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120058	EE0002787	Multiparameter Fiber Optic Sensing System for Monitoring Enhanced Geothermal Systems	Challener	William	GE Global Research	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120109	719	Multipurpose Acoustic Sensor for Downhole Fluid Monitoring	Pantea	Cristian	Los Alamos National Laboratory	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120071	EE0002754	OM-300 - MWD Geothermal Navigation Instrument	Ohme	Bruce	Honeywell International, Inc.	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120207	EE0002788	Perforating System for Geothermal Applications	Smart	Moises	Schlumberger Technology Corporation	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120057	EE0002755	Pressure Sensor and Telemetry Methods for Measurement While Drilling in Geothermal Wells	Vert	Alexey	GE Global Research	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120147	EE0002784	Stinger enhanced bits for engineered geothermal systems (EGS)	Hall	David	Novatek, Inc.	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120188	704	Technology Development and Field Trials of EGS Drilling Systems	Raymond	David	Sandia National Laboratories	High Temp Tools, Drilling Systems, Zonal Isolation
GTO120019	EE0002856	Beowawe Bottoming Binary Project	McDonald	Dale	Beowawe Power, LLC	Low Temperature and Co-Production Demonstration

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120048	GO15153	Demonstration of a Variable Phase Turbine Power System for Low Temperature Geothermal Resources	Hays	Lance	Energent Corporation	Low-Temperature and Co-Production Demonstration
GTO120218	EE0002860	Dixie Valley Bottoming Binary Project	McDonald	Dale	Terra-Gen	Low-Temperature and Co-Production Demonstration
GTO120163	EE0004430	Kalex Advanced Low Temperature Geothermal Power Cycle (The Bald Mountain Project)	Bandt	Dr. Larry	Oski Energy, LLC	Low-Temperature and Co-Production Demonstration
GTO120126	NREL FY11 AOP1	Low Temperature Power Production Field Validation	Williams	Tom	National Renewable Energy Laboratory	Low-Temperature and Co-Production Demonstration
GTO120081	EE0002858	Novel Energy Conversion Equipment for Low Temperature Geothermal Resources	Minor	Eric	Johnson Controls, Inc.	Low-Temperature and Co-Production Demonstration
GTO120155	EE0002859	Osmotic Heat Engine for Energy Production from Low Temperature Geothermal Resources	McGinnis	Dr. Robert	Oasys Water	Low-Temperature and Co-Production Demonstration
GTO120216	EE0003006	Rural Cooperative Geothermal Development- Electric and Agriculture	Silveria	Daniel	Surprise Valley Electrification Corp.	Low-Temperature and Co-Production Demonstration
GTO120047	EE0004423	Scale Resistant Heat Exchangers for Low Temperature Geothermal Binary Cycle Power Plant	Welch	Phillip	Energent Corporation	Low-Temperature and Co-Production Demonstration
GTO120046	EE0004435	Small Scale Electrical Power Generation from Heat Co-Produced in Geothermal Fluids: Mining Operation	Clark	Tom	ElectraTherm, Inc.	Low-Temperature and Co-Production Demonstration
GTO120236	EE0002853	Technical Demonstration and Economic Validation of Geothermally-Produced Electricity from Coproduced Water at Existing Oil/Gas Wells in Texas	Luchini	Chris	Universal GeoPower, LLC	Low-Temperature and Co-Production Demonstration

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120118	EE0004431	The Canby Cascaded Geothermal Development Project	Merrick	Dale	Modoc Contracting Company	Low-Temperature and Co-Production Demonstration
GTO120242	EE0002759	A new analytic-adaptive model for EGS assessment, development and management support	Danko	George	University of Nevada, Reno	Modeling
GTO120221	GO18194	Analysis of Geothermal Reservoir Stimulation using Geomechanics-Based Stochastic Analysis of Injection-Induced Seismicity	Ghassemi	Ahmad	Texas A&M University	Modeling
GTO120210	EE0002763	Development of an Advanced Stimulation/Production Predictive Simulator for Enhanced Geothermal Systems	Pritchett	John	Science Applications International Corporation	Modeling
GTO120094	LBNL FY11 AOP 4	Modeling Supporting the Demonstration of a Deep Enhanced Geothermal System at the Northwest Geysers Geothermal Field, California	Rutqvist	Jonny	Lawrence Berkeley National Laboratory	Modeling
GTO120103	300	Predicting Stimulation-Response Relationships for Engineered Geothermal Reservoirs	Carrigan	Charles	Lawrence Livermore National Laboratory	Modeling
GTO120091	511 FY11 AOP 10	Application of Microearthquake (MEQ) Monitoring for Characterizing Enhanced Geothermal Systems	Majer	Ernie	Lawrence Berkeley National Laboratory	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120248	EE0002747	Characterizing Fractures in Geysers Geothermal Field by Micro-seismic Data, Using Soft Computing, Fractals, and Shear Wave Anisotropy	Aminzadeh	Dr. Fred	University of Southern California	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120116	GO18190	Detection and Characterization of Fractures for the Development of EGS	Toksoz	M. Nafi	Massachusetts Institute of Technology	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120084	900	Fluid Imaging of Enhanced Geothermal Systems through Joint 3D Geophysical Inverse Modeling	Newman	Greg	Lawrence Berkeley National Laboratory	Seismicity, Fluid Imaging, Reservoir Fracture Characterization

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120250	EE0002750	Fracture Network and Fluid Flow Imaging for Enhanced Geothermal Systems: Applications from Multi-Dimensional Electrical Resistivity Structure	Wannamaker	Phillip	University of Utah	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120092	512 FY11 AOP 5	Imaging Fluid Flow in Geothermal Wells Using Distributed Thermal Perturbation Sensing	Freifeld	Barry	Lawrence Berkeley National Laboratory	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120110	AID 19712	Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in Enhanced Geothermal Systems (EGS) Reservoirs	Huang	Lianjie	Los Alamos National Laboratory	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120090	510 FY11 AOP 13	Joint Seismic-Electromagnetics Inversion for Iceland Geothermal Systems	Newman	Greg	Lawrence Berkeley National Laboratory	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120104	508	Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing	Templeton	Dennise	Lawrence Livermore National Laboratory	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120053	GO18187	Micro-earthquake Technology for EGS Fracture Characterization	Foulger	Dr. Gillian	Foulger Consulting	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120117	GO18197	Monitoring and Modeling Fluid Flow in a Developing EGS Reservoir	Fehler	Michael	Massachusetts Institute of Technology	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120070	GO18191	Seismic Fracture Characterization Methods for Enhanced Geothermal Systems	Queen	Dr. John H.	Hi-Q Geophysical Inc.	Seismicity, Fluid Imaging, Reservoir Fracture Characterization

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120249	EE0002749	Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-Exposed High-Velocity Rocks	Hardage	Dr. Bob	University of Texas at Austin	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120257	GO18189	The Role of Geochemistry and Stress on Fracture Development and Proppant Behavior in EGS Reservoirs	Moore	Joseph	University of Utah	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120214	GO18192	The Use of Downhole Technologies to Characterize Fractures in EGS Reservoirs	Horne	Roland	Stanford University	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120152	ORNL FY11 AOP 1	Ultra High Resolution Cold Neutron Imaging of Fluid Flow and Fracture in EGS Environments	Bingham	Philip	Oak Ridge National Laboratory	Seismicity, Fluid Imaging, Reservoir Fracture Characterization
GTO120252	EE0002766	Development of Chemical Model to Predict the Interactions between Supercritical CO2 and Fluid, Rocks in EGS Reservoirs	Mcpherson	Dr. Brian	University of Utah	Supercritical Carbon Dioxide
GTO120087	1004	Enhanced Geothermal Systems (EGS) with CO2 as Heat Transmission Fluid	Kneafsey	Tim	Lawrence Berkeley National Laboratory	Supercritical Carbon Dioxide
GTO120166	EE0002765	Experiment-Based Model for the Chemical Interactions between Geothermal Rocks, Supercritical Carbon Dioxide and Water	Petro	Miroslav	PARC (Palo Alto Research Center)	Supercritical Carbon Dioxide
GTO120086	1003	Laboratory and Field Experimental Studies of CO2 as Heat Transmission Fluid in Enhanced Geothermal Systems (EGS)	Xu	Tianfu	Lawrence Berkeley National Laboratory	Supercritical Carbon Dioxide
GTO120066	EE0004432	Single-Well Low Temperature CO2-Based Engineered Geothermal System	Eastman	Alan	GreenFire Energy	Supercritical Carbon Dioxide

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120264	EE0002745	Analysis of Low Temperature Utilization of Geothermal Resources	Anderson	Brian	West Virginia University	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120023	EE0002851	DOE Geothermal Data Repository	Snyder	Walter	Boise State University	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120251	EE0002744	Economic Impact Analysis for EGS	Christensen	Gary	University of Utah	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120001	EE0002739	Estimation and Analysis of Life Cycle Costs of Baseline Enhanced Geothermal Systems	Turaga	Uday	Adi Analytics, LLC	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120141	NREL	Geothermal Prospector and other data provision tasks at NREL	Witherbee	Kermit	National Renewable Energy Laboratory	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120187	100	Geothermal Systems Engineering and Analysis	Lowry	Tom	Sandia National Laboratories	Systems Analysis, Resources Assessment, Data System Development & Population, Education

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120261	EE0003063	GEOTHERMAL WORKFORCE EDUCATION DEVELOPMENT AND RETENTION	Calvin	Wendy	UNR	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120213	EE0002852	Heat Flow Database Expansion for NGDS Data Development, Collection and Maintenance	Blackwell	David	Southern Methodist University	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120130	NREL FY11AOP2.3	Hydrothermal and Resource Confirmation analysis - Data Gap Analysis, Exploration Success Metric and Case Studies I changed the title - used to be called NREL FY11AOP2.3 Exploration Best Practices & Success Rates	Young	Katherine	National Renewable Energy Laboratory	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120005	113	Life Cycle Analysis of Geothermal Systems	Wang	Michael	Argonne National Laboratory	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120022	EE0001120	National Geothermal Data System Architecture Design, Testing and Maintenance	Snyder	Walter	Boise State University	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120232	EE0001501	National Geothermal Resource Assessment and Classification	Williams	Colin	U.S. Geological Survey	Systems Analysis, Resources Assessment, Data System Development & Population, Education

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120228	EE0003776	Northern Nevada Renewable Energy Training Project (NV)	Nichols	Jim	Truckee Meadows Community College	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120010	EE0002850	State Geological Survey Contributions to NGDS Data Development, Collection and Maintenance	Allison	Lee	Arizona Geological Survey	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120243	EE0003997, ID14311	UNR - Great Basin Center for Geothermal Energy (I\IV)	Calvin	Wendy	University of Nevada, Reno	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120006	114	Water Resource and Water Quality Assessment of Geothermal Systems	Wang	Michael	Argonne National Laboratory	Systems Analysis, Resources Assessment, Data System Development & Population, Education
GTO120075	1205	Advancing Reactive Tracer Methods for Measuring Thermal Evolution in CO2- and Water-Based Geothermal Reservoirs	Hull	Laurence	Idaho National Laboratory	Tracers and Tracer Interpretation
GTO120088	1202	Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS Systems	Kennedy	Mack	Lawrence Berkeley National Laboratory	Tracers and Tracer Interpretation
GTO120173	EE0003032	Novel Multidimensional Tracers for Geothermal Inter-Well Diagnostics	Tang	Dr.	Power, Environmental and Energy Research Institute	Tracers and Tracer Interpretation
GTO120253	EE0002768	Quantum Dot Tracers for Use in Engineered Geothermal Systems	Rose	Peter	University of Utah	Tracers and Tracer Interpretation

