Geothermal Technologies Program
Annual Peer Review
May 7, 2012

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Geothermal Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
Geothermal Technologies Program Mission

Vision: Geothermal will be a major contributor to the nation's baseload energy supply

Accelerate Near Term Hydrothermal Growth

• Decrease exploration risks and costs.
• Lower cost of electricity to 6 cents/kWh by 2020.
• Development of 30 GWe of undiscovered resources.

Secure the Future with Enhanced Geothermal Systems (EGS)

• Demonstrate that EGS is technically feasible by 2020.
• Lower EGS cost of electricity to 9 cents/kWh by 2020 and 6 cents/kWh by 2030.
• Accelerate the development of 100 GWe by 2050 (MIT).
Industry Current Activity

Steady Growth

- **Total installed capacity of 3,187 MW**
  - 97% in California and Nevada
  - Five new plants came online in 2011-12 (91 MW)

- **147 confirmed projects under development in the US**
  - Development capacity 4,116-4,525 MW
  - Additional 16 exploration prospects underway
  - Activity in 13 additional states besides NV and CA

  *Source: Geothermal Energy Assoc. (2012)*

- **There are 6-10 geothermal rigs operating in the US at any time**
  - Compare to +1900 for onshore oil and gas (+50% horizontal)

  *Source: Baker Hughes (2012)*
  *Geothermal = green*
Realizing the Full Potential of Geothermal
Exploring the upside
Geothermal Potential by 2030
Program Support Critical to Growth

USGS 2008 Geothermal Estimate

<table>
<thead>
<tr>
<th>Resource Type</th>
<th>Probability</th>
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<tbody>
<tr>
<td></td>
<td>5%</td>
</tr>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>95%</td>
</tr>
<tr>
<td>Hydrothermal</td>
<td>16.4</td>
</tr>
<tr>
<td>Blind System</td>
<td>73.3</td>
</tr>
<tr>
<td>EGS</td>
<td>727.0</td>
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</tbody>
</table>

Installed Capacity (GWe)

Year


EGS
Blind
Coproduced
Discovery Phase (GEA)
Confirmation Phase (GEA)
Power Plant Construction Phase (GEA)
Existing Capacity
Geothermal Program Direction
Creating Impact

*Increased Focus*

- Identification of New Geothermal Prospects
  - Lowering risk and cost

- Regulatory Roadmaps and Streamlining
  - Programmatic Environmental Impact Assessment

- EGS Test Sites
  - Advancing new techniques and technologies

- Strategic Mineral Assessment

- Increased Funding Leverage
Currently reviewing projects that extend beyond 2013 to identify ways to accelerate costing to meet the new OMB Guidance on ARRA spending.
Mortgage Forecast
The reason behind no FY12 FOA’s

- The FY12 Conference Report stated “GTP may not announce new funding opportunities that result in total mortgages on future fiscal years in excess of half of the program's fiscal year 2012 appropriation”
- In FY12 the mortgage barrier is $19M
- In FY13 the barrier is $32.5M (based on the EERE request & assuming the conference report language persists)

The Program anticipates being able to release FOAs starting in Jan 2013
R&D Integrates Across Subprograms
2008-Present
Hydrothermal and Resource Characterization

Innovative Exploration Technologies – FY13 Request $13.5M

Current Portfolio

- 20 ARRA projects to validate innovative exploration technologies and confirm 400 MW of new hydrothermal resources by 2014
  - Projects in Nevada, California, New Mexico, Alaska, Colorado, Hawaii, and Oregon
  - About 30-60 new MW’s already identified
- 19 R&D projects focused on increasing exploration success through
  - Advanced geophysical surveys and processing
  - New geochemical signals and improved analysis
  - Innovative drilling systems
- USGS resource assessment efforts

FY13

- Continued research and development to lower exploration risk and costs
  - Phase II funding for successful R&D projects that accomplish technical milestones
- Regional Data Gathering and Analysis to identify new opportunities

Project Highlight – Lithium Extraction from Geothermal Brine

- $3M ARRA award
- Successfully scaled up laboratory process for making a lithium extraction material
- Currently running a pilot plant that filters 20 gallons/minute
- A commercial plant, near Salton Sea, CA, will begin construction in late 2012

Subprogram goal: Lower LCOE to 6 cents/kWh by 2020
Hydrothermal and Resource Characterization

Technology Readiness Level (TRL) Context

**Reservoir Characterization**
- Resource Assessment
- Geophysical techniques
- Geochemical methods
- Remote sensing

**Access Reservoir**
- Drilling systems
- Advanced drilling tools

**Energy Conversion**
- Co-production demonstrations
- Thermodynamic cycles
- Operations and maintenance
- Low temperature demonstrations

**TRL 2-3**
- [Stanford University](#)
- [University of Nevada, Reno](#)

**TRL 4-6**
- [Oak Ridge National Laboratory](#)
- [Los Alamos](#)

**TRL 7-9**
- [OASYS Water](#)
- [Johnson Controls](#)
## HRC: Technical Challenges
### Program Investment Matrix

<table>
<thead>
<tr>
<th>CHARACTERIZATION</th>
<th>ACCESS</th>
<th>ENERGY CONVERSION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective and low cost subsurface characterization</td>
<td>Low cost drilling</td>
<td>Low cost O&amp;M and high efficiency energy conversion</td>
</tr>
</tbody>
</table>

### Geophysical- joint inversion and seismic
- Metric: Reduce non-uniqueness of gravity models from millions of solutions to hundreds; 17 Projects / $72,598,943
- Geophysical- self potential, resistivity and shallow temperature
  - Metric: 400MW by 2016; 6 Projects/ $10,646,794

