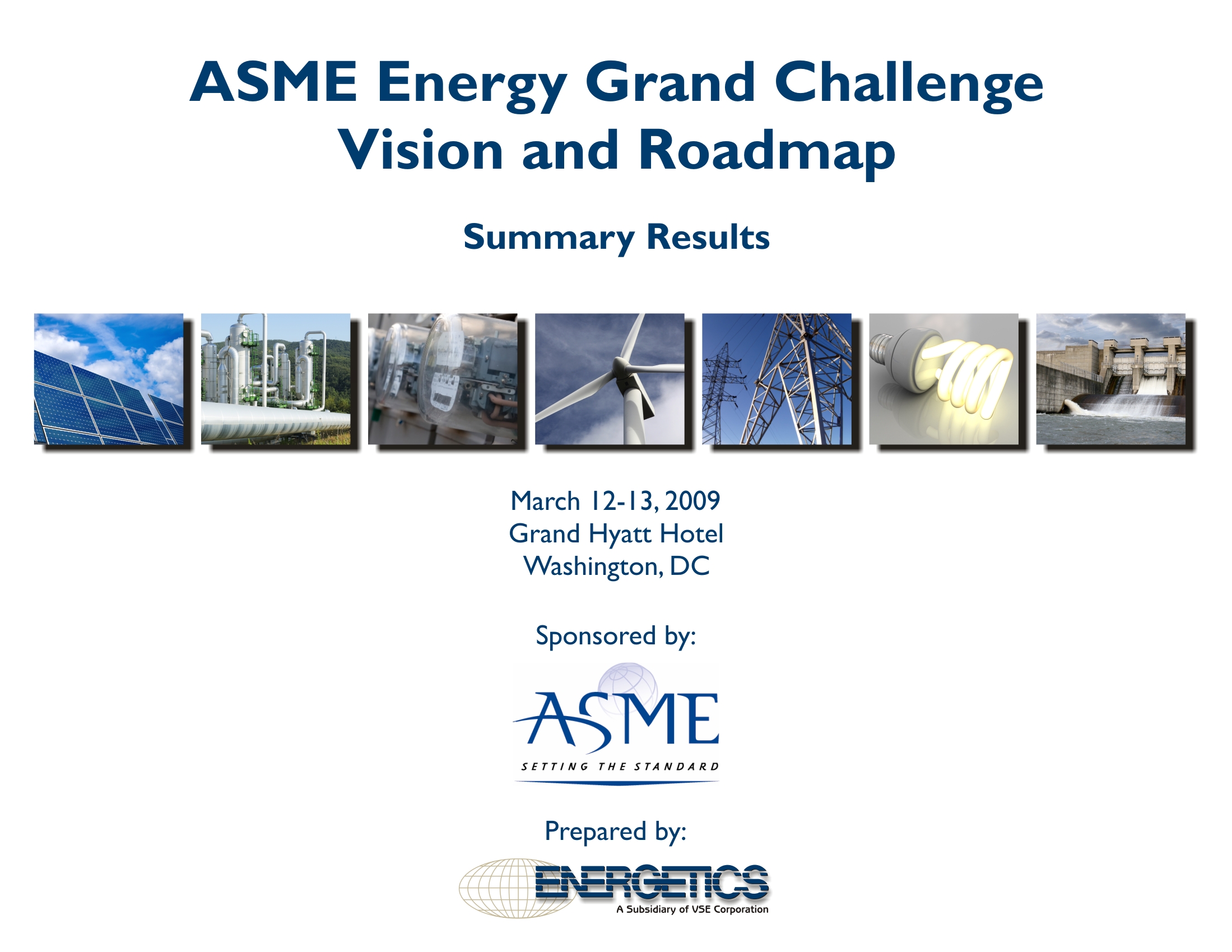
**Technology Planning Workshop**

**July 13-14, 2010 Golden, Colorado**

**Low-Temperature, Coproduced, and Geopressured Geothermal Power**

**Raw Results**



**Geothermal Technologies Program**

**Energy Efficiency and Renewable Energy**

**U.S. Department of Energy**

### Geothermal Technologies Program

### Low-Temperature, Coproduced, and Geopressured Geothermal Power Workshop

**July 13-14, 2010**

**Marriot Denver West**

**Golden, Colorado**

**Contents**

[Summary 3](#_Toc268099529)

[Relative Impacts of Focus Areas – All Groups 5](#_Toc268099530)

[Breakout Group 1 7](#_Toc268099531)

[Breakout Group 2 18](#_Toc268099532)

[Breakout Group 3 29](#_Toc268099533)

[Appendix: Relative Impact Data 43](#_Toc268099534)

[Group 1: 43](#_Toc268099535)

[Group 2: 44](#_Toc268099536)

[Group 3: 45](#_Toc268099537)

[Workshop Totals (Average for All Groups): 46](#_Toc268099538)

### Geothermal Technologies Program

**Low-Temperature, Coproduced, and Geopressured Geothermal Power Workshop**

# Summary

The Geothermal Technology Program (GTP) low-temperature subprogram aims to provide the global geothermal community with the means to achieve development and widespread deployment of economically viable, innovative, and scalable technologies—including those involving coproducts—that will capture a significant portion of the low-temperature geothermal resource base over the next two decades. To that end, GTP held a Technology Roadmapping Workshop on July 13-14, 2010 in Golden, Colorado.

The intent of the workshop was to focus strategically on accelerating the use of low-temperature, coproduced, and geopressured geothermal power in the United States and scope out an overall action agenda for the Geothermal Technologies Program (GTP) of the U.S. Department of Energy’s Office of Energy Efficiency and Renewable Energy (EERE). The Workshop generated the information that will form the basis of an action agenda for the Geothermal Technologies Program.

Attendees included diverse group of experts from industry, academia, and government to discuss how GTP can best leverage its efforts and resources to enable technology breakthroughs, promote deployment of new technology. There were a total of three breakout groups for the Workshop. Each group was preselected in order to bring diverse viewpoints into the discussion. The groups focused on developing:

* A prioritized set of the defining characteristics or conditions of a future in which Low Temperature Geothermal installed capacity is 3 gigawatts; serving as potential strategic targets for a national geothermal agenda.
* A prioritized “To Do” list for GTP that identifies actions, projects, and/or initiatives for an integrated GTP action agenda to advance technology, promote deployment, and inform policy.
* A set of detailed pathway maps that specify the activities, milestones, outcomes, obstacles, and partners for successful achievement of high priority action items.

In addition, each participant was asked to rank the perceived relative impact realized if DOE were to focus efforts on 1.) Advancing Technology, 2.) Fostering Deployment, and 3.) Informing Policy for Low-Temperature, Coproduced, and Geopressured Geothermal Power applications.

The results of this session will lay the groundwork for a GTP strategy to accelerate the use of low-temperature geothermal power and help achieve the overall goal of providing 25% of U.S. electricity generation using renewable sources by 2020.

This document contains a summary of the raw results produced during the July Roadmap Workshop. These workshop results will be used to develop the *2010 Low-Temperature, Coproduced, and Geopressured Geothermal Power Roadmap.* The results presented below are the true representation of the information supplied by the workshop participants.

The 2010 Roadmap will provide the research community and their funding organizations with updated information on the research and development needs of the Low-Temperature Geothermal Industry.

Please submit comments on these workshop results to:

Chris Kelley

Energetics Incorporated

410.423.6554

ckelley@energetics.com

# Relative Impacts of Focus Areas – All Groups

The data below represent average scores for all breakout groups. Each group’s individual scores are noted in the subsequent pages.