P2RMIS ID	Client ID	Project Title	Last Name	First Name	Organization	Panel
GTO120258	GO18193	Use of Tracers to Characterize Fractures in Engineered Geothermal Systems	Rose	Peter	University of Utah	Tracers and Tracer Interpretation
GTO120165	AID 20002	Using Thermally Degrading, Partitioning and Nonreactive Tracers to Determine Temperature Distribution and Fracture/Heat Transfer Surface Area in Geothermal Reservoirs	Reimus	Paul	Pacific Northwest National Laboratory	Tracers and Tracer Interpretation
GTO120029	EE0002767	Verification of Geothermal Tracer Methods in Highly Constrained Field Experiments	Becker	Matthew	California State University - Long Beach	Tracers and Tracer Interpretation
GTO120007	204	Chemical Energy Carriers (CEC) for the Utilization of Geothermal Energy	Bassam Jody	Jody	Argonne National Laboratory	Working Fluids
GTO120164	203	Development of New Biphasic Metal Organic Working Fluids for Subcritical Geothermal Systems	McGrail	Peter	Pacific Northwest National Laboratory	Working Fluids
GTO120146	GO88020	Geothermal Working Fluids	Brennecke	Joan	Notre Dame University	Working Fluids
GTO120055	EE0002769	High-Potential Working Fluids for Next Generation Binary Cycle Geothermal Power Plants	Zia	Jalal	GE Global Research	Working Fluids
GTO120056	EE0002752	High-Temperature-High-Volume Lifting For Enhanced Geothermal Systems	Turnquist	Norman	GE Global Research	Working Fluids
GTO120234	EE0002770	Tailored Working Fluids for Enhanced Binary Geothermal Power Plants	Mahmoud	Dr. Ahmad	United Technologies Research Center	Working Fluids
GTO120211	EE0002790	Technologies for Extracting Valuable Metals and Compounds from Geothermal Fluids	Harrison	Stephen	Simbol Materials	Working Fluids
GTO120151	202	Working Fluids and Their Effect on Geothermal Turbines	Sabau	Adrian	Oak Ridge National Laboratory	Working Fluids

Appendix C: Sample Project Evaluation Form via P2RMIS

2012 Geothermal Technologies Office 2012 Peer Review

XXXX Projects Proposal Review

Critique Details

Reviewer:
LogNo and PI Last Name:
Title:

Relevance/Impact of Research

ENTER COMMENTS HERE

Score:

Scientific/Technical Approach

ENTER COMMENTS HERE

Score:

Accomplishments, Results, and Progress

ENTER COMMENTS HERE

Score:

Project Management/Coordination

ENTER COMMENTS HERE

Score:

Strengths

ENTER COMMENTS HERE

Weaknesses

ENTER COMMENTS HERE

Improvements

ENTER COMMENTS HERE

Appendix D: 2012 Peer Review Meeting Detailed Agenda

2012 Geothermal Technologies Office Peer Review - TRACK 1: STANDLEY 2

Systems Analysis, Resources Assessment, Data System Development & Population, Education
High Temp Tools, Drilling Systems, Zonal Isolation

TRACK 1	Monday, May 7th, 2012		
8:00 am to 9:00 am	Continental Breakfast and Registration		
9:00 am to 9:10 am	Plenary Session Opening and Introduction (Ava Coy, U.S. DOE Geothermal Technologies Office)		
9:10 am to 9:30 am	Welcome Address to Reviewers and Presenters (Dr. Kate Young, Peer Review Chair)		
9:30 am to 10:00 am	Geothermal Technologies Office Overview (Douglas Hollett, U.S. DOE Geothermal Technologies Office Manager)		
10:00 am to 10:30 am	Question and Answer Panel (Office Manager Douglas Hollett, Team Leads Eric Hass, Hidda Thorsteinsson and Jay Nathwani)		
10:30 am to 10:45 am	Break		
10:45 am to 11:45 am	International Panel (IPGT Member Country Represenatives)		
11:45 am to 12:15 pm	Meeting Overview for Reviewers		
12:15 pm to 1:30 pm	Lunch - Presentation: Davis Bacon Act/Cost Principles (Jay Nathwani, Genevieve Wozniak and Melissa Jacobi)		
2:00 pm to 2:30 pm	High Temp Tools, Drilling Systems, Zonal Isolation	High Temperature Downhole Motor (SNL) - (FY11 AOP 3.3)	Principal Investigator: David Raymond
2:30 pm to 3:00 pm	High Temp Tools, Drilling Systems, Zonal Isolation	Multipurpose Acoustic Sensor for Downhole Fluid Monitoring (LANL) - 719	Principal Investigator: Cristian Pantea
3:00 pm to 3:15 pm		Break	
3:15 pm to 3:45 pm	High Temp Tools, Drilling Systems, Zonal Isolation	OM-300 - MWD Geothermal Navigation Instrument (Honeywell) - EE0002754	Principal Investigator: Bruce Ohme
3:45 pm to 4:15 pm	High Temp Tools, Drilling Systems, Zonal Isolation	High-Temperature Circuit Boards for use in Geothermal Well Monitoring Applications (CTD) - EE0002751	Principal Investigator: Matthew W. Hooker
4:15 pm to 4:45 pm	High Temp Tools, Drilling Systems, Zonal Isolation	Harsh Environment Silicon Carbide Sensor Technology (UC, Berkeley) - EE0002753	Principal Investigator: Albert Pisano
4:45 pm to 5:15 pm	High Temp Tools, Drilling Systems, Zonal Isolation	Pressure Sensor and Telemetry Methods for Measurement While Drilling in Geothermal Wells (GE Global) - EE0002755	Principal Investigator: Alexey Vert
5:30 pm to 7:30 pm		**Networking Event**	

2012 Geothermal Technologies Office Peer Review - TRACK 1

TRACK 1	Tuesday, May 8th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
9:00 am to 9:30 am	High Temp Tools, Drilling Systems, Zonal Isolation	Complete Fiber/Copper Cable Solution for Long-Term Temperature and Pressure Measurement in Supercritical Reservoirs and EGS Wells (Draka) - EE0002786	Principal Investigator: Mark Lowell
9:30 am to 10:00 am	High Temp Tools, Drilling Systems, Zonal Isolation	Base Technologies and Tools for Supercritical Reservoirs (SNL) - 717	Principal Investigator: Scott Lindblom
10:00 am to 10:30 am	High Temp Tools, Drilling Systems, Zonal Isolation	Multiparameter Fiber Optic Sensing System for Monitoring Enhanced Geothermal Systems (GE Global) - EE0002787	Principal Investigator: William Challener
10:30 am to 10:45 am		Break	
10:45 am to 11:15 am	High Temp Tools, Drilling Systems, Zonal Isolation	Detecting Fractures Using Technology at High-Temperatures and Depths (Baker Hughes) - GO18186	Principal Investigator: Doug Patterson
11:15 am to 11:45 am	High Temp Tools, Drilling Systems, Zonal Isolation	Perforating System for Geothermal Applications (Sclumberger) - EE0002788	Principal Investigator: Moises Smart
11:45 am to 12:15 pm	High Temp Tools, Drilling Systems, Zonal Isolation	Development of a Multichip Module(MCM) to Enhance High Temperature Accelerometer Measurements (SNL) - FY11 AOP2.4	Principal Investigator: Scott Lindblom
12:15 pm to 1:30 pm		Lunch - Presentation: National Geothermal Data System - DOE Geothermal Data Repository Node (Arlene Anderson, U.S. DOE Geothermal Technologies Office)	
1:30 pm to 2:00 pm	High Temp Tools, Drilling Systems, Zonal Isolation	Enhanced High Temperature/High Speed Data Link for Logging Cables (SNL) - FY11 AOP3.1	Principal Investigator: Scott Lindblom
2:00 pm to 2:30 pm	High Temp Tools, Drilling Systems, Zonal Isolation	Energetic Materials for EGS Well Stimulation (SNL) - FY12 AOP4.5 / Gas Generator Development and Testing for Controlled Rapid Pressurization Using Liquid Propellants for EGS Well Stimulation (SNL) - 710	Principal Investigator: Scott Lindblom, Mark Grubelich
2:30 pm to 3:00 pm	High Temp Tools, Drilling Systems, Zonal Isolation	Auto-Indexer for Percussive Hammers (SNL) - FY11 AOP3.4	Principal Investigator: JiAnn Su
3:00 pm to 3:15 pm		Break	
3:15 pm to 3:45pm	High Temp Tools, Drilling Systems, Zonal Isolation	Technology Development and Field Trials of EGS Drilling Systems (SNL) - 704	Principal Investigator: David Raymond
3:45 pm to 4:15 pm	High Temp Tools, Drilling Systems, Zonal Isolation	High Temperature 300°C Directional Drilling System (Baker Hughes) - EE0002782	Principal Investigator: Aaron Dick
4:15 pm to 4:45 pm	High Temp Tools, Drilling Systems, Zonal Isolation	Modeling of Thermally Induced Spall of Brittle Geomaterials (LLNL) - FY11 AOP	Principal Investigator: Ilya Lomov
4:45 pm to 5:15 pm	High Temp Tools, Drilling Systems, Zonal Isolation	Development of a Hydrothermal Spallation Drilling System for EGS (Potter) - EE0002746	Principal Investigator: Jared Potter

2012 Geothermal Technologies Office Peer Review - TRACK 1

TRACK 1	Wednesday, May 9th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
9:00 am to 9:30 am	High Temp Tools, Drilling Systems, Zonal Isolation	Microhole Arrays Drilled With Advanced Abrasive Slurry Jet Technology To Efficiently Exploit Enhanced Geothermal Systems (Impact) - EE0002783	Principal Investigator: Kenneth Oglesby
9:30 am to 10:00 am	High Temp Tools, Drilling Systems, Zonal Isolation	Stinger Enhanced Bits for Engineered Geothermal Systems (Novatek) - EE0002784	Principal Investigator: David Hall
10:00 am to 10:30 am	High Temp Tools, Drilling Systems, Zonal Isolation	Evaluation of Corrosion/Erosion of Casing Materials Under Extreme Conditions (ORNL) - FY11 AOP 3	Principal Investigator: John Jy-An Wang, Fei Ren
10:30 am to 10:45 am		Break	
10:45 am to 11:15 am	High Temp Tools, Drilling Systems, Zonal Isolation	High Temperature, High Pressure Devices for Zonal Isolation in Geothermal Wells (CTD) - EE0002771	Principal Investigator: Paul Fabian
11:15 am to 11:45 am	High Temp Tools, Drilling Systems, Zonal Isolation	Application of Geothermally Produced Silica in Reservoir Management (LLNL) - FY11 AOP	Principal Investigator: William Bourcier
11:45 am to 12:15 pm	High Temp Tools, Drilling Systems, Zonal Isolation	Geopolymer Sealing Materials (BNL) - 600	Principal Investigator: Toshi Sugama
12:15 pm to 1:30 pm		Lunch - Presentation: Drilling Best Practices (Doug Blankenship, Sandia National Laboratory)	
1:30 pm to 2:15 pm	Systems Analysis, Resources Assessment, Data System, Education	National Geothermal Data System Architecture Design, Testing and Maintenance (BSU) - EE0001120	Principal Investigator: Walter Snyder
2:15 pm to 3:00 pm	Systems Analysis, Resources Assessment, Data System, Education	State Geological Survey Contributions to NGDS Data Development, Collection and Maintenance (AZGS) - EE0002850	Principal Investigator: Lee Allison
3:00 pm to 3:15 pm		Break	
3:15 pm to 4:00 pm	Systems Analysis, Resources Assessment, Data System, Education	DOE Geothermal Data Repository (BSU) - EE0002851	Principal Investigator: Walter Snyder
4:00 pm to 4:45 pm	Systems Analysis, Resources Assessment, Data System, Education	Heat Flow Database Expansion for NGDS Data Development, Collection and Maintenance (SMU) - EE0002852	Principal Investigator: David Blackwell
4:45 pm to 5:15 pm	Systems Analysis, Resources Assessment, Data System, Education	Geothermal Prospector and other data provision tasks (NREL)	Principal Investigator: Kermit Witherbee
5:15 pm to 6:15 pm		Geothermal Prospector Demonstration	

2012 Geothermal Technologies Office Peer Review - TRACK 1

TRACK 1	Thursday, May 10th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
9:00 am to 9:30 am	Systems Analysis, Resources Assessment, Data System, Education	National Geothermal Resource Assessment and Classification (USGS)	Principal Investigator: Colin Williams
9:30 am to 10:00 am	Systems Analysis, Resources Assessment, Data System, Education	Hydrothermal and Resource Confirmation analysis - Data Gap Analysis, Exploration Success Metric and Case Studies (NREL) - FY11AOP2.3	Principal Investigator: Katherine Young
10:00 am to 10:30 am	Systems Analysis, Resources Assessment, Data System, Education	UNR - Great Basin Center for Geothermal Energy (UNR) - EE0003997, ID14311, EE0003231	Principal Investigator: Wendy Calvin
10:30 am to 10:45 am		Break	
10:45 am to 11:15 am	Systems Analysis, Resources Assessment, Data System, Education	Geothermal Workforce Education Development and Retention (UNR) - EE0003063	Principal Investigator: Wendy Calvin
11:15 am to 11:45 am	Systems Analysis, Resources Assessment, Data System, Education	Northern Nevada Renewable Energy Training Project (TMCC) - EE0003776	Principal Investigator: Jim Nichols
11:45 am to 12:15 pm	Systems Analysis, Resources Assessment, Data System, Education	GETEM Development (INL) - 112	Principal Investigator: Greg Mines
12:15 pm to 1:30 pm		Lunch - Presentation: Hydrothermal Exploration Data Gap Analysis Update (Kate Young, National Renewable Energy Laboratory)	
1:30 pm to 2:00 pm	Systems Analysis, Resources Assessment, Data System, Education	Estimation and Analysis of Life Cycle Costs of Baseline Enhanced Geothermal Systems (ADI) - EE0002739	Principal Investigator: Uday Turaga
2:00 pm to 2:30 pm	Systems Analysis, Resources Assessment, Data System, Education	Geothermal Systems Engineering and Analysis (SNL) - 100	Principal Investigator: Tom Lowry
2:30 pm to 3:00 pm	Systems Analysis, Resources Assessment, Data System, Education	Life Cycle Analysis of Geothermal Systems (ANL) - 113	Principal Investigator: John Sullivan
3:00 pm to 3:15 pm		Break	
3:15 pm to 3:45 pm	Systems Analysis, Resources Assessment, Data System, Education	Water Resource and Water Quality Assessment of Geothermal Systems (ANL) - 114	Principal Investigator: Corrie Clark
3:45 pm to 4:15 pm	Systems Analysis, Resources Assessment, Data System, Education	Economic Impact Analysis for EGS (U of U) - EE0002744	Principal Investigator: Varun Gowda
4:15 pm to 4:45 pm	Systems Analysis, Resources Assessment, Data System, Education	Analysis of Low-Temperature Utilization of Geothermal Resources (WVU) - EE0002745	Principal Investigator: Brian Anderson

2012 Geothermal Technologies Office Peer Review - TRACK 2: WESTMINSTER BALLROOM III

Enhanced Geothermal System Demonstrations
Seismicity, Fluid Imaging & Reservoir Fracture Characterization
Modeling

TRACK 2	Monday, May 7th, 2012		
8:00 am to 9:00 am	Continental Breakfast and Registration		
9:00 am to 9:10 am	Plenary Session Opening and Introduction (Ava Coy, U.S. DOE Geothermal Technologies Office)		
9:10 am to 9:30 am	Welcome Address to Reviewers and Presenters (Dr. Kate Young, Peer Review Chair)		
9:30 am to 10:00 am	Geothermal Technologies Office Overview (Douglas Hollett, U.S. DOE Geothermal Technologies Office Manager)		
10:00 am to 10:30 am	Question and Answer Panel (Office Manager Douglas Hollett, Team Leads Eric Hass, Hidda Thorsteinsson and Jay Nathwani)		
10:30 am to 10:45 am	Break		
10:45 am to 11:45 am	International Panel (IPGT Member Country Represenatives)		
11:45 am to 12:15 pm	Meeting Overview for Reviewers		
12:15 pm to 1:30 pm	Lunch - Presentation: Davis Bacon Act/Cost Principles (Jay Nathwani, Genevieve Wozniak and Melissa Jacobi)		
1:30 pm to 2:15 pm	Enhanced Geothermal System Demonstrations	Desert Peak East EGS Project (Ormat) - ID14406	Principal Investigator: Peter Drakos
2:15 pm to 3:00 pm	Enhanced Geothermal System Demonstrations	Feasibility of EGS Development at Brady's Hot Springs (Ormat) - GO18200	Principal Investigator: Peter Drakos
3:00 pm to 3:15 pm		Break	
3:15 pm to 4:00 pm	Enhanced Geothermal System Demonstrations	Demonstration of an Enhanced Geothermal System at the Northwest Geysers Geothermal Field (Geysers) - GO18201	Principal Investigator: Mark Walters
4:00 pm to 4:45 pm	Enhanced Geothermal System Demonstrations	Concept Testing and Development at the Raft River Geothermal Field, Idaho (U of U) - EE0000215	Principal Investigator: Joseph Moore
4:45 pm to 5:45 pm		**Preliminary Environmental Assessment and Analysis of EGS Technologies Meeting**	
5:45 pm to 7:30 pm		**Networking Event**	

2012 Geothermal Technologies Office Peer Review - TRACK 2

TRACK 2	Tuesday, May 8th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
9:00 am to 9:45 am	Enhanced Geothermal System Demonstrations	Newberry Volcano EGS Demonstration (AltaRock) - EE0002777	Principal Investigator: Susan Petty
10:30 am to 10:45 am		Break	
12:15 pm to 1:30 pm		Lunch - Presentation: National Geothermal Data System - DOE Geothermal Data Repository Node (Arlene Anderson, U.S. DOE Geothermal Technologies Office)	
1:30 pm to 2:00 pm	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	The Use of Downhole Technologies to Characterize Fractures in EGS Reservoirs (Stanford) - GO18192	Principal Investigator: Roland Horne
2:00 pm to 2:30 pm	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Application of Microearthquake (MEQ) Monitoring for Characterizing Enhanced Geothermal Systems (LBNL) - 511 / FY11 AOP 10	Principal Investigator: Ernie Majer
2:30 pm to 3:00 pm	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Mapping Diffuse Seismicity for Geothermal Reservoir Management with Matched Field Processing (LLNL) - 508	Principal Investigator: Dennise Templeton
3:00 pm to 3:15 pm		Break	
3:15 pm to 3:45 pm	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Imaging Fluid Flow in Geothermal Wells Using Distributed Thermal Perturbation Sensing (LBNL) - 512 / FY11 AOP 5	Principal Investigator: Barry Freifield
3:45 pm to 4:15 pm	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Monitoring and Modeling Fluid Flow in a Developing EGS Reservoir (MIT) - GO18197	Principal Investigator: Michael Fehler
4:15 pm to 4:45 pm	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Fluid Imaging of Enhanced Geothermal Systems through Joint 3D Geophysical Inverse Modeling (LBNL) - 900	Pricipal Investigator: Greg Newman
4:45 pm to 5:15 pm	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Imaging, Characterizing, and Modeling of Fracture Networks and Fluid Flow in Enhanced Geothermal Systems (EGS) Reservoirs (LANL) - AID 19712	Principal Investigator: Lianjie Huang

2012 Geothermal Technologies Office Peer Review - TRACK 2

TRACK 2	Wednesday, May 9th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
9:00 am to 9:30 am	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Ultra High Resolution Cold Neutron Imaging of Fluid Flow and Fracture in EGS Environments (ORNL) - FY11 AOP 1	Principal Investigator: Philip R. Bingham
9:30 am to 10:00 am	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Fracture Network and Fluid Flow Imaging for Enhanced Geothermal Systems: Applications from Multi-Dimensional Electrical Resistivity Structure (U of U) - EE0002750	Principal Investigator: Philip Wannamaker
10:00 am to 10:30 am	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	The Role of Geochemistry and Stress on Fracture Development and Proppant Behavior in EGS Reservoirs (U of U) - GO18189	Principal Investigator: Joseph Moore
10:30 am to 10:45 am		Break	
10:45 am to 11:15 am	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Detection and Characterization of Fractures for the Development of EGS (MIT) - GO18190	Principal Investigator: M. Nafi Toksoz
11:15 am to 11:45 am	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Micro-earthquake Technology for EGS Fracture Characterization (Foulger) - GO18187	Principal Investigator: Gillian Foulger
11:45 am to 12:15 am	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Joint Seismic-Electromagnetics Inversion for Iceland Geothermal Systems (LBNL) - 510 / FY11 AOP 13	Principal Investigator: Greg Newman
12:15 pm to 1:30 pm		Lunch - Presentation: Drilling Best Practices (Doug Blankenship, Sandia National Laboratory)	
1:30 pm to 2:00 pm	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Seismic Fracture Characterization Methods for Enhanced Geothermal Systems (Hi-Q) - GO18191	Principal Investigator: John H. Queen
2:00 pm to 2:30 pm	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Characterizing Fractures in Geysers Geothermal Field by Micro-seismic Data, Using Soft Computing, Fractals, and Shear Wave Anisotropy (USC) - EE0002747	Principal Investigator: Fred Aminzadeh
2:30 pm to 3:00 pm	Seismicity, Fluid Imaging & Reservoir Fracture Characterization	Seismic Technology Adapted to Analyzing and Developing Geothermal Systems Below Surface-Exposed High-Velocity Rocks (UT, Austin) - EE0002749	Principal Investigator: Bob A. Hardage
3:00 pm to 3:15 pm		Break	
3:15 pm to 3:45 pm	Modeling	A new analytic-adaptive model for EGS assessment, development and management support (UNR) - EE0002759	Principal Investigator: George Danko
3:45 pm to 4:15 pm	Modeling	Modeling Supporting the Demonstration of a Deep Enhanced Geothermal System at the Northwest Geysers Geothermal Field, CA (LBNL) - FY11 AOP 4	Principal Investigator: Jonny Rutqvist
4:15 pm to 4:45 pm	Modeling	Analysis of Geothermal Reservoir Stimulation using Geomechanics-Based Stochastic Analysis of Injection-Induced Seismicity (Texas A&M) - GO18194	Principal Investigator: Ahmad Ghassemi