Breakout Group 1:

**Facilitator: Chris Kelley, Energetics Incorporated,** [**ckelley@energetics.com**](mailto:ckelley@energetics.com)

|  |  |  |
| --- | --- | --- |
| **Name** | **Organization** | **Email** |
| Brian Anderson | West Virginia University/National Energy Technology Laboratory | [Brian.Anderson@mail.wvu.edu](mailto:Brian.Anderson@mail.wvu.edu) |
| David Anderson | GE Global Research | [Anderson@research.ge.com](mailto:Anderson@research.ge.com) |
| Erin Anderson | National Renewable Energy Laboratory | [Erin.Anderson@nrel.gov](mailto:Erin.Anderson@nrel.gov) |
| Mark Antkowiak | National Renewable Energy Laboratory | [Mark.Antkowiak@nrel.gov](mailto:Mark.Antkowiak@nrel.gov) |
| David Blackwell | Southern Methodist University | [Blackwell@mail.smu.edu](mailto:Blackwell@mail.smu.edu) |
| Richard Campbell | CH2M Hill | [Richard.Campbell@ch2m.com](mailto:Richard.Campbell@ch2m.com) |
| George Danko | University of Nevada | [Danko@unr.edu](mailto:Danko@unr.edu) |
| Lyle Johnson | DOE/Rocky Mountain Oilfield Testing Center | [Lyle.Johnson@rmotc.doe.gov](mailto:Lyle.Johnson@rmotc.doe.gov) |
| Doug Kaempf | DOE | [Doug.Kaempf@ee.doe.gov](mailto:Doug.Kaempf@ee.doe.gov) |
| Masami Nakagawa | National Renewable Energy Laboratory /Colorado School of Mines | [Masami.Nakagawa@nrel.gov](mailto:Masami.Nakagawa@nrel.gov) |
| Timothy Reinhardt | DOE | [Timothy.Reinhardt@ee.doe.gov](mailto:Timothy.Reinhardt@ee.doe.gov) |
| Pete Rose | Energy & Geoscience Institute/University of Utah | [PRose@egi.utah.edu](mailto:PRose@egi.utah.edu) |
| Martin Saar | University of Minnesota | [Saar@umn.edu](mailto:Saar@umn.edu) |

**What actions, projects, and/or initiatives does the Low Temp Geothermal**

| **Advancing**  **Technology** | **Fostering**  **Deployment** | **Informing**  **Policy** |
| --- | --- | --- |
| * Develop full-fledged LT geothermal validation facility or facilities - C, G, L ●●●● * Improve cooling systems/reduced water consumption. Water efficient and R&D project include field test demo C, L, G ●●●● * Reservoir studies including modeling and field studies ●●●● * Ultra-low, binary or chemical energy cycle to convert heat (140°F) to electricity - research, DOE - L. Standalone, modular (<200°F) energy recovery unit (~100kW) Research, DOE - L ●● * Conduct fundamental and applied research on using CO2 as a subsurface working fluid in both EGS and reservoir geothermal systems to double efficiency compared to water. Also test and validate method L, C ●● * Conduct research in hybrid systems - solar thermal, adsorption chillers, other ●● * Site survey - thermal, accessibility, infrastructure, etc. design bases ●● * Fund R&D focused on lowering usable temperatures for electricity generation, C&L ● * Identify cost of energy drivers entitlement vs. laggards ● * DOE projects (FOA’s) targeting Low-temp challenges: - resource assessment, high flow rates, efficient electric production * Focused research on efficient low temperature power production units - all | * Support demo projects, L, G, C. Support multiple CHP projects to prove and improve LT generation units - modular and scalable ●●●● * Perform detailed technoeconomic evaluations of C, L, G technologies and publish ●●● * Identify local/state/federal incentives and publish in one location ●● * Create new markets by getting utilities to readily connect to and accept power from new projects no matter how small (i.e., <1MW) CLG ● * Hold/host conference or workshop with oil/gas industry, mining industry and geothermal ● * Combine CO2 sequestration and/or EOR with geothermal energy recovery, using CO2 as the subsurface working fluid, L, C ● * Work on tax incentives for installation of (LT) geothermal systems in new and old oil and gas operations, C-G * Cascading usage study/deployment * Develop numerical simulation models for recovery prediction and cost analysis, G, L * Work with utility grid owners to insure access of geothermal power | * Cut permitting time and cost, GEA industry government partner, CLG ●●● * Increase marketing - elevator pitch and slogan, impacts politicians and society - C, L ●● * Calculate LTG supply curves for (3) C, L, G technologies for range of scenarios in policy and technical deployment ● * Develop the trade or professional group that can effectively lobby for what you need C,L,G ● * NRC - identify basic science research L ●   Co-production  Low Temp  Geopresured |

Subprogram need to do/achieve in order to facilitate the 3GW future

| **Technical**  **Advancement**  **(Specific to low temp)** | **Integrate with**  **existing systems infrastructure** | **Resource Assessment/Risk**  **Mitigation** |
| --- | --- | --- |
| * Power production units that operate efficiently below 200°F ●●● * Sub-step: xGW low temperature waste heat recovery ●●● * Technologies for Welec generation beyond binary organic Rankine - cogeneration, hybrid ●●● * Develop “out-of-box” research projects ●● * More efficient and lower cost cooling systems ●● * Unconventional sources - non-hydrothermal, non-co-produced will be included ● * Robust, reliable building blocks (Hx, turbo-expanding water treatment ) small footprint * Need heat exchangers/coolers that deal with extreme conditions of T, P, and chemistry * Technology/design development for communal (district) heating/cooling with low-temp geothermal sources. 100 kW range x thousands of applications in home heating * Technology demonstrations sedimentary rock EGS at shallow depth for industrial applications, e.g., for mining or for oil and gas energy recovery )100 kW range x thousand of applications) * Technology development - get industry to develop very low temperature binary cycle that can operate in the waste heat regime. A module of a few kW x 106 = a few GW | * Costs driven down by standard designs/mass production ●● * Different systems are combined, e.g., -co-generation, CO2 sequestration and geothermal while reducing/eliminating water resources ● * Turnkey(s) systems * 3GW power - 30+ GW thermal (10% eff), lots of wells, modular interchangeable systems * Need to have utilities that are incentivized to purchase distributed geothermal power * Dispatchable - complements other renewables, grid stability | * DOE to take or share risk in unproven areas (e.g., loan guarantees) ●●●●● * Geologic/thermal/hydraulic modeling ●● * Resource assessment/enablement ●● * Direct use of Low Temp. resources that offset fossil-based energy - not just heating, energy integration ● * Many immediate test projects to examine varying conditions * Hot spring community and geothermal - small systems |

**What are the characteristics of a future in which Low Temperature**

**Geothermal installed capacity is 3 GW**

| Policy Support | Education/Public Perception | Supporting Thoughts |
| --- | --- | --- |
| * Incentives such as PTC, RPS need to be in place -- increase and extend ●●●● * State and federal incentives exist supporting technology development and deployment ● * Financial incentives ● * Streamline NEPA processes ● * Large power companies accept and pay for “small” amounts of distributed electric power - feed-in tariffs ● * Streamline federal involvement (permitting) * Strong business case established - e-production, district heating, other benefits * Established “best practices” in the field that address analysis, engineering, leasing, permitting, NEPA, PPA, etc. | * Active O&G partnerships ●●●● * Conditions - acceptance from communities, knowledgeable politicians ● * NRC-specific initiatives ● * Education of oil/gas industry, public, lawmakers ● * Develop a marketing campaign to educate both investors and society on LT and its benefits ● * Better marketing * Everyone is used to seeing geothermal exploration, drilling, (stimulation), fluid distribution) - public acceptance * Assigned owners(s) for geothermal education * Public acceptance is achieved | * Should occur within 15 yrs, 10 yrs is better * Will be highly distributed and integrated with other APPS * Small-scale distributed systems are in place * Widely distributed if η = ηearnot and T = 150°C m = 30,000 kg/s |