2012 Geothermal Technologies Office Peer Review - TRACK 2

TRACK 2	Thursday, May 10th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
9:00 am to 9:30 am	Modeling	Predicting Stimulation-Response Relationships for Engineered Geothermal Reservoirs (LLNL) - 300	Principal Investigator: Charles Carrigan
9:30 am to 10:00 am	Modeling	Development of an Advanced Stimulation/Production Predictive Simulator for Enhanced Geothermal Systems (SAIC) - EE0002763	Principal Investigator: John Pritchett
12:15 pm to 1:30 pm		Lunch - Presentation: Hydrothermal Exploration Data Gap Analysis Update (Kate Young, National Renewable Energy Laboratory)	
1:30 pm to 3:00 pm		**Modeling Working Group Meeting**	
3:00 pm to 3:15 pm		Break	
3:15 pm to 5:00 pm		**GeoTek Go/No Go Decision Review (closed meeting)**	

2012 Geothermal Technologies Office Peer Review - TRACK 3: WESTMINSTER BALLROOM IV

Tracers and Tracer Interpretation
Exploration Validation
Presentation Only

TRACK 3	Monday, May 7th, 2012			
8:00 am to 9:00 am	Continental Breakfast and Registration			
9:00 am to 9:10 am	Plenary Session Opening and Introduction (Ava Coy, U.S. DOE Geothermal Technologies Office)			
9:10 am to 9:30 am	Welcome Address to Reviewers and Presenters (Dr. Kate Young, Peer Review Chair)			
9:30 am to 10:00 am	Geothermal Technologies Office Overview (Douglas Hollett, U.S. DOE Geothermal Technologies Office Manager)			
10:00 am to 10:30 am	Question and Answer Panel (Office Manager Douglas Hollett, Team Leads Eric Hass, Hidda Thorsteinsson and Jay Nathwani)			
10:30 am to 10:45 am	Break			
10:45 am to 11:45 am	International Panel (IPGT Member Country Represenatives)			
11:45 am to 12:15 pm	Meeting Overview for Reviewers			
12:15 pm to 1:30 pm	Lunch - Presentation: Davis Bacon Act/Cost Principles (Jay Nathwani, Genevieve Wozniak and Melissa Jacobi)			
1:30 pm to 2:00 pm	Tracers and Tracer Interpretation		Integrated Approach to Use Natural Chemical and Isotopic Tracers to Estimate Fracture Spacing and Surface Area in EGS (LBNL) - 1202	Principal Investigator: Mack Kennedy
2:00 pm to 2:30 pm	Tracers and Tracer Interpretation		Advancing Reactive Tracer Methods for Measuring Thermal Evolution in CO2- and Water-Based Geothermal Reservoirs (INL) - 1205	Principal Investigator: Laurence Hull
2:30 pm to 3:00 pm	Tracers and Tracer Interpretation		Using Thermally Degrading, Partitioning and Nonreactive Tracers to Determine Temp Distribution and Fracture/Heat Transfer Surface Area in Geothermal Reservoirs (PNNL) - AID 20002	Principal Investigator: Vince Vermeul
3:00 pm to 3:15 pm			Break	
3:15 pm to 3:45 pm	Tracers and Tracer Interpretation		Use of Tracers to Characterize Fractures in Engineered Geothermal Systems (U of U) - GO18193	Principal Investigator: Peter Rose
3:45 pm to 4:15 pm	Tracers and Tracer Interpretation		Verification of Geothermal Tracer Methods in Highly Constrained Field Experiments (Cal St, LB) - EE0002767	Principal Investigator: Matthew Becker
4:15 pm to 4:45 pm	Tracers and Tracer Interpretation		Quantum Dot Tracers for Use in Engineered Geothermal Systems (U of U) - EE0002768	Principal Investigator: Peter Rose
4:45 pm to 5:15 pm	Tracers and Tracer Interpretation		Novel Multidimensional Tracers for Geothermal Inter-Well Diagnostics (PEERI) - EE0003032	Principal Investigator: Yongchun Tang
5:30 pm to 7:30 pm			**Networking Event**	

2012 Geothermal Technologies Office Peer Review - TRACK 3

TRACK 3	Tuesday, May 8th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
9:00 am to 9:30 am	Exploration Validation	High Precision Geophysics & Detailed Structural Exploration & Slim Well Drilling (Nevada Geothermal) - EE0002835	Principal Investigator: John Casteel
9:30 am to 10:00 am	Exploration Validation	Merging High Resolution Geophysical and Geochemical Surveys to Reduce Exploration Risk at Glass Buttes, OR (Ormat) - EE0002836	Principal Investigator: Patrick Walsh
10:00 am to 10:30 am	Exploration Validation	Validation of Innovative Exploration Techniques at Pilgrim Hot Springs, AK (U of AK, Fairbanks) - EE0002846	Principal Investigator: Gwen Holdmann
10:30 am to 10:45 am		Break	
10:45 am to 11:15 am	Exploration Validation	Direct Confirmation of Commercial Geothermal Resources in Colorado using Remote Sensing & On-Site Exploration, Testing & Analysis (Flint) - EE0002828	Principal Investigator: Lee Robinson
11:15 am to 11:45 am	Exploration Validation	Innovative Exploration Techniques for Geothermal Assessment at Jemez Pueblo, NM (Pueblo of Jemez) - EE0002841	Principal Investigator: Greg Kaufman
11:45 am to 12:15 am	Exploration Validation	Conducting a 3D Converted Shear Wave Project to reduce exploration risk at Wister, CA (Ormat) - EE0002838	Principal Investigator: Patrick Walsh
12:15 pm to 1:30 pm		Lunch - Presentation: National Geothermal Data System - DOE Geothermal Data Repository Node (Arlene Anderson, U.S. DOE Geothermal Technologies Office)	
1:30 pm to 2:00 pm	Exploration Validation	Advanced Seismic data Analysis Office - The "Hot Pot Project" (Oski) - EE0002839	Principal Investigator: Theodore De Rocher
2:00 pm to 2:30 pm	Exploration Validation	Validation of Innovative Exploration Technologies for Newberry Volcano (Davenport) - EE0002833	Principal Investigator: Albert F. Waibel
2:30 pm to 3:00 pm	Exploration Validation	El Paso County Geothermal Electric Generation Project: Innovative Research Technologies Applied to the Geothermal Resource Potential at Ft. Bliss (Ruby Mtn) - EE0002827	Principal Investigator: Jon Lear
3:00 pm to 3:15 pm		Break	
3:15 pm to 3:45 pm	Exploration Validation	Recovery Act: Detachment Faulting and Geothermal Resources – An Innovative Integrated Geological and Geophysical Investigation of Pearl Hot Spring, Nevada (U of TX) - EE0002960	Principal Investigator: Daniel Stockli
4:15 pm to 4:45 pm	Exploration Validation	The Snake River Geothermal Drilling Project - Innovative Approaches to Geothermal Exploration (UT State) - EE0002848	Principal Investigator: John W. Shervais
4:45 pm to 5:15 pm	Exploration Validation	Comprehensive Evaluation of the Geothermal Resource Potential within the Pyramid Lake Paiute Reservation (Pyramid Lake Paiute Tribe) - EE0002842	Principal Investigator: Donna Noel
5:30 pm to 9:30 pm		**IPGT Meeting**	

2012 Geothermal Technologies Office Peer Review - TRACK 3

TRACK 3	Wednesday, May 9th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
10:00 am to 10:30 am	Exploration Validation	Alum Innovative Exploration Project (Ram Power) - EE0002845	Principal Investigator: Clay Miller
10:30 am to 10:45 am		Break	
10:45 am to 11:15 am	Exploration Validation	Integrated Chemical Geothermometry System for Geothermal Exploration (LBNL) - 904 / FY11 AOP 3	Principal Investigator: Nicolas Spycher
11:15 am to 11:45 am	Exploration Validation	Characterizing Structural Controls of EGS-Candidate and Conventional Geothermal Reservoirs in the Great Basin: Developing Successful Exploration Strategies in Extended Terranes (UNR) - EE0002748	Principal Investigator: James Faulds
11:45 am to 12:15 am	Exploration Validation	Development of Exploration Methods for Engineered Geothermal Systems through Integrated Geophysical, Geologic and Geochemical Interpretation (AltaRock) - EE0002778	Principal Investigator: Joe Iovenitti
12:15 pm to 1:30 pm		Lunch - Presentation: Drilling Best Practices (Doug Blankenship, Sandia National Laboratory)	
1:30 pm to 1:45 pm	Presentation Only	Geothermal Resource Dev with Zero Mass Withdrawal, Engineered Convection, and Wellbore Energy Conversion (LA State Univ) - EE0005125	Principal Investigator: Chris White
1:45 pm to 2:00 pm	Presentation Only	Extreme Temp (300 C) P/MWD with Energy Storage & Generation, Enabling Substantial Cost & Risk Reduction in Exploration (FastCAP) - EE0005503	Principal Investigator: Riccardo Signorelli
2:00 pm to 2:15 pm	Presentation Only	Advanced Horizontal Well Recirculation Systems for Geothermal Energy Recovery in Sedimentary Formations (Terralog) - EE0005126	Principal Investigator: Mike Bruno
2:15 pm to 2:30 pm		**Question and Answer Panel**	
2:30 pm to 2:45 pm	Presentation Only	Geothermal Energy Production Coupled with CCS: Heat Recovery Using an Innovative High Efficiency Supercritical Co2 Turboexpansion Cycles (LBNL)	Principal Investigator: Barry Freifeld
2:45 pm to 3:00 pm	Presentation Only	Active Management of Integrated Geothermal & CO2 Storage Reservoirs in Sedimentary Formations (LLNL) - EE0005127	Principal Investigator: Tom Buscheck
3:00 pm to 3:15 pm		Break	
3:15 pm to 3:30 pm	Presentation Only	Novel Geothermal Development of Deep Sedimentary systems in the US (U of U) - EE0005128	Principal Investigator: Joe Moore
3:30 pm to 3:45 pm		**Question and Answer Panel**	
3:45 pm to 4:00 pm	Presentation Only	GeoTek Gravity Head Energy System Pilot Plant Project (Geotek) - EE0005129	Principal Investigator: Dave Marshall
4:00 pm to 4:15pm	Presentation Only	Heat Extraction from Permeable Sedimentary Rocks (Physical Optics) - EE0005130	Principal Investigator: Michael Reznikov
4:15 pm to 4:30 pm	Presentation Only	Geothermal Drilling Using Encapsulated Chemical Energy Sources (LANL)	Principal Investigator: James Sims
4:30 pm to 4:45 pm		**Question and Answer Panel**	

2012 Geothermal Technologies Office Peer Review - TRACK 3

TRACK 3	Thursday, May 10th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
9:00 am to 9:15 am	Presentation Only	Development of a 300°C, 200 level, 3C Fiber Optic Downhole Seismic Receiver Array for Surveying and Monitoring of Geothermal Reservoirs (Paulsson) - EE0005509	Principle Investigator: Bjorn Paulsson
9:15 am to 9:30 am	Presentation Only	Advanced Percussive Drilling Technology for Geothermal Exploration and Development (Atlas Copco) - EE0005502	Principle Investigator: Dale Wolfer
9:30 am to 9:45 am	Presentation Only	Deep Geothermal Drilling using Millimeter Wave Technology (Impact) - EE0005504	Principal Investigator: Kenneth Oglesby
9:45 am to 10:00 am		**Question and Answer Panel**	
10:00 am to 10:15 am	Presentation Only	Directional Measurement-While-Drilling System for Geothermal Applications (Baker Hughes) - EE0005505	Principal Investigator: John Macpherson
10:15 am to 10:30 am	Presentation Only	Development and Demonstration of Self-Expanding Well Construction (Geothermal Expandables) - EE0005506	Principal Investigator: Jeff Spray
10:30 am to 10:45 am		Break	
10:45 am to 11:00 am	Presentation Only	Development and Demonstration of a Commercial Hole Opening System for Geothermal Well Enhancement (Potter) - EE0005507	Principal Investigator: Jared Potter
11:00 am to 11:15 am		**Question and Answer Panel**	
11:15 am to 11:30 am	Presentation Only	Corrosive Resistant Foam Well-Costing Cement Composites (BNL)	Principal Investigator: Toshi Sugama
11:30 am to 11:45 am	Presentation Only	Integration of Nontraditional Isotopic Systems Into Reaction-Transport Models of EGS For Exploration, Evalof Water-Rock Interaction, & Impacts of Water Chemistry on Reservoir Sustainability (LBNL)	Principal Investigator: Eric Sonnenthal
11:45 am to 12:00 pm		**Question and Answer Panel**	
12:15 pm to 1:30 pm		Lunch - Presentation: Hydrothermal Exploration Data Gap Analysis Update (Kate Young, National Renewable Energy Laboratory)	
1:30 pm to 1:45 pm	Presentation Only	Improved Geothermometry Through Multivariate Reaction Path Modeling & Eval of Geomicrobiological Influences on Geochemical Temp Indicators (INL)	Principal Investigator: Craig Cooper
1:45 pm to 2:00 pm	Presentation Only	Stochastic Joint Inversion for Integrated Data Interpretation in Geothermal Exploration (LLNL)	Principal Investigator: Rob Mellors
2:00 pm to 2:15 pm	Presentation Only	Imaging Fault Zones Using a Novel Elastic Reverse-Time Migration Imaging Technique (LANL)	Principal Investigator: Lianjie Huang
2:15 pm to 2:30 pm		**Question and Answer Panel**	

2012 Geothermal Technologies Office Peer Review - TRACK 4: COTTON CREEK II

Low Temperature, Co-Production Demonstration
Supercritical Carbon Dioxide
Working Fluids
Presentation Only

TRACK 4	Monday, May 7th, 2012		
8:00 am to 9:00 am	Continental Breakfast and Registration		
9:00 am to 9:10 am	Plenary Session Opening and Introduction (Ava Coy, U.S. DOE Geothermal Technologies Office)		
9:10 am to 9:30 am	Welcome Address to Reviewers and Presenters (Dr. Kate Young, Peer Review Chair)		
9:30 am to 10:00 am	Geothermal Technologies Office Overview (Douglas Hollett, U.S. DOE Geothermal Technologies Office Manager)		
10:00 am to 10:30 am	Question and Answer Panel (Office Manager Douglas Hollett, Team Leads Eric Hass, Hidda Thorsteinsson and Jay Nathwani)		
10:30 am to 10:45 am	Break		
10:45 am to 11:45 am	International Panel (IPGT Member Country Represenatives)		
11:45 am to 12:15 pm	Meeting Overview for Reviewers		
12:15 pm to 1:30 pm	Lunch - Presentation: Davis Bacon Act/Cost Principles (Jay Nathwani, Genevieve Wozniak and Melissa Jacobi)		
1:30 pm to 2:00 pm	Low Temp, Co-Production Demo	Small Scale Electrical Power Generation from Heat Co-Produced in Geothermal Fluids: Mining Operation (Electra Therm) - EE0004435	Principal Investigator: Tom Clark
2:00 pm to 2:30 pm	Low Temp, Co-Production Demo	Technical Demo and Economic Validation of Geothermally-Produced Electricity from Coproduced Water at Existing Oil/Gas Wells in TX (Universal Geo) - EE0002853	Principal Investigator: Chris Luchini
2:30 pm to 3:00 pm	Low Temp, Co-Production Demo	Beowawe Bottoming Binary Project (Beowawe) - EE0002856	Principal Investigator: Dale McDonald
3:00 pm to 3:15 pm		Break	
3:15 pm to 3:45 pm	Low Temp, Co-Production Demo	Novel Energy Conversion Equipment for Low Temperature Geothermal Resources (Johnson Controls) - EE0002858	Principal Investigator: Eric Minor
3:45 pm to 4:15 pm	Low Temp, Co-Production Demo	Osmotic Heat Engine for Energy Production from Low Temperature Geothermal Resources (Oasys) - EE0002859	Principal Investigator: Robert McGinnis
4:15 pm to 4:45 pm	Low Temp, Co-Production Demo	Dixie Valley Bottoming Binary Project (Terra Gen) - EE0002860	Principal Investigator: Dale McDonald
4:45 pm to 5:15 pm	Low Temp, Co-Production Demo	Rural Cooperative Geothermal Development- Electric and Agriculture (Surprise Valley) - EE0003006	Principal Investigator: Daniel Silveria
5:30 pm to 7:30 pm		Networking Event	

2012 Geothermal Technologies Office Peer Review

TRACK 4	Tuesday, May 8th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
9:00 am to 9:30 am	Low Temp, Co-Production Demo	Scale Resistant Heat Exchangers for Low Temperature Geothermal Binary Cycle Power Plant (Energent) - EE0004423	Principal Investigator: Phillip Welch
9:30 am to 10:00 am	Low Temp, Co-Production Demo	Kalex Advanced Low Temperature Geothermal Power Cycle -The Bald Mountain Project (Oski) - EE0004430	Principal Investigator: Larry Bandt
10:00 am to 10:30 am	Low Temp, Co-Production Demo	The Canby Cascaded Geothermal Development Project (Modoc) - EE0004431	Principal Investigator: Dale Merrick
10:30 am to 10:45 am		Break	
10:45 am to 11:15 am	Low Temp, Co-Production Demo	Demonstration of a Variable Phase Turbine Power System for Low Temperature Geothermal Resources (Energent) - GO15153	Principal Investigator: Lance Hays
11:15 am to 11:45 am	Low Temp, Co-Production Demo	Low Temperature Power Production Field Validation (NREL) - FY11 AOP1	Principal Investigator: Tom Williams
11:45 am to 12:15 am	Supercritical Carbon Dioxide	Single-Well Low Temperature CO2-Based Engineered Geothermal System (GreenFire) - EE0004432	Principal Investigator: Alan D. Eastman
12:15 pm to 1:30 pm		Lunch - Presentation: National Geothermal Data System - DOE Geothermal Data Repository Node (Arlene Anderson, U.S. DOE Geothermal Technologies Office)	
1:30 pm to 2:00 pm	Supercritical Carbon Dioxide	Laboratory and Field Experimental Studies of CO2 as Heat Transmission Fluid in EGS (LBNL) - 1003	Principal Investigator: Tianfu Xu
2:00 pm to 2:30 pm	Supercritical Carbon Dioxide	Enhanced Geothermal Systemswith CO2 as Heat Transmission Fluid (LBNL) - 1004	Principal Investigator: Tim Kneafsey
2:30 pm to 3:00 pm	Supercritical Carbon Dioxide	Experiment-Based Model for the Chemical Interactions between Geothermal Rocks, Supercritical CO2 and Water (PARC) - EE0002765	Principal Investigator: Miroslav Petro
3:00 pm to 3:15 pm		Break	
3:15 pm to 3:45pm	Supercritical Carbon Dioxide	Development of Chemical Model to Predict the Interactions between Supercritical CO2 and Fluid, Rocks in EGS Reservoirs (U of U) - EE0002766	Principal Investigator: Brian Mcpherson
3:45 pm to 4:15 pm	Working Fluids	Development of New Biphasic Metal Organic Working Fluids for Subcritical Geothermal Systems (PNNL) - 203	Principal Investigator: Peter McGrail
4:15 pm to 4:45 pm	Working Fluids	Chemical Energy Carriers (CEC) for the Utilization of Geothermal Energy (ANL) - 204	Principal Investigator: Bassam Jody
4:45 pm to 5:15 pm	Working Fluids	High-Potential Working Fluids for Next Generation Binary Cycle Geothermal Power Plants (GE Global) - EE0002769	Principal Investigator: Jalal Zia

2012 Geothermal Technologies Office Peer Review

TRACK 4	Wednesday, May 9th, 2012			
8:00 am to 9:00 am			Continental Breakfast	
9:00 am to 9:30 am	Working Fluids		Tailored Working Fluids for Enhanced Binary Geothermal Power Plants (UTRC) - EE0002770	Principal Investigator: Ahmad Mahmoud
9:30 am to 10:00 am	Working Fluids		Geothermal Working Fluids (Notre Dame) - GO88020	Principal Investigator: Joan Brennecke
10:00 am to 10:30 am	Working Fluids		Working Fluids and Their Effect on Geothermal Turbines (ORNL) - 202	Principal Investigator: Adrian S. Sabau
10:30 am to 10:45 am			Break	
10:45 am to 11:15 am	Working Fluids		High-Temperature-High-Volume Lifting For Enhanced Geothermal Systems (GE Global) - EE0002752	Principal Investigator: Norm Turnquist
11:15 am to 11:45 am	Working Fluids		Technologies for Extracting Valuable Metals and Compounds from Geothermal Fluids (Simbol) - EE0002790	Principal Investigator: Stephen Harrison
12:15 pm to 1:30 pm			Lunch - Presentation: Drilling Best Practices (Doug Blankenship, Sandia National Laboratory)	
1:30 pm to 1:45 pm	Presentation Only		SPI Conformance Gel Applications in Geothermal Zonal Isolation (Clean Tech Innovations) - EE0005508	Principal Investigator: Lyle Burns
1:45 pm to 2:00 pm	Presentation Only		Self Consuming Downhole Packer (SNL) - 552-1522	Principal Investigator: Jiann-cherng Su
2:00 pm to 2:15 pm	Presentation Only		Self-Degrading Temporary Cementation Sealers (BNL)	Principal Investigator: Toshi Sugama
2:15 pm to 2:30 pm			**Question and Answer Panel**	
2:30 pm to 2:45 pm	Presentation Only		Monitoring EGS Stimulation and Reservoir Dynamics with InSAR and MEQ (Temple) - EE0005510	Principal Investigator: Nicholas Davatzes
2:45 pm to 3:00 pm	Presentation Only		Rotation-Enabled 7-DOF Seismometer for Geothermal Resource Development (A-Tech Corp) - EE0005511	Principal Investigator: Darren Laughlin
3:00 pm to 3:15 pm			Break	
3:15 pm to 3:30 pm	Presentation Only		Novel use of 4D Monitoring Techniques to Improve Reservoir Longevity and Productivity in EGS (NETL) - 0522-1611	Principal Investigator: Kelly Rose
3:30 pm to 3:45 pm			**Question and Answer Panel**	
3:45 pm to 4:00 pm	Presentation Only		Extracting and Applying SV-SV Shear Modes from Vertical Vibrator Data Across Geothermal Prospects (UT, Austin) - EE0005512	Principal Investigator: Bob A. Hardage
4:00 pm to 4:15 pm	Presentation Only		Time-lapse Joint Inversion of Gepphysical Data and its Application to Geothermal Prospecting - GEODE (CSM) - EE0005513	Principal Investigator: Andre Revil, Mike Batzle
4:15 pm to 4:30 pm	Presentation Only		Indentification of Hidden, High-Enthalpy Systems Through Exploration Incorp MT, Soil Gas Geochem & Structural Analysis (U of U) - EE0005514	Principal Investigator: Phil Wannamaker
4:30 pm to 4:45 pm			**Question and Answer Panel**	