**What are the characteristics of a future in which Low Temperature Geothermal installed capacity is 3 GW**

|  |  |
| --- | --- |
| **Worksheet** | |
| **Priority TO DO Item: Develop Full-fledged LTG Validation Facility** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) technical support | * Currently, no facility exists for industry-wide, standardized testing |
| - mechanical/electrical |  |
| - I & C |  |
| 2) Physical testing |  |
| - calibrated load system |  |
| - calibrated measurement system (flow, T, P, geochem) |  |
| 3) Evaluation and Prediction |  |
| - technical and economic |  |
| - simulation & modeling |  |
|  |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | No obvious or foreseeable reason |
|  |  |
| **WHEN** |  |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| * 6 mos - requirements development (facility technical requirements) |  |
| * 9 mos - based on requirements, ID specific facilities |  |
| * 12 mos - 90% facility design |  |
| * 18 mos - completed design and ground breaking | **WHO** |
| * 24 mos - facilities on-line | **Partners/Stakeholders** |
|  | *Please identify the partners/stakeholders that need to be involved and the role* |
|  | *they need to play* |
|  | Industry equipment manufacturers/providers |
| Start Date End Date | Federal facilities (RMOTC, NREL, etc.) |
| Aug. 2010 Aug. 2012 | Utilities |
|  |  |

|  |  |
| --- | --- |
| **Worksheet** | |
| **Priority TO DO Item: Innovative Cooling Systems/Reduced Water Consumption** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Air Cooling | * Present large air cooling systems are limited in the hotter areas of the |
| 2) Chillers | Western geothermal area |
| 3) Hybrid - dry & wet towers, combination systems | * Need to have a tested and validated, higher efficient system |
| 4) alternative/new configurations | * Would reduce risk associated costs |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | May be too expensive on a large enough scale to validate |
|  |  |
| **WHEN** |  |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| * 1 yr - have FOA focused on cooling systems |  |
| * 2 yr - identify systems and initiate testing project |  |
| * 3 yr - have a validated testing started |  |
| * 5 yr - complete long term testing | **WHO** |
|  | **Partners/Stakeholders** |
|  | *Please identify the partners/stakeholders that need to be involved and the role* |
|  | *they need to play* |
|  | Power system manufacturers |
|  | Engineering design firms |
|  | Equipment manufacturers |
|  |  |

|  |  |
| --- | --- |
| **Worksheet** | |
| **Priority TO DO Item: Perform Technoeconomic Evaluations of Co-production, low-temperature, and geopressured systems** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) gathering existing cost data for capital and drilling | * Provide a rated list of options, in financial terms, the benefit of deploying low-T, |
| - surface and subsurface | co-produced, or geopressured geothermal energy systems. This would provide |
| 2) collect relevant reservoir data and develop design scenarios and | Information to allow private industry to make informed decisions or deployment. |
| reservoir simulations for subsurface scenarios | inputs to supply curves |
| 3) sensitivity analysis on reservoir production, design scenarios, policy or |  |
| Incentives to characterize uncertainty |  |
| 4) predict/calculate financial or systems based on the sensitivity analysis | **WHY NOT** |
| Cash flow/NPV/payback | **Obstacles** |
| 5) apply learning curves to cost curves | *Please list potential obstacles* |
|  | Availability or accuracy of data, uncertainty |
|  | Uncertainty in lifetime of reservoirs and analysis and predictive methods |
|  | Uncertainty in PPAs, RTC, etc. |
|  |  |
|  |  |
| **WHEN** | **WHO** |
| **Milestones** | **Partners/Stakeholders** |
| *Please identify 2-5 milestones for measuring progress* | *Please identify the partners/stakeholders that need to be involved and the role* |
| * Complete the database of relevant existing cost data, reservoir and | *they need to play* |
| Available technology - list of options | Co-produced and geopressured |
| * Ranked list of technology scenarios based on economic evaluation | Oil and gas - need their data and their buy-in |
| * Economic costs of wide range of inputs (design scenarios) | Manufacturers of surface conversion equipment - cost and design of equipment |
|  | Local communities - have demand needs for distributed electric on direct use needs |
|  | Low-Temperature |
|  | Geothermal producers - have potential for bottoming cycles & wells of opportunity |
|  | Manufacturers of plants |
|  | Local communities |
|  | \* both NREL analysis group |
|  |  |
|  |  |
|  |  |
|  |  |

|  |  |
| --- | --- |
| **Worksheet** | |
| **Priority TO DO Item: Subsurface Fluid Flow Reservoir Studies - understanding flow, permeability, size, lifetime of reservoir**  **(longevity)** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Modeling thermal properties of horizontal wells | * Improved/scalable heat extraction rates |
| 2) New exploration tools, new subsurface working fluids, e.g., CO2 | * Better characterization of reservoirs and risk minimization |
| 3) Identify/exploration of geopressured reservoir | * Improved (~ doubled) heat mining efficiencies, compared to water and reduce/ |
|  | Eliminate water usage |
|  | * Add to USGS geopressured reservoir database |
|  |  |
|  |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | 1) Not having appropriate numerical simulators and/or input data |
|  | 2a) Cultural noise, e.g., electromagnetic, seismic/vibrations |
| **WHEN** | 2b) Obstacles associated with CO2 sequestration and/or enhanced oil recovery |
| **Milestones** | (EOR), e.g., CO2 leakage, establishment of carbon cap-and-trade market |
| *Please identify 2-5 milestones for measuring progress* | (although not necessary), CO2 hydrocarbon mixing |
| 1 co-pro base/applied Sept.2013 | 3) Difficulties identifying over-pressured formations |
|  |  |
| 2. LT research Sept 2013 |  |
|  | **WHO** |
| 3. Geopressed Sept 2013 | **Partners/Stakeholders** |
|  | *Please identify the partners/stakeholders that need to be involved and the role* |
| Start date: Oct. 2010 | *they need to play* |
|  | 1-3 - initially: government (universities/labs in collaboration with industry |
|  | Later: transition to majority industry funding/involvement as otherwise not |
|  | Enough funds are available |
|  | 1 - oil/gas along with labs/universities |
|  | 2a - medical imaging community (for MRI) and oil/gas with labs/universities |
|  | 2b - work with CO2 regeneration partnerships (e.g., PCOR) and oil/gas/coal industry |
|  | (e.g., power plants) or ethanol plants and labs/universities |
|  | 3 - oil/gas and labs/universities |

|  |  |
| --- | --- |
| **Worksheet** | |
| **Priority TO DO Item: Permitting Process Facilitation** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Develop background and literature study based on wind/solar | * Streamlined process for completing the permitting process |
| development challenges | * Dramatically reduce time, money, and confusion |
| 2) Identify relevant agencies and their respective requirements | * Identify favorable opportunities regarding site, size, etc. |
| 3) Map out current process and highlight problem areas |  |
| 4) Create and release and FOA based upon finding sin 1,2, 3 |  |
| 5) Deliverables: optimized process(s) |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | 1. Conflicts with existing bureaucracies |
|  | 2. Constantly changing regulations |
| **WHEN** | 3. Interstate/interagency variations |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| 1) complete background study 1 Jan. 2011 |  |
| 2) release FOA 1 Apr. 2011 |  |
| 3) deliver the deliverables 31 Mar 2011 |  |
|  | **WHO** |
|  | **Partners/Stakeholders** |
|  | *Please identify the partners/stakeholders that need to be involved and the role* |
|  | *they need to play* |
| Start date End Date | Developers - finance and approval |
| Oct. 2010 (1st Qtr. 2011 31 Mar. 2011 | Regulatory agencies |
| End of 2nd Qtr 2012 | Government, politicians |
|  |  |