2012 Geothermal Technologies Office Peer Review

TRACK 4	Thursday, May 10th, 2012		
8:00 am to 9:00 am		Continental Breakfast	
9:00 am to 9:15 am	Presentation Only	Integration of Full Tensor Gravity and ZTEM Passive Low Frequency EM Instruments for Simultaneous Data Acquisition (Bell Geospace) - EE0005515	Principal Investigator: Scott Wieberg
9:15 am to 9:30 am	Presentation Only	Characterizing fracture properties using resistivity measured at different frequencies (Stanford) - EE0005516	Principal Investigator: Roland Horne
9:30 am to 9:45 am	Presentation Only	Spectral SP: A New Approach to Mapping Reservoir Flow and Permeability (U of HI) - EE0005517	Principal Investigator: Donald Thomas
9:45 am to 10:00 am		**Question and Answer Panel**	
10:00 am to 10:15 am	Presentation Only	Dev of a low cost method to estimate the seismic signature of a geothermal field from ambient seismic noise analysis (UNR) - EE0005518	Principal Investigator: Ileana M. Tibuleac
10:15 am to 10:30 am	Presentation Only	Methodologies for Reservoir Characterization Using Fluid Inclusion Gas Chemistry (Hattenburg, Dilley & Linnell) - EE0005519	Principal Investigator: Lorie Dilley
10:30 am to 10:45 am		Break	
10:45 am to 11:00 am	Presentation Only	Novel Coupled Thermochronometric & Geochem Investigation of Blind Resources in Fault- Controlled Dilational Corners, Dixie Valley, NV (UT, Austin) - EE0005520	Principal Investigator: Daniel Stockli
11:00 am to 11:15 am		**Question and Answer Panel**	
11:15 am to 11:30 am	Presentation Only	Innovative computational tools for reducing exploration risk through integration of water-rock interactions and MT surveys (U of U) - EE0005521	Principal Investigator: Joe Moore
11:30 am to 11:45 am	Presentation Only	Advances in Hydrogeochemical Indicators for the Discovery of New Geothermal Resources in the Great Basin (CSM) - EE0005522	Principal Investigator: Stuart Simmons
11:45 am to 12:00 pm	Presentation Only	Optimizing Parameters for Predicting the Geochemical Behavior & Discrete Fracture Networks in Geothermal Systems (NETL) - 0522-1615	Principal Investigator: J. Alexandra Hakala
12:00 pm to 12:15 pm		**Question and Answer Panel**	
12:15 pm to 1:30 pm		Lunch - Presentation: Hydrothermal Exploration Data Gap Analysis Update (Kate Young, National Renewable Energy Laboratory)	
1:30 pm to 3:00 pm		NGDS Design & Testing Go/No Go Decision Review (closed meeting)	
3:00 pm to 3:15 pm		Break	
3:15 pm to 5:00 pm		NGDS Design & Testing Go/No Go Decision Review (closed meeting, con't)	

2012 Geothermal Technologies Office Peer Review - TRACK 5: COTTON CREEK I

TRACK 5	Monday, May 7th, 2012
8:00 am to 9:00 am	Continental Breakfast and Registration
9:00 am to 9:10 am	Plenary Session Opening and Introduction (Ava Coy, U.S. DOE Geothermal Technologies Office)
9:10 am to 9:30 am	Welcome Address to Reviewers and Presenters (Dr. Kate Young, Peer Review Chair)
9:30 am to 10:00 am	Geothermal Technologies Office Overview (Douglas Hollett, U.S. DOE Geothermal Technologies Office Manager)
10:00 am to 10:30 am	Question and Answer Panel (Office Manager Douglas Hollett, Team Leads Eric Hass, Hidda Thorsteinsson and Jay Nathwani)
10:30 am to 10:45 am	Break
10:45 am to 11:45 am	International Panel (IPGT Member Country Represenatives)
11:45 am to 12:15 pm	Meeting Overview for Reviewers
12:15 pm to 1:30 pm	Lunch - Presentation: Davis Bacon Act/Cost Principles (Jay Nathwani, Genevieve Wozniak and Melissa Jacobi)

TRACK 5	Tuesday, May 8th, 2012	
8:30 am to 9:00 am		Meeting Overview for Reviewers
1:30 pm to 3:00 pm		Tracers Working Group Meeting
3:00 pm to 3:15 pm		Break
3:15 pm to 5:15 pm		Tracers Working Group Meeting (con't)

TRACK 5	Wednesday, May 9th, 2012	
8:30 am to 9:00 am		Meeting Overview for Reviewers
1:30 pm to 3:00 pm		Exploration Technologies Workshop
3:00 pm to 3:15 pm		Break
4:00pm to 8:00 pm		IPGT Meeting

TRACK 5	Thursday, May 10th, 2012	
8:30 am to 9:00 am		Meeting Overview for Reviewers

Appendix E: Peer Review Attendees

First Name	Last Name	Organization
Charles	Able	Dura Drilling
Michael	Albrecht	TBA Power, Inc.
Rick	Allis	Utah Geological Survey
M. Lee	Allison	Arizona Geological Survey
Fred	Aminzadeh	University of Southern California
Arlene	Anderson	U.S. DOE Geothermal Technologies Office
Julie	Anderson	U.S. Department of Energy
Brian	Anderson	University of West Virginia
Lawrence	Anovitz	Oak Ridge National Laboratory
Chad	Augustine	National Renewable Energy Laboratory
Piyush	Bakane	University of Nevada, Reno
Kate	Baker	Independent Consultant
Larry	Bandt	Oski Energy, LLC
Phillip	Bandy	DataAP (Boise State University)
Jacob	Barker	Composite Technology Development, Inc.
Benjamin	Barker	Barker Engineering
Stephen	Bauer	Sandia National Laboratories
Frank	Baumgardt	Johnson Controls, Inc.
Rob	Bectel	U.S. DOE Office of Energy Efficiency and Renewable Energy
Carlon	Bennett	Ruby Mountain, Inc.
Desikan	Bharathan	National Renewable Energy Laboratory
Evan	Bianco	Agile Geoscience
Rachel	Bilyk	SRA International
Philip	Bingham	Oak Ridge National Laboratory
David	Blackwell	Southern Methodist University
Doug	Blankenship	Sandia National Laboratories
Kit	Bloomfield	APEX Petroleum Engineering
William	Bourcier	Lawrence Livermore National Laboratory
Ron	Boyd	Atlas Copco Secoroc LLC
Lauren	Boyd	U.S. DOE Geothermal Technologies Office
Toni	Boyd	Geo-Heat Center
Pat	Brady	Sandia National Laboratories
Joan	Brennecke	University of Notre Dame
Chris	Bromley	GNS
Ryan	Broshar	SRA International
Mike	Bruno	Terralog Technologies USA, Inc.
Carol	Bruton	Simbol Materials
Lyle	Burns	Clean Tech Innovations, LLC
Thomas	Buscheck	Lawrence Livermore National Laboratory
Wendy	Calvin	University of Nevada
Erin	Camp	SRA International
Richard	Campbell	CH2M Hill
Charles	Carrigan	Lawrence Livermore National Laboratory
Clifton	Carwile	Independent Consultant

First Name	Last Name	Organization
Trish	Cassen	U. S. Department of Energy (SDSE Contractor)
Ethan	Chabora	GeothermEx, a Schlumberger Company
Bill	Challener	GE Global
Trenton	Cladouhos	AltaRock Energy
Tom	Clark	ElectraTherm Inc.
Travis	Coleman	Electric Power Research Institute
John	Cooley	FastCAP Systems Corp.
Craig	Cooper	Idaho National Laboratory
George	Cooper	University of California, Berkeley
Ava	Coy	U.S. DOE Geothermal Technologies Office
Dustin	Crandall	URS, National Energy Technology Laboratory
Robert	Creed	Independent Consultant
Lynn	Culp	Surprise Valley Electric
David	Cuyler	Sandia National Laboratories
George	Danko	University of Nevada, Reno
Nicholas	Davatzes	Temple University
Keith	Davis	Jason Associates
Matthew	Deady	Australia Department of Resources, Energy and Tourism
Aaron	Dick	Baker Hughes
Lorie	Dilley	Hattenburg, Dilley & Linnell
Patrick	Dobson	Lawrence Berkeley National Laboratory
Richard	Doctor	Argonne National Laboratory
William	Downs	Independent Consultant
Christopher	Dunne	SDSE LLC
Barb	Dutrow	Louisiana State University
Ronald	Dykhuizen	Sandia National Laboratories
Elisabeth	Easley	Thermochem Inc.
Alan	Eastman	GreenFire Energy
Ariel	Esposito	National Renewable Energy Laboratory
Ed	Eugeni	SRA International
Paul	Fabian	Composite Technology Development, Inc.
David	Faulder	TerraGen Power LLC
James	Faulds	Nevada Bureau of Mines and Geology
Micheal	Fehler	MIT
Olafur	Flovenz	ISOR - Iceland GeoSurevy
Fritz	Foss	Universal GeoPower
John	Fox	Electra Therm Inc.
Joe	Fox	Novatek, Inc.
Melissa	Fox	Los Alamos National Laboratory
Luke	Frash	Colorado School of Mines
Barry	Freifeld	Lawrence Berkeley National Laboratory
Pengcheng	Fu	Lawrence Livermore National Laboratory
Laura	Garchar	Colorado School of Mines
Sabodh	Garg	SAIC
Daniel	Getman	National Renewable Energy Laboratory
Zann	Gill	ecoDESYN Lab

First Name	Last Name	Organization
Michelle	Giron	Energent
Sara	Gonnion	CNJV
Varun	Gowda	Energy Commercialization Center
Hal	Gurgenci	The University of Queensland
Pablo	Gutierrez	California Energy Commission
Marte	Gutierrez	Colorado School of Mines
Alexandra	Hakala	National Energy Technology Laboratory
Andrew	Hammond	MagiQ Technologies
Daniel	Hand	Sustainable Engineering
Bob	Hardage	Bureau of Economic Geology
Markus	Haring	Geothermal Explorers Intl. Ltd.
Stephen	Harrison	Simbol Materials
Christopher	Harto	Argonne National Laboratory
Eric	Hass	U.S. DOE Geothermal Technologies Office
Jordan	Hastings	Nevada Bureau of Mines and Geology
Lance	Hays	Energent
Aaron	Huen	Berrendo Energy
Stephen	Hickman	U.S. Geological Survey
Gwen	Holdmann	Alaska Center for Energy & Power
Jamie	Holladay	Pacific Northwest National Laboratory
Douglas	Hollett	U.S. DOE Geothermal Technologies Office
Matthew	Hooker	Composite Technology Development, Inc.
Roland	Horne	Stanford University
Litang	Hu	Colorado School of Mines
Lianjie	Huang	Los Alamos National Laboratory
Khalid	Hussein	CU, Boulder
Phillip	Hussels	Siemen Corporate Research
Gerry	Huttrer	Geothermal Management Company, Inc.
Joe	Iovenitti	AltaRock Energy
Melissa	Jacobi	U.S. Department of Energy
Todd	Jaffe	Davenport Newberry Holdings
Dale	Jenne	National Renewable Energy Laboratory
Gudni	Johannesson	Orkustofnun - The Icelandic National Energy Authority
Joel	Johnson	Berrendo Geothermal
Bruce	Julian	Foulger Consulting
Krishna Kumar	Kamichetty	University of Nevada, Reno
Paul	Kasameyer	Lawrence Livermore National Laboratory
John	Kaszuba	University of Wyoming
Greg	Kaufman	Pueblo of Jemez
Sharad	Kelkar	Los Alamos National Laboratory
B. Mack	Kennedy	Lawrence Berkeley National Laboratory
George	King	Apache Corporation
Tim	Kneafsey	Lawrence Berkeley National Laboratory
Steven	Knudsen	Sandia National Laboratories
Dharmendra	Kumar	Colorado School of Mines
Michael	Lane	Oski Energy, LLC
Kang	Lao	Terralog Technologies USA, Inc.

First Name	Last Name	Organization
Anna Lis	Laursen	GE Global Research Center
Dan	Lear	Ruby Mountain Inc.
Jon	Lear	Ruby Mountain Inc.
Justin	Lee	SDSE
James	Leggett	Baker Hughes
John	Lens	University of Vermont School of Engineering
Kewen	Li	Stanford University
Scott	Lindblom	Sandia National Laboratories
Grant	Logsdon	CJNV
Ilya	Lomou	Lawrence Livermore National Laboratory
Mark	Lowell	Draka Cableteq USA
Thomas	Lowry	Sandia National Laboratories
Chris	Luchini	Universal GeoPower
Douglas	MacGugan	Honeywell Aerospace
Ahmad	Mahmoud	United Technologies Research Center
Ernie	Majer	Lawrence Berkeley National Laboratory
Frank	Maldonado	Sandia National Laboratories
Caroline	Mann	U.S. Department of Energy
Dave	Marshall	GeoTek Energy LLC
Glenn	Masada	University of Texas
James	Mataragio	Bell Geospace Inc.
Joseph	McCabe	SRA International
Dale	McDonald	Terra-Gen Operating Company
Robert	McGinnis	Oasys Water
Peter	McGrail	Pacific Northwest National Laboratory
John	McLennan	University of Utah
Brian	McPherson	University of Utah
Jim	McVeigh	SRA International
Robert	Mellors	Lawrence Livermore National Laboratory
Dale	Merrick	Modoc Contracting, Canby Geothermal, LLC
Laura	Merrick	U.S. Department of Energy
Elisabet	Metcalfe	SRA International
Rob	Miani	Davenport Newberry Holdings LLC
Clay	Miller	Ram Power Corp.
John	Mims	Bell Geospace, Inc.
Greg	Mines	Idaho National Laboratory
Frank	Misseldine	Oski Energy, LLC
Fabian	Moerchen	Siemens Corporate Research
Michael	Moore	AltaRock Energy
Joseph	Moore	Energy & Geoscience Institute, University of Utah
Michael	Mugerwa	Technip
Thomas	Muth	Oak Ridge National Laboratory
Gregory	Nash	Energy & Geoscience Institute, University of Utah
Jay	Nathwani	U.S. DOE Geothermal Technologies Office
Gregory	Newman	Lawrence Berkeley National Laboratory
Robin	Newmark	National Renewable Energy Laboratory
Jim	Nichols	Truckee Meadows Community College

First Name	Last Name	Organization
John	Niple	Applied Physics System
Josh	Nordquist	Ormat Technologies
Randy	Normann	Perma Works LLC
Ken	Oglesby	Impact Technologies LLC
Pat	Oglesby	Impact Technologies LLC
Bruce	Ohme	Honeywell Aerospace
Feng	Pan	University of Utah
Cristian	Pantea	Los Alamos National Laboratory
Mark	Paster	Independent Consultant
Kim	Patten	Arizona Geological Survey
Doug	Patterson	Baker Hughes Inc
Edward	Patton	Physical Optics Corporation
Bjorn	Paulsson	Paulsson, Inc.
Loic	Peiffer	Lawrence Berkeley National Laboratory
Douglas	Perry	Davenport Newberry
Miroslav	Petro	PARC
Susan	Petty	AltaRock Energy
Benjamin	Phillips	SRA International
Michael	Pierce	GeoTek Energy, LLC
Bob	Pierson	ATA / A-Tech
Albert	Pisano	University of California, Berkeley
Mitchell	Plumber	Idaho National Laboratory
Robert	Podgorney	Idaho National Laboratory
Greg	Pohll	Desert Research Institute
Yarom	Polsky	Oak Ridge National Laboratory
Jared	Potter	Potter Drilling
John	Pritchett	Science Applications International Corp.
Tatiana	Pyatina	Brookhaven National Laboratory
Xuele (Ryan)	Qi	GE Global Research
John	Queen	Hi-Q Geophysical Inc.
Marge	Queen	Hi-Q Geophysical Inc.
David	Raymond	Sandia National Laboratories
Talee	Redcorn	Rendezvous Resources, LLC
Kenneth	Rehfeldt	Los Alamos National Laboratory
Paul	Reimus	Los Alamos National Laboratory
Timothy	Reinhardt	U.S. DOE Geothermal Technologies Office
Fei	Ren	Oak Ridge National Laboratory
Joel	Renner	Independent Consultant
Andre	Revil	Colorado School of Mines
Michael	Reznikov	Physical Optics Corporation
Stephen	Richard	Arizona Geological Survey
Kevin	Rigsby	Hydro Resources Midcontinent
Andrew	Rittgers	U.S. Department of Energy
Joe	Rivers	Jason Associates Corporation
Jeff	Roberts	Lawrence Livermore National Laboratory
F. Lee	Robinson	Flint Geothermal LLC

First Name	Last Name	Organization
Jean-Claude	Roegiers	University of Oklahoma
Kelly	Rose	National Energy Technology Laboratory
Peter	Rose	Energy and Geoscience Institute, University of Utah
Frederick	Ross	SRA International
Fred	Rothauge	Hydro Resources
Jonny	Rutqvist	Lawrence Berkeley National Laboratory
Adrian	Sabau	Oak Ridge National Laboratory
Andrew	Sabin	NAVFAC ESC
Arno	Scaaf	CSIRO
Jochen	Schnitger	Baker Hughes
Marylin	Segall	University of Utah
Brittany	Segneri	New West Technologies LLC
Manoj	Shah	GE Global Research Center
John	Shelton	National Energy Technology Laboratory
John	Shervais	Utah State University
Gunter	Siddiqi	Swiss Federal Office of Energy
Stuart	Simmons	Department of Geology and Geologic, Colorado School of Mines
James	Sims	Los Alamos National Laboratory
Sandyn	Skudneski	SRA International
Lee	Slater	Rutgers University, Newark
Moises Enrique	Smart	Schlumberger Technology Corp.
Karen	Smith	Argonne National Laboratory
Neil	Snyder	National Renewable Energy Laboratory
Walter	Snyder	Boise State University
Eric	Sonnethal	Lawrence Berkeley National Laboratory
Jeff	Spray	Geothermal Expandables, LLC
Nicolas	Spycher	Lawrence Berkeley National Laboratory
Mark	Steffen	Ram Power Corp.
Paul	Stern	PLS Environmental, LLC
Greg	Stillman	U.S. DOE Geothermal Technologies Office
Daniel	Stockli	University of Texas at Austin
Kristen	Stone	U.S. Department of Energy
Casey	Stickland	U.S. Department of Energy
Blake	Sturtevant	Los Alamos National Laboratory
Jiann	Su	Sandia National Laboratories
Gene	Suemnicht	EGS, Inc.
Toshifumi	Sugama	Brookhaven National Laboratory
John	Sullivan	Argonne National Laboratory
Robin	Sweeney	U.S. Department of Energy
Yongchun	Tang	PEER Institute
Robert	Taylor	Composite Technology Development, Inc.
Dennise	Templeton	Lawrence Livermore National Laboratory
Steven	Thoma	Sandia National Laboratories
Donald	Thomas	University of Hawaii, Center for the Study of Active Volcanoes
Hildigunnur	Thorsteinsson	U.S. DOE Geothermal Technologies Office
Ileana	Tibuleac	Nevada Seismological Laboratory, University of Nevada, Reno,

First Name	Last Name	Organization
Ingrid	Tomac	Colorado School of Mines
Uday	Turaga	ADI Analytics LLC
Norman	Turnquist	GE Global Research
John	Ullo	John Ullo, LLC
William	Vandermeer	U.S. DOE Geothermal Technologies Office
Vince	Vermeul	Pacific Northwest National Laboratory
Alexey	Vert	GE Global Research
Charles	Visser	National Renewable Energy Laboratory
Paul	von Hirtz	Thermochem, Inc.
Al	Waibel	Davenport Newberry
Patrick	Walsh	Ormat Nevada
Mark	Walters	Calpine
Michael	Wang	Argonne National Laboratory
Jy-An	Wang	Oak Ridge National Laboratory
Herb	Wang	University of Wisconsin-Madison
Phil	Wannamaker	University of Utah/EGI
Andrew	Wernsdorfer	Berrendo Energy
Mark	White	Pacific Northwest National Laboratory
Chris	White	Louisiana State University
Scott	Wieberg	Bell Geospace, Inc.
Colin	Williams	US Geological Survey
Tom	Williams	National Renewable Energy Laboratory
Mark	Williams	Pacific Northwest National Laboratory
Kermit	Witherbee	National Renewable Energy Laboratory
Tom	Wood	Idaho National Laboratory
Genevieve	Wozniak	U.S. Department of Energy
Mike	Wright	Wright Geoconsulting
Yu-Shu	Wu	Colorado School of Mines
Yi	Xiong	Colorado School of Mines
Tianfu	Xu	Lawrence Berkeley National Laboratory
Karen	Yamamoto	Lawrence Berkeley National Laboratory
Katherine	Young	National Renewable Energy Laboratory
Anton	Zavriyev	MagiQ Technologies
Ezra	Zemach	Ormat Nevada Inc.
Catherine	Zerger	Australia Department of Resources, Energy and Tourism
Jeff	Zhao	W.L. Gore & Associates, Inc.
Jalal	Zia	GE Global Research
John	Ziagos	Lawrence Livermore National Laboratory
Jenn	ZiBerna	SRA International
Mark	Ziegenbein	U.S. DOE Geothermal Technologies Office