|  |  |
| --- | --- |
| **Worksheet** | |
| **Priority TO DO Item: Facilitate State Laws and Regulations Development** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Legal definition of geothermal resources - - water, mineral | * Geothermal development cannot go forward unless there are processes |
| 2) Develop a set of regulations concerning leasing on private & state land | in place for leasing, regulations for drilling, etc. |
| 3) Create an agency or subset of an existing agency to implement the |  |
| regulations, and arrange for funding of the entity |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | 1) Could be difficult to get through state legislatures |
|  | 2) Could be resistance from competing industries, environmental groups, etc. |
| **WHEN** |  |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| * Need to start immediately because it could take 2 to 3 years to get |  |
| Through the states’ legislative processes |  |
|  |  |
|  | **WHO** |
| Start date: some state legislatures only meet End Date: | **Partners/Stakeholders** |
| Now every other year 2 to 3 yrs | *Please identify the partners/stakeholders that need to be involved and the role* |
|  | *they need to play* |
|  | Producers, landholders, users, everybody |
|  |  |
|  |  |
|  |  |

Breakout Group 2:

**Facilitator: Fred Hansen, Energetics Incorporated,** [fhansen@energetics.com](mailto:fhansen@energetics.com)

|  |  |  |
| --- | --- | --- |
| **Name** | **Organization** | **Email** |
| Liz Battocletti | Bob Lawrence & Associates, Inc. | [ecbatto@aol.com](mailto:ecbatto@aol.com) |
| Desikan Bharathan | National Renewable Energy Laboratory | [desikan.bharathan@nrel.gov](mailto:desikan.bharathan@nrel.gov) |
| Ted DeRocher | OSKI Energy | [tderocher@oskienergy.com](mailto:tderocher@oskienergy.com) |
| Richard Erdlac | Erdlac Energy Consulting | [rcerdlac@cleansed.net](mailto:rcerdlac@cleansed.net) |
| John Fox | Electratherm, Inc. | [jfox@electratherm.com](mailto:jfox@electratherm.com) |
| Mirek Gruszkiewicz | Oak Ridge National Laboratory | [gruszkiewicz@ornl.gov](mailto:gruszkiewicz@ornl.gov) |
| Pablo Gutiérrez | California Energy Commission | [pgutierr@energy.state.ca.us](mailto:pgutierr@energy.state.ca.us) |
| Bassam Jody | Argonne National Laboratory | [bjody@anl.gov](mailto:bjody@anl.gov) |
| Gary McKay | Global Power Solutions | [gary.mckay@powersolns.com](mailto:gary.mckay@powersolns.com) |
| Chuck Kutscher | National Renewable Energy Laboratory | [Chuck.Kutscher@nrel.gov](mailto:Chuck.Kutscher@nrel.gov) |
| Greg Mines | Idaho National Laboratory | [Gregory.Mines@inl.gov](mailto:Gregory.Mines@inl.gov) |
| William Peter | Oak Ridge National Laboratory | [peterwh@ornl.gov](mailto:peterwh@ornl.gov) |
| Charlie Visser | National Renewable Energy Laboratory | [charles\_visser@nrel.gov](mailto:charles_visser@nrel.gov) |
| Tom Williams | National Renewable Energy Laboratory | [tom.williams@nrel.gov](mailto:tom.williams@nrel.gov) |

Characteristics & Themes of 3GW Future for Low-Temperature Geothermal Energy

(● = Vote for most important enablers of the future)

| Characteristics Of 3gw Future |
| --- |
| * Engaged oil and gas industry with increased number of companies and professionals producing geothermal energy (i.e., AAPG) ●●●●●●● * Fast and inexpensive permitting; <18 months for large operations, < 3 months for smaller distributed generation operations below 50 megawatt ●●●●●● * Greater public knowledge, awareness and acceptance of low temp geothermal ●●●●● * Enhanced exploration toolbox enables locating LTGT resources with higher certainty (than today) ●●●●● * Radically advanced drilling technologies (increased ROP, lifetime of tools/materials) ●●● * Geo energy production cost at 20% less than competition ●●● * True cost of power (including emissions, transmission, energy security, etc) is calculated to allow true comparison of relative merits across sources ●●● * State and federal RPSs include geo MWe and MWt and energy saved (EE) ●●● * Widespread point of use generation - industrial parks, district heat, planned communities ●●● * Advanced thermodynamics cycles - using mixed working fluids ●●● * Cross technology fertilization caused by better communication (different areas and technologies, e.g., solar, wind, etc., all know who’s doing what ●● * Adoption of Iceland practices in U.S. greenhouses, recreation ●● * Developed better technology to bring the geothermal heat to the surface with minimal loss of “availability” or exergy when used for power generation (e.g., using multiple fluids looses energy) ● * Engineering toolbox that enables LTGT production from a range of resource conditions ● * Hybridization of geothermal with other renewable energy resources (storage/fuel cells/CHP) - geothermal seen as another tool ● * Industries choose to site facilities to utilize geothermal resource ● * Modular LTGT plants that can be transported cross country, with switch “on”, turn-key operation ● * Transmission grid decongestion through distributed generation ● * Thermal desalination of Colorado River and Salton Sea ● * Hydrogen projection for remote off-grid locations ● * Long-term consistent, DOE RD&D program ● * Effectively manage side effects, and perceptions of side effects, of LTGT that are low risk but controversial ● * 10x (?) expansion of skilled workforce in (full) LTGT (i.e., entire process from exploration to production) ● |

| Characteristics Of 3gw Future - continued |
| --- |
| * Develop standard property and model bases for rapid evaluation of technologies (e.g., for electric energy production) * Multiple suppliers of above-ground equipment * Inexpensive, reliable, flexible well pumps * Per well electric production for distributed (ex. GHES, thermal-electric) * Energy policy is not an ideological position of political parties - energy policy is bi-partisan and de-politicized * LTGT is effectively marketed/branded with general public; e.g., LTGT has a spokesperson (Sarah Palin” go “Drill, baby, drill”) * Improved efficiencies (e.g., by 20%) in energy conversion/recovery * Establish an exchange or market of waste heat supply and demand for matching capacities (industrial, municipal, etc.) * Geothermal heating and cooling in new construction * Reasonable power sales terms and rates * Transport geothermal energy for cogeneration applications...integrate geothermal/power cycle/end user * District heating/cooling - using geothermal develop communities * Use hot air for heat rejection by Nat. Conv. * Geo-powered cars are equipped w/GPS devices and basically drive themselves * Reasonable financing cost and terms * Elevated cost of petroleum and natural gas * There are GHPs in the White House, Capital, etc. * Lots of installations close to population centers * Lower cost well construction and reduced costs for production and disposal of fluids |

| Key Themes for Enabling the Future |
| --- |
| * Advancement in technology and LTGT toolbox for exploration, drilling, production, etc. * Industry (esp. O&G) engagement and adoption of new practices * Improvement of permitting and regulatory nuts and bolts (i.e., faster, easier, smoother) * Improvement of general policy orientation and approach (RPS, incentives, funding, policy maker awareness) * Public education, awareness, and acceptance based on true cost/benefit comparisons and accurate, complete knowledge * Cross-over fertilization and systems integration – breakdown of barriers and differences across sources, technologies, infrastructure, etc. * Reduced resource risk and cost |