Appendix F: List of Peer Reviewers

First Name	Last Name	Organization
Brian	Anderson	West Virginia University
Ben	Barker	Barker Engineering
Steve	Bauer	Sandia National Laboratories
Robert	Bectel	U.S. Department of Energy
Doug	Blankenship	Sandia National Laboratories
Kit	Bloomfield	APEX Petroleum Engineering
Patrick	Brady	Sandia National Laboratories
Chris	Bromley	GNS Science
Charles	Carrigan	Lawrence Livermore National Laboratory
Clifton	Carwile	Independent Consultant
George	Cooper	University of California, Berkeley
Robert	Creed	Independent Consultant
David	Cuyler	Sandia National Laboratories
Patrick	Dobson	Lawrence Berkeley National Laboratory
Richard	Doctor	Argonne National Laboratory
William	Downs	Independent Consultant
Barb	Dutrow	Louisiana State University
Ronald	Dykhuizen	Sandia National Laboratories
David	Faulder	TerraGen Power, LLC
Ólafur	Flóvenz	ISOR - Iceland GeoSurvey
Sabodh	Garg	SAIC
Hal	Gurgenci	The University of Queensland
Pablo	Gutierrez	California Energy Commission
Daniel	Hand	Sustainable Engineering
Marcus	Haring	Geothermal Explorers International Ltd.
Steve	Hickman	U.S. Geological Survey
Matthew	Hooker	Composite Technology Development, Inc.
Gerry	Huttrer	Geothermal Management Company, Inc.
Allan	Jelacic	Independent Consultant
Paul	Kasameyer	Lawrence Livermore National Laboratory
George	King	Apache Corporation
Ernie	Majer	Lawrence Berkeley National Laboratory
Peter	McGrail	Pacific Northwest National Laboratory
Randy	Normann	Perma Works, LLC
Cristian	Pantea	Los Alamos National Laboratory
Mark	Paster	Independent Consultant
Doug	Patterson	Baker Hughes, Inc.
Albert	Pisano	University of California, Berkeley
Robert	Podgorney	Idaho National Laboratory
Yarom	Polsky	Oak Ridge National Laboratory
Xuele	Qi	GE Global Research
David	Raymond	Sandia National Laboratories
Joel	Renner	Independent Consultant
Jean-Claude	Roegiers	University of Oklahoma
Andrew	Sabin	NAVFAC ESC
Gunter	Siddiqi	Swiss Federal Office of Energy

First Name	Last Name	Organization
Lee	Slater	Rutgers University, Newark
Daniel	Stockli	University of Texas, Austin
Gene	Suemnicht	EGS, Inc.
John	Ullo	John Ullo, LLC
Alexey	Vert	GE Global Research
Charles	Visser	National Renewable Energy Laboratory
Herb	Wang	Oak Ridge National Laboratory
Christopher	White	Louisiana State University
Mark	White	Pacific Northwest National Laboratory
Thomas	Wood	Idaho National Laboratory
Phillip	Wright	Wright Geoconsulting
John	Ziagos	Lawrence Livermore National Laboratory

Appendix G: Logistical Lessons Learned from the 2012 Peer Review Meeting

The 2012 Geothermal Technologies Office Peer Review Meeting took place on May 7-10, 2012 at the Westin Westminster Hotel in Westminster, CO. A total of 169 projects were presented with 115 of them being evaluated by the expert reviewers. Approximately 60 subject-matter experts participated as review panel members.

The 2012 Peer Review Meeting was organized into four tracks or sessions and focused on the following areas geothermal technology areas:

- Track 1 - High Temperature Tools, Drilling Systems, Zonal Isolation; and Systems Analysis, Resources Assessment, Data System Development & Population, Education
- Track 2 - Enhanced Geothermal Systems Demonstrations; Seismicity, Fluid Imaging & Reservoir Fracture Characterization; and Modeling
- Track 3 - Tracers and Tracer Interpretation and Exploration Validation
- Track 4 – Low-Temperature and Co-Production Demonstration; Supercritical Carbon Dioxide; and Working Fluids

In addition to the reviewed projects, time was included in Tracks 3 and 4 for presentation of projects too early in their award life to warrant review, or which had scored highly in previous reviews that the Program Managers determined additional peer evaluation was not warranted in this annual cycle. Projects included in the "Presentation Only" category will be officially evaluated during the 2013 peer review meeting.

The following is a list of comments and actionable recommendations made by reviewers and review attendees, aimed at improving the process for future Geothermal Technologies Office peer review meetings.

Lessons Learned

- **Hotel**
  - Podium/stage placement should be forward enough to allow the Principal Investigators to view what is on the screen.
  - Meeting room placement - try to group the meeting rooms as close together as possible. If one of the rooms have windows, it would be preferred that you use that as the lunch room.
  - Re-assess how the room block is estimated. The 2012 projection was based off the number of 2011 attendees.
  - Consider how to handle the issue of people wanting to book rooms outside of the room block date range (specifically international attendees). The hotel website would tell them that the block was full (when it wasn't) if they tried to book a room outside of the range.
  - Check with the hotel to see if they can offer the group rate a few days before and after the block as a concession.
- **Reviewers, Peer Review Process, and Project Presentation Content**
  - Recommended that the content presented by Principal Investigators be even more technically oriented.
    - The office should considering lengthening the project summary to incorporate the required information and then allow presentations to focus on more technical details.
  - Reviewers would like to see a comparison of project goals/challenges and proposed or active solutions.
  - Create an interface where Principal Investigators and reviewers can interact prior to the meeting.
  - The office should have the economics evaluated by non- technical experts when reviewing these projects.
  - The office should ask the Principal Investigators to include the levelized cost of energy (LCOE) and cost per kilowatt metric/information in their project summary and presentation.

- The office may want to consider using the project summaries to include the information currently listed in mandatory slides, and reserve the review session for a more open presentation by Principal Investigators. The Principal Investigators should get to present on what they are doing.
- The Principal Investigators should make copies of their references available to the reviewers.
- The office should make the previous year's presentations and project summaries available to the reviewers.
- Emphasize to Principal Investigators that they should take advantage of the opportunity to discuss their projects with expert reviewers.
- The office should consider including a mandatory slide for the current state-of-the-art (technology baseline) in the peer review presentations.
- Though some data is certainly proprietary, project partners and results should not be proprietary.
- The presentations at the review should focus more on science and engineering and less on budget and a project management timeline.
- The reviewers would like to see the proposals when evaluating the projects.
    - Inform reviewers that they need to do a Freedom of Information Act request in order to get access to project FOAs and SOPOs.
- The office should reduce the Low Temperature Demonstrations presentations from 30 minutes down to 20 minutes.
- The office should have a different Principal Investigator/presenter in the EGS Demonstration technology area to discuss rock mechanics, reservoir engineering, exploration geophysics, etc. for each project presented at future peer review meetings.
- Have printed schedules available for each reviewer at the start of the review that shows their full list of assigned projects along with when those projects are presenting.
- Have a larger version of the agenda available near the registration desk.
- Consider adding carpooling information to the Peer Review website.

A/V, P2RMIS, and Technology

- Use loaner laptops provided by a local A/V company. A/V companies typical have better resources and support available to assist in troubleshooting any technical problems that may arise with the laptops.
- Improve reviewer loaner laptop procedure.
    - Determine if the reviewers need laptops in the presentation room.
    - Determine if the reviewers need laptops in the reviewer room.
- Post previous year's peer review report in P2RMIS or make it available to the reviewers prior to the review.
- Have the office make a decision on animation and audio/video files in advance of the meeting and stick with the decision.
    - Perhaps Principal Investigators can submit audio/video files that are not embedded in the presentation.
- Confirm A/V requirements with all side meetings and prepare for last second request that will likely occur at the meeting.
- Budget for at least two to three power strips per room (A/V budget).
- Have microphones set two per table.
- Prepare to handle complaints about the lack of wireless/Internet access.

Best Practices

- **Hotel**
  - The size of the Westin Westminster worked really well and was an excellent meeting space.
  - Hotel staff was very courteous and helpful.
- **Reviewer Assignments**
  - It is best to have a minimum of four reviewers assigned to each project. If one reviewer did not show up or dropped off at the last moment, it was not an issue as only a minimum of three are required by EERE peer review guidelines.
  - The office should offer an opportunity for reviewers to deliver one round of questions to Principal Investigators through the Department of Energy to clear up primary issues in advance of the review.
- **A/V and Technology**
  - Laser pointers were widely used and much appreciated. Suggested continued use in the future. The pointers that advance the slides are preferable.

Appendix H: Acronym List:

ANL: Argonne National Laboratory
AOP: Annual Operating Plan
ARRA: 2009 American Recovery and Reinvestment Act
CEC: Chemical Energy Carriers
CO_2: carbon dioxide
DOE: United States Department of Energy
EERE: Office of Energy Efficiency and Renewable Energy
EGS: Enhanced Geothermal Systems
FOA: Funding Opportunity Announcement
FY: Fiscal Year
GAO: U.S. General Accounting Office
GDR: Geothermal Data Repository
GETEM: Geothermal Electricity Technology Evaluation Model
GTO: Geothermal Technologies Office
GWe: Gigawatt(s) electric
H_2O: water
JEDI: Jobs and Economic Development Model
kWh: kilowatt hour(s)
IEA-GIA: International Energy Agency's Geothermal Implementing Agreement
IET: Innovative Exploration Technologies
IPGT: International Partnership for Geothermal Technologies
LANL: Los Alamos National Laboratory
LBNL: Lawrence Berkeley National Laboratory
LCOE: levelized cost of energy
LLNL: Lawrence Livermore National Laboratory
MEQ: microearthquakes
MOHCs: Metal Organic Heat Carriers
MWD: Measurement-While-Drilling
MWe: Megawatt(s) electric
NAS: National Academy of Sciences
NCG: non-condensable gas
NEPA: National Environmental Policy Act
NGDS: National Geothermal Data System
NREL: National Renewable Energy Laboratory
OMB: White House Office of Management and Budget
ORNL: Oak Ridge National Laboratory
PI: Principle Investigator
PNNL: Pacific Northwest National Laboratory
P2RMIS: Program and Peer Review Management Information System
R&D: Research and Development
RD&D: Research, Development and Demonstration
SAM: System Advisor Model
$scCO_2$: supercritical carbon dioxide
SiC: Silicon Carbide
SNL: Sandia National Laboratories
SWIW: single-well injection withdrawal
THMC: Thermal Hydrological Mechanical Chemical (model)

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For more information, please visit:
http://www.eere.energy.gov/geothermal

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