High Priority LTGT Subprogram Action Items

| Advancing Technology To-Do’s |
| --- |
| * Create R&D FOA’s targeted to specific needs - e.g., drilling, efficiency, exploration, field validation of promising technology * Establish a competition between states for the next “new plant” demo - e.g., an LTGT x-prize * Fund/implement R&D initiative on a submersible well pump * Fund/initiate basic research of thermal energy storage technology (chemical, physical) * Fund/implement R&D initiative on ground cooling of binary cycle plant * Fund/initiate research to increase GT electric during hot summer days (utility peak) * Fund/initiate low temp RD focused projects - fluids for geothermal (downhole and binary), reduced cost drilling technology - enhanced casings/cements (different than EGs) * Actively seek/identify transferable technology from other industries * Develop student, university team competition for making most power from defined resource |

| Fostering Deployment to-Do’s |
| --- |
| * Enhance and centralize comprehensive geological data on BLM land to reduce risk * Create a program to provide technical support to new opportunities (DOD, Government, community) * Establish petroleum GT working group to develop strategic roadmap US/industry/?/Labs * Co-sponsor new conferences and workshops with oil and gas * Bring together DOE low temp group and DOE Oil & Gas Group to exchange information and establish joint plan * Make paperwork for geothermal development by O&G companies less of a burden (tax savings, green credits....) - need to reduce O&G’s entrenched resistance to working with Fed government * Identify low-temp resources adjacent to existing communities. Publish information - make locals/government aware * Engage utilities and to breakdown interconnection issues, e.g., in CA Rule 21 for distributed generation * Initiate program to couple industry to resource (servers, greenhouses) * Develop education program and market platform for geothermal industry - directed at users (industry, communities, municipalities) * Support geothermal curricula at community colleges - would include LTGT uses (power generation, heat, CHP, direct use) * Engage professional O&G organizations to connect with independent producers for co-produced and distributed power generation * Establish panels/subpanels (industry/government/academic) from other DOE/DOD programs for cross pollenization * Conduct analysis of obstacles to moving from validation to commercialization and address them * DOE O&G Group + LTGT Group work together to find independent O&G early adopters to build successes - include existing industry groups * Establish internet accessible database that includes a resource assessment of oil and gas well fields as well as data storage and collection with GIS layers for geothermal, wind, solar, ocean and tidal with industrial and large commercial (ASIC codes) * Work with O&G industry on demonstration projects and develop reliable technology and economic database; establish dedicated funding opportunity for petroleum LTGT demo projects $100M |

High Priority LTGT Subprogram Action Items - *continued*

| Informing Policy to-Do’s |
| --- |
| * Create a viral internet, Google, YouTube, Facebook, Twitter campaign designed to create excitement about and intrigue around geothermal - “the other renewable energy” * Raise awareness of geothermal/successes by state - within government and public * Develop a “Geothermal” Spa,Museum in LV. Attract visitors (high visibility areas) * Definitive, objective studies on resource, technology options, benefits to inform policy makers * Public education campaign to generate interest in and excitement for geothermal; fund public relations/awareness program - spokesperson and staff - a LTGT community outreach (this would be non-political deployment of objective data) * Develop a rating system that quantifies such values as “independence from foreign sources” local advantages, etc - best use policy/multiple use ability |

| Cross-cutting to-Do’s |
| --- |
| * Create database of technologies across disciplinary boundaries that involve heat to electricity, cooling technology, etc. * Create a comprehensive digital tool kit (data, analysis, information) * Establish a site for public to find information - technology, regulatory * Set up a low temperature heat utilization R&D program not limited to geothermal but include solar, industrial and geothermal * Fund environmental sensitivities and mitigative measures specific to low temperature geothermal; compile in a fact book/reference for regulators to defend decisions * Establish a low temperature geothermal consortium * Conduct follow-up workshop/panel to evaluate implementation of roadmap from this workshop * Use and build upon past experience and work |

|  |  |
| --- | --- |
| **Worksheet** | |
| **Priority TO DO Item:  *High Risk High Payoff Research on Energy Conversion*** | |
| **WHAT** | **WHY** |
| **Key Components**  Please list the 3-5 major elements of this TO DO item  1) Improved working fluids  a. binary b. well c. chemical heat pipes  2) Improved system components (decreased cost and/or improved efficiency)  a. turbine machinery c. modular/standardized units  b. new materials d. cost reduction  3) Thermal to electric conversion methods/equipment  4) Advanced hear and mass transfer  a. heat exchange b. heat rejection  5) Hybridization with alternate hear sources  a. solar b. CHP c. methane production | **Results**  Please list the impacts, benefits, or outcomes that would indicate success   * 20% reduction in electricity costs * Achieve 85% of the carnot efficiency * Ultimately takes low temperature geothermal technologies to reaching 3GW goal |
| **WHY NOT** |
| **Obstacles**  Please list potential obstacles   * Limit of current data (baseline required) * Existing infrastructure and mind set * Complex system with many parts (many points to lose energy) * Limitations with existing materials and systems |
| **WHEN** |
| **Milestones**  Please identify 2-5 milestones for measuring progress   * Milestone 1: establish baseline on efficiency and cost (status quo) * Milestone 2: develop conceptual designs and select practical concepts * Milestone 3: final design * Milestone 4: Prototype and validation * Milestone 5: Field test & performance data collection and evaluation   Milestone 1 Milestone 2 Milestone 3 Milestone 4 Milestone 5  Start date End Date  Oct. 2010 Sep. 2015 |
| **WHO** |
| **Partners/Stakeholders**  Please identify the partners/stakeholders that need to be involved and the role they need to play   * Laboratories * Universities - include university competition * Industrial Partners |

|  |  |  |
| --- | --- | --- |
| **Worksheet Addendum: Advancing Technology** | | |
|  |  |  |
| Basic Science Knowledge | Development/Applied Research | Demonstration/Testing & Validation |
| * Existing equipment * Existing cost * Existing materials * Existing working fluids * Existing cycle efficiency * Existing mind set * Existing infrastructure | * Improved working fluids:   Composition/multi-component vs. temp range   * Improved system components   Turbo-machinery  Materials  Modularity - (standardized design)   * Improved thermal to electric conversion   Methods/equipment (Specifics not defined yet; Analysis of system will direct specifics to approach LA)   * Improved heat and mass transfer   Heat exchange  Heat rejection   * Improved economics   Efficiency improvement  Equipment/materials cost reduction  Hybridization opportunities | * Lab cycle demonstration - data presentation      * Communication of existing baseline data to drive market and research direction      * Lab testing of equipment designs      * Communication of materials/equipment modeling and testing results            Long - Term   * Pilot plant design, construction, operation, performance evaluation |

|  |  |
| --- | --- |
| **Worksheet** | |
| **Priority TO DO Item:  *Database/Tool-Portal*** (This is not a database, but links to existing data. Some data stored on site. Dynamic links. Interactive - people can post data; forums) | |
| **WHAT** | **WHY** |
| **Key Components**  Please list the 3-5 major elements of this TO DO item  1) Resource data  2) Power plant information - Google earth location  3) Taxes, incentives, RPS, permitting  4) Ability to interactively post data  5) News, big events, who is doing what, who is who  - GPS display, maps | **Results**  Please list the impacts, benefits, or outcomes that would indicate success   * People need information and tools to do conceptual analysis * Supports education by teaching through use * Preliminary economic analysis * Solving technical problems |
| **WHY NOT** |
| **Obstacles**  Please list potential obstacles   * Getting word out, search engine optimization (just part of doing it, no so much obstacle * Security issues (DOE sites) * Budget to build, also lower budget to maintain * This is low risk - not a lot of obstacles |
| **WHEN** |
| **Milestones**  Please identify 2-5 milestones for measuring progress      Prototype  - links, static  Interactive  - moderated  - shared data  - Wiki  - forum  All NGDS data linked  - power plant links  - incentives, RPS  - GIS  *(DOE security requirements important to schedule)*  Navigation tools, analysis tools, priorities of sites  GRC  1 mo  6 mos  12 mos |
| **WHO** |
| **Partners/Stakeholders**  Please identify the partners/stakeholders that need to be involved and the role they need to play  - Google - National Labs  - State energy office, other agencies - BLM, state permitting org  - Industry - Forest service  - GRC and GEA  - Oil and Gas |

|  |  |
| --- | --- |
| **Worksheet** | |
| **Priority TO DO Item:  *Conduct Public Education to Promote Geothermal Energy*** | |
| **WHAT** | **WHY** |
| **Key Components**  Please list the 3-5 major elements of this TO DO item  1) Target audiences  a. identify targets and demographics  b. market research to identify current knowledge base  c. Focus on “Elites” as specific target (elites - policymakers, business  Leaders, early adopters, “thought leaders”, Microsoft, Google, Apple,  Relevant NGO leaders  d. Define target state (end point)  2) Design campaign targeted by demographics  - TV, print, radio, internet, YouTube (viral videos), Twitter, Facebook,  webcasts, T-shirts, bumper stickers, road shows, super bowl ad,  3) Implement campaign  4) Measure results  5) Publish and widely publicize results | **Results**  Please list the impacts, benefits, or outcomes that would indicate success   * By end of project, major city of public is aware of and supports geothermal energy * Increase demand for geothermal energy and effect industry growth * energy security * reduced dependence of fossil fuels * jobs * effect policies that continues industry growth |
| **WHY NOT** |
| **Obstacles**  Please list potential obstacles   * Perception of federal promotion of an industry * Insufficient funding (>$10M) * Must be able to respond to naysayer’s |
| **WHEN** |
| **Milestones**  Please identify 2-5 milestones for measuring progress   * Year 1 - planning and market research * Year 2 - design 2 to 3 campaigns, roll out “Elite” campaign * Year 3 - Roll out Mass Public campaign, Roll out campaign for younger Target audience * Year 4 - monitor and adjust campaign * Year 5 - Assess success (measure and publish/publicize)   Start date: 2011 End date: 2016 |
| **WHO** |
| **Partners/Stakeholders**  Please identify the partners/stakeholders that need to be involved and the role they need to play   * Innovative and creative marketing firm working in conjunction with GEA, GRC, Google, DOE....... |

|  |  |
| --- | --- |
| **Worksheet** | |
| **Priority TO DO Item:  *DOE Internal Collaboration Between Low Temperature GEO and Oil and Gas*** | |
| **WHAT** | **WHY** |
| **Key Components**  Please list the 3-5 major elements of this TO DO item  1) Information exchange between groups  2) Identify common areas of focus - potential overlap  3) Facilitate external relationships between aggressive/early adopters within industry, and professional organizations and state government (CA, TX)  4) Hold cross functional workshop   * opportunities/barriers/action plans   5) Successful demonstration within O&G industry | **Results**  Please list the impacts, benefits, or outcomes that would indicate success   * Focus limited resources * Cross sharing of information * Identifying early adopters with common interests * Breaking down barriers to deployment * Accelerate progress - get results |
| **WHY NOT** |
| **Obstacles**  Please list potential obstacles   * Limited staff within DOE - with different goals/philosophy * Support at high levels to foster cooperation * Industry commitment for change? Different - hard - resistance * Education and knowledge of opportunities is limited * Other priorities |
| **WHEN** |
| **Milestones**  Please identify 2-5 milestones for measuring progress    DOE initial collaboration  DOE Joint Plan  External outreach  9/10  Workshop  Action plans  12/10  4/11  7/11  9/11  Start Date  7/10  End Date  12/11 |
| **WHO** |
| **Partners/Stakeholders**  Please identify the partners/stakeholders that need to be involved and the role they need to play   * DOE Sr. Management must support collaboration * DOE GTP Group and DOE O&G (producers/service/professional orgs) * Leading state governments - TX, CA * Industry experts - service orgs./balance of plant/ORC conversion companies |

Breakout Group 3:

**Facilitator: Gareth Williams, Energetics Incorporated,** [gwilliams@energetics.com](mailto:gwilliams@energetics.com)

|  |  |  |
| --- | --- | --- |
| **Name** | **Organization** | **Email** |
| John Anderson | Clean Energy Solutions | [jva1000@gmail.com](mailto:jva1000@gmail.com) |
| Chad Augustine | National Renewable Energy Laboratory | [chad.augustine@nrel.gov](mailto:chad.augustine@nrel.gov) |
| Toni Boyd | Geo-Heat Center | [toni.boyd@oit.edu](mailto:toni.boyd@oit.edu) |
| Michael Hillesheim | National Renewable Energy Laboratory | [michael.hillesheim@nrel.gov](mailto:michael.hillesheim@nrel.gov) |
| Pete McGrail | Pacific Northwest National Laboratory | [pete.mcgrail@pnl.gov](mailto:pete.mcgrail@pnl.gov) |
| Jim Meehan | MHC Green Energy, Inc. | [jmeehan-mhc@comcast.net](mailto:jmeehan-mhc@comcast.net) |
| Jeremy Newman | Redhorse Constructors, Inc | [jeremy@redhorseconstructors.com](mailto:jeremy@redhorseconstructors.com) |
| Josh Nordquist | Ormat Technologies | [jnordquist@ormat.com](mailto:jnordquist@ormat.com) |
| Daniel Prull | Redhorse Constructors, Inc | [danprull@redhorseconstructors.com](mailto:danprull@redhorseconstructors.com) |
| Loy Sneary | Gulf Coast Green Energy | [loys@sbcglobal.net](mailto:loys@sbcglobal.net) |
| Neil Snyder | National Renewable Energy Laboratory | [neil.snyder@nrel.gov](mailto:neil.snyder@nrel.gov) |
| Kermit Witherbee | Bureau of Land Management | [Kermit\_Witherbee@blm.gov](mailto:Kermit_Witherbee@blm.gov) |

Breakout Group 3 Raw Output: Breakout Session 1

| *What are the characteristics of a future in which Low Temperature Geothermal installed capacity is 3 GW?* |
| --- |
| ● = Idea voted by group member as important to achieving the 3 GW future |
| * Permitting Optimization   + Streamlined permitting process; streamlined development process (in areas that can be) ●●●●●●●●   + Low/no barriers to small producer entry     - Regulatory     - Permitting   + Preliminary site permitting   + Permitting/development streamlining—coordination among various regulatory agencies * Information Resources   + Centralized database ●●●●●●●   + Informed public, end user, local governments on technical efficiencies ●●   + Public education about benefits of geothermal ●●     - Stay ahead of negative perception     - Aggressive approach to public outreach     - Need a national organization to undertake outreach efforts     - PR campaign like Wind Industry   + Data! ●     - Where are wells     - Temperature     - Field perm./porosity     - Water producing potential     - Greopressured zones   + Digital Legacy     - Ease access to info for permitting, exploration, etc., in digital database   + Information reporting requirements     - Engage Oil & Gas and their existing knowledge and data   + Identification of potential O&G sources   + Inventory high-potential low temp areas—“low hanging fruit”--coproduction * Resource Potential and Classifications   + Technology characterization and potential: ●●●●●     - What are the technologies?     - How big is the resource   + Needed to achieve 3GW:     - 12,000 RMOTC     - 3,000 Pleasant Bay     - 100 30 MWe sedimentary Low Temp EGS * Advanced Technology Capabilities   + Improved pumping technologies ●●●     - Efficient and high flow pumping   + Improved whole system analysis and modeling ●●●   + Efficient Exploration technology ●●●     - Reduce dry hole risk   + Low water consumption cooling systems ●   + Higher efficiency power conversion cycles ●   + Advanced low-temp engine options ●   + New power production paradigm—gang a set of smaller engines, adapt to resource over time * Industry Partnerships   + Oil & Gas must see produced water as desirable; Oil &Gas acceptance & interest ●●   + Paradigm shift in economics (i.e., payback period)     - Income from cogeneration * Risk Reduction   + Cost effective exploration ●●   + Research program to clearly define the risks associated with Low Temp geo development vs. “business as usual.” The risks associated w/geo already make financing difficult—so additional risk is an issue ●     - Difficult to obtain funding for technology with unknown risks   + Development of field projects with appropriate funding/low interest loans ●   + Better understanding of geo-hydrodynamics * Market Demand   + Price on carbon or emissions policy ●   + Stable markets for green power at premium price   + Green power demand development   + Some sort of PPA rate guarantee… or feed in tariff enforced by government to eliminate risk of getting a PPA   + National RPS   + Strong desire to offset carbon/negative environmental impacts |

Breakout Group 3 Raw Output: Breakout Session 2

| *What actions, projects, and/or initiatives does the Low Temperature Geothermal subprogram need to do/achieve in order to facilitate the 3 GW future?* |
| --- |
| ● = Category identified by group member as having greatest potential for impact  ● = Category identified by group member as having least potential for impact  ● = Idea voted by group member as important to achieving the 3 GW future |
| * Advancing Technology ●●●●   + Identify technological or economic constraints to further deployment ●●●●● [see Worksheet #1]   + Advanced reservoir simulation development ●●●● [see Worksheet #2]   + Organic Rankine cycle for low temp; advanced working fluid initiative ●●●● [see Worksheet #3]   + Define opportunities to create [promote & install] energy efficiency—recognize and require—for existing technologies ●●● [see Worksheet #4]     - Industrial process efficiency = low-hanging fruit   + Develop transparent and defensible system analysis tools to prioritize R&D ● [combined with first bullet for Worksheet #1]     - Oil & gas company needed     - Modeling—coupled geomechanics     - Government research into sedimentary basins   + Prioritize technical capabilities, then focus on priority tech     - Most industry benefit     - Quickest R&D → Deployment     - Involvement with industry to prove confidence     - More $, industry support     - Faster execution   + Advanced Drilling technology initiative   + Perform tech characterization     - Models (w/ econ.) for each type of tech to identify what works   + Coproduction     - Demo projects     - Bring in O&G operations     - Economic modeling   + Resource assessment     - Coproduced     - Geopressure     - Mineral ownership       * Federal       * Non-Fed       * State   + Look for different types/users and/or new resources with innovative tech * Fostering Deployment ●●●●●●●●   + National database/data gathering ●●●●●●● [see Worksheet #5]     - Partner with Fossil Energy to obtain oil & gas industry research data     - Partner with Google for search functionality (don’t reinvent the wheel)     - Structure database to configure groups of wells—coproduction   + Industrial partnering demonstration program ●●●●●●● [see Worksheet #6]     - Oil and gas exploration leveraging   + Mobile demonstration project to foster deployment in promising locations ●●●●●● [combined with above bullet on Worksheet #6]     - Overcome Oil & Gas industry hesitancy due to costs, etc.     - Partner with industry to deploy where opportunities exist     - Will require large amount of funding to get underway   + Optimize and automate permitting ●●●● [see Worksheet #7]     - National Best Practices for permitting     - Automate permitting     - Clarify well classification     - Develop a way to compare proposed projects to existing projects     - Flow chart     - Work with Department of the Interior (BLM) and states to standardize process   + Estimate resource potential for each technology; identify and inform on areas of opportunity ●● [see Worksheet #8]   + Supercritical carbon dioxide demonstration program, joint EERE/FE ●   + More emphasis and funding for projects that have clear success [potential]     - More funding for fewer projects     - Identify projects that can happen without DOE   + Sponsor/participate in seminars to educate prospective investors and lenders about LGT   + Funding sources for development     - Low/no interest loans projects that are ready * Informing Policy ●●●●●●●●   + White Papers:     - Cmte Briefing Congress     - WGA     - NACO     - State geothermal working groups   + Develop prototype designs for LT systems to support education and research |

|  |  |
| --- | --- |
| **Worksheet #1** | |
| **Priority TO DO Item: Identify and address technical and economic constraints** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Collect industry input and feedback | * Identification of key barriers |
| 2) Assess technology and economic benefits. Incorporate system | * Industry buy-in → eagerness to collaborate on barriers |
| performance and development costs into overall system model to identify |  |
| and prioritize constraints |  |
| 3) Validate findings with industry |  |
| 4) Feed results into program planning process |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | * Sorting anecdotal stories from thematic |
|  | * Balancing level of tech detail with generally applicable results/actionable items |
|  | * Transparency/traceability of results—is outcome credible? |
| **WHEN** |  |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| * Milestone 1: Feedback |  |
| * Milestone 2: System model |  |
| * Milestone 3: ID/prioritize constraints (end of Year 1) | **WHO** |
| * Milestone 4: Validation complete (Year 1.5) | **Partners/Stakeholders** |
| * Milestone 5: Complete (Year 2) | *Please identify the partners/stakeholders that need to be involved and the role* |
|  | *they need to play* |
|  | DOE |
| Milestone 1 Milestone 2 Milestone 3 Milestone 4 Milestone 5 | Industry: |
| Start date End Date | * Oil & Gas |
| Now Year 2 | * Geothermal |
|  | * Equipment suppliers |
|  | National laboratories |
|  |  |
|  |  |

|  |  |
| --- | --- |
| **Worksheet #2** | |
| **Priority TO DO Item: Advanced Reservoir Simulation** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Coupled geomechanics and multiphase flow simulator development | * Reliability of prediction improved |
| 2) Develop higher resolution subsurface characterization methods | * Reduce risk to projects |
| 3) Fracture network characterization and representation in continuum | * Lower cost of projects and faster development |
| mechanics models | * Benefit wider geothermal industry |
| 4) High performance computing platforms |  |
|  |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | * Sparse number of capable simulators |
|  | * Lack of validation opportunities |
|  |  |
| **WHEN** |  |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| * Milestone 1: Complete 3–4 validation exercises (2 years) |  |
| * Milestone 2: Release new simulators (2–3 years) |  |
| * Milestone 3: Field testing of 1–2 new reservoir characterization tools | **WHO** |
| (4–5 years) | **Partners/Stakeholders** |
|  | *Please identify the partners/stakeholders that need to be involved and the role* |
| Simulators---------------| Validation-------------| | *they need to play* |
|  | National laboratories |
| | Field Testing----------------------| | Oil & Gas industry |
| Start date End Date | Universities |
| 0 years 8 years |  |
|  |  |
|  |  |
|  |  |
|  |  |

|  |  |
| --- | --- |
| **Worksheet #3** | |
| **Priority TO DO Item: Organic Rankine Cycle Development/Improvement** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Identify ORC technology suppliers; ≥ 1MW, ≤ 1MW | * Need to create path for better system development |
| 2) Develop advanced design/organic fluids development | * Need to require energy efficiency improvements to utilize cheapest energy |
| 3) Advanced heat transfer/advancement technology and second stage air | source |
| coolers (condensers) | * No standard for utilizing heat, processing, or system efficiency improvements |
| 4) Brainstorm heat exchanger/cooler technology |  |
|  |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | * No policy for utilizing waste energy pressure heat, system efficiency |
|  | * Policy needed to reward energy efficiency to recognize carbon reduction of |
|  | Industrial applications |
| **WHEN** |  |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| * Milestone 1: Heat transfer research (now) |  |
| * Milestone 2: Indentify suppliers |  |
| * Milestone 3: Fluid applications (3 month) | **WHO** |
| * Milestone 4: Waste avoidance to heat transfer technology (6 months) | **Partners/Stakeholders** |
|  | *Please identify the partners/stakeholders that need to be involved and the role* |
|  | *they need to play* |
|  | Industrial partners |
| Milestone 1 Milestone 2 Milestone 3 Milestone 4 | ORC system suppliers |
| Start date End Date | Universities--:SU, SMU |
|  | National laboratories |
|  |  |
|  |  |
|  |  |
|  |  |

|  |  |
| --- | --- |
| **Worksheet #4** | |
| **Priority TO DO Item: Advancing technology that fosters development** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Systems level analysis and modeling | * Improve performance/efficiency |
| 2) Advanced drilling/exploration techniques/tools | * Lower cost |
| 3) Pumping technologies (high flow, efficient) | * Current R&D in these areas is limited |
| 4) Heat rejection/low water consumption advancements |  |
|  |  |
|  |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | * Modeling—lack of defensible opportunities |
|  | * Current market size does not justify R&D |
|  |  |
| **WHEN** |  |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| * Milestone 1: First release (model, tools, prototypes) in 4–5 years |  |
| * Milestone 2: Validation and testing in 2–3 years |  |
|  | **WHO** |
|  | **Partners/Stakeholders** |
|  | *Please identify the partners/stakeholders that need to be involved and the role* |
| First release---------------------------------| Testing----------------------------| | *they need to play* |
|  | Industry (manufacturers, service providers, developers) |
|  | Universities and national laboratories (up front theoretical/experimental) |
| Start date End Date |  |
| Now 7 years |  |
|  |  |

|  |  |
| --- | --- |
| **Worksheet #5** | |
| **Priority TO DO Item: Data gathering** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Bring in Oil & Gas borehole data | * Facilitation of development |
| 2) Data digitizing of legacy data (g.t., water, o & g, mining, etc.) | * Land use decisions |
| 3) Identify gaps/other resources | * Research |
| 4) Cost information (projects) | * Reduce time, project time, & risk |
| 5) Land use, in digital form | * Accurate assumptions |
| 6) Sustainability | * PR |
| 7) Flexibility of database platform |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | * Time and budget |
|  | * Proprietary data issues |
|  | * Prioritization of tasks/data |
| **WHEN** | * Data driven as user driven |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| * Milestone 1: Study of gaps |  |
| * Milestone 2: Prioritization of work |  |
| * Milestone 3: Develop data (best practices, standardization, metrics) | **WHO** |
| * Milestone 4: Long-term funding | **Partners/Stakeholders** |
| * Milestone 5: Acquire data | *Please identify the partners/stakeholders that need to be involved and the role* |
|  | *they need to play* |
|  | Federal government |
| Milestone 1-------| | State governments |
| Milestone 2 & Milestone 3-------------| | Universities |
| Milestone 4-----------------------------------------| Maintenance---------🡪 | Developers |
| Milestone 5-------------------------------------------------------------------------🡪 |  |
|  |  |
|  |  |
|  |  |

|  |  |
| --- | --- |
| **Worksheet #6** | |
| **Priority TO DO Item: Industrial Demo Program (Mobile Demo Program is subset)** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Identify (Oil & Gas) partners | * Energy efficiency |
| 2) Identify applications (coproduced fluids, thermal systems, pressure | * New electricity source |
| systems) | * Reduce O&G environmental impact |
| 3) Identify available technologies and vendors |  |
| 4) Define DOE/industrial partnering/funding structure |  |
| 5) Execute projects |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | * Payback period too long for typical O&G company |
|  |  |
|  |  |
| **WHEN** |  |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| * Milestone 1: Identify priorities |  |
| * Milestone 2: Establish design parameters |  |
| * Milestone 3: Project complete | **WHO** |
|  | **Partners/Stakeholders** |
|  | *Please identify the partners/stakeholders that need to be involved and the role* |
|  | *they need to play* |
|  | Oil & Gas industry |
| Milestone 1 (3 months) Milestone 2 (6 months) Milestone 3 | DOE |
| Now 9 months-1 year | National laboratories |
|  | Geothermal practitioners |
|  | Any entity that produces waste heat and/or pressure |
|  |  |
|  |  |

|  |  |
| --- | --- |
| **Worksheet #7** | |
| **Priority TO DO Item: Permitting Optimization and Automation** | |
| **WHAT** | **WHY** |
| **Key Components** | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Automation | * Reduce permit risk |
| 2) Streamline process by eliminating agency overlap (i.e., Federal, state, | * Foster approval |
| county)—MOUs (BLM/State) | * More efficient use |
| 3) Unify definitions—geothermal—mineral, etc. |  |
| 4) Priority—classify land use priority areas for LT Geothermal |  |
|  |  |
|  |  |
|  | **WHY NOT** |
|  | **Obstacles** |
|  | *Please list potential obstacles* |
|  | * Time |
|  | * Budget |
|  | * Politics |
| **WHEN** | * Jurisdiction—authority—regulatory management |
| **Milestones** |  |
| *Please identify 2-5 milestones for measuring progress* |  |
| * Milestone 1: Study—permitting required |  |
| * Milestone 2: Convince states to develop MOUs or modify |  |
| * Milestone 3: Develop software | **WHO** |
| * Milestone 4: Analysis of potential for LT coproduction | **Partners/Stakeholders** |
| * Milestone 5: Make data sets available | *Please identify the partners/stakeholders that need to be involved and the role* |
|  | *they need to play* |
|  | Federal: BLM, FS, DOE |
|  | State |
|  | County, local gov’t |
|  |  |
|  |  |
|  |  |
|  |  |
|  |  |

|  |  |  |
| --- | --- | --- |
| **Worksheet #8** | | |
| **Priority TO DO Item: Estimate resource potential** | | |
| **WHAT** | | **WHY** |
| **Key Components** | | **Results** |
| *Please list the 3-5 major elements of this TO DO item* | | *Please list the impacts, benefits, or outcomes that would indicate success* |
| 1) Gather raw data | | * Establish realistic geothermal potential for establishing national RE deployment |
| 2) Develop methodology for processing data/filling in missing info | | goals |
| 3) Using taxonomy below, estimate resource potential as function of power | | * Identify and inform on areas of opportunity in Low-T Geothermal Subprogram |
| cost | |  |
|  | |  |
| **Source** | **Well devel.** |  |
| Existing O&G | *Exist. well{active, inactive* |  |
| * *Coproduction* | *Redev.* | **WHY NOT** |
| * *Geopressure* | *New well* | **Obstacles** |
| * *Sedimentary (EGS)* | *New wells* | *Please list potential obstacles* |
| Traditional Hydrothermal | *Fracturing Tech* | * Gaps in data |
|  |  | * Results depend on projected advances in tech |
|  | |  |
| **WHEN** | |  |
| **Milestones** | |  |
| *Please identify 2-5 milestones for measuring progress* | |  |
|  | |  |
|  | |  |
|  | | **WHO** |
|  | | **Partners/Stakeholders** |
|  | | *Please identify the partners/stakeholders that need to be involved and the role* |
|  | | *they need to play* |
|  | | DOE |
|  | | National laboratories |
|  | | Industry—O&G—help with data collection and feasibility of tech scenarios |
|  | | Universities (data) |
|  | | (see National Database worksheet) |
|  | |  |
|  | |  |
|  | |  |

# Appendix: Relative Impact Data

Detail data for the Relative Impact charts noted above in are provided in this Appendix.

## Group 1:



## Group 2:



## Group 3:



## Workshop Totals (Average for All Groups):