### Geophysical- remote sensing
- Metric: Decrease processing efficiency from months to weeks, increase depth of penetration of airborne surveys from 400m to 2 km; 8 Projects / $64,830,793

### Geology
- Metric: Categorize geothermal settings in US; 3 Projects / $30,664,757
- Geochemistry- thermochronometric, chronostratigraphy, geothermometers
  - Metric: Add at 1+ geophysical signature to reaction transport models; 3 Projects / $13,163,010
- Geochemistry- soil gas/fluid inclusion and isotopes
  - Metric: Identify 1+ new geothermal signature, 20% increase in # of mineral phases in database; 3 Projects / $15,721,199

### Drilling Systems
- Metric: crystalline rock, 30 ft/hr for 1000 ft; 8 Projects / $19,350,308

### Surface equipment- working fluids
- Metric: >20% thermal conversion efficiency; 4 Projects / $6,168,145

### Surface equipment- mineral recovery
- Metric: 15,000 tonnes per year of lithium carbonate at >99.5% purity; 1 Project / $9,633,543

### Surface equipment- cooling
- Metric: obtain 85% of powerplant maximum theoretical efficiency; 3 Projects / $3,174,022

### Power production demo- low temperature and coproduction
- Metric: Install 20 MW by 2016; 10 Projects / $68,221,841

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Energy Efficiency & Renewable Energy
Geothermal Resource Opportunities
Critical Tool for Industry Growth

Dwindling number of identified new prospects

USGS estimates 30 GW hydrothermal and 500+ GW EGS undiscovered

Aggressively confirm and establish new resource opportunities

Accelerated development of geothermal potential

<table>
<thead>
<tr>
<th>2012</th>
<th>2013 Competition</th>
<th>2014</th>
</tr>
</thead>
</table>

Data Gap Analysis
Deliverable: Selected areas for regional data gathering

Data Gathering
Deliverable: New data compiled into NGDS

Compilation
Deliverable: New geothermal opportunities identified

Prize: Lower risk and lower costs for exploration and development
**Current Portfolio**

- 17 demonstration projects in progress including low temperature and co-produced resources
  - Projects in Nevada, North Dakota, Oregon, California, Texas, Colorado, Massachusetts, and Idaho
- Testing sites at Rocky Mountain Oilfield Testing Center (RMOTC)
  - Providing lessons learned and preliminary cost data.
  - Demonstrations in commercial fields in planning stages
- ARRA R&D projects focused on working fluids and efficient cooling

**FY13**

- Demonstration projects
  - Phase II funding of demonstration projects that successfully complete phase I.

**Subprogram goal:** Lower LCOE to 6 cents/kWh by 2020

*Photo provided by Surprise Valley Electric Cooperative*
**Enhanced Geothermal Systems**

**FY13 Request $43.6M**

**Current Portfolio**

- *Six EGS demonstrations* to validate reservoir creation in different geologic conditions
- *110 R&D projects* related to fracture characterization, coupled modeling, high temperature tools and sensors, etc.

<table>
<thead>
<tr>
<th>Performer</th>
<th>Project Site</th>
<th>Site Information</th>
<th>Funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ormat Technologies Inc.</td>
<td>Desert Peak, NV</td>
<td>Adjacent to existing hydrothermal sites</td>
<td>$ 4.3 M</td>
</tr>
<tr>
<td>Geysers Power Company, LLC</td>
<td>The Geysers, CA</td>
<td>Two existing wells will be reopened and deepened for injection and stimulation</td>
<td>$ 6.2 M</td>
</tr>
<tr>
<td>University of Utah</td>
<td>Raft River, ID</td>
<td>Improve the performance of the existing Raft River geothermal field</td>
<td>$ 8.9 M</td>
</tr>
<tr>
<td>Ormat Technologies Inc.</td>
<td>Bradys Hot Springs, NV</td>
<td>Improve the performance of the existing geothermal field</td>
<td>$ 3.4 M</td>
</tr>
<tr>
<td>AltaRock Energy Inc.</td>
<td>Newberry Volcano, OR</td>
<td>High potential in an area without existing geothermal development</td>
<td>$ 21.4 M</td>
</tr>
<tr>
<td>NakNek Electric Association</td>
<td>NakNek, AK</td>
<td>Located in remote location in Alaska without existing geothermal development</td>
<td>$ 12.4 M</td>
</tr>
</tbody>
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**FY13 Efforts**

- EGS field test sites effort initiated
  - Multi-user pre-competitive R&D environment for *EGS testing and validation*
  - *Up to three geologically unique sites*

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**Targets: Demonstrate technical feasibility of EGS at commercial scale by 2020 and lower LCOE to 6 cents/kWh by 2030**
Current EGS Demo Schedule
March 2012
Enhanced Geothermal Systems

Technology Readiness Level (TRL) Context

**Reservoir Characterization**
- Fracture characterization
  - Seismic
- Drilling
- Stress orientation and magnitude (minifrac)

**Reservoir Creation**
- Stimulation technologies
- Zonal isolation
- MEQ Imaging

**Reservoir Sustainability**
- Reservoir monitoring
- Coupled reservoir modeling
- Fluid imaging (neutron and joint inversion)

Note: not all entities listed
### EGS: Technical Challenges

**Program Investment Matrix**

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<tr>
<th>ACCESS HOT FORMATION</th>
<th>CREATE RESERVOIR</th>
<th>SUSTAIN RESERVOIR</th>
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<tbody>
<tr>
<td><strong>Fracture characterization (pre- and post-stimulation)</strong>&lt;br&gt;Metric: location (+/- 10m), azimuth (+/- 15°); 9 Projects / $9,899,992</td>
<td><strong>In-situ stress diagnostics and inventory</strong>&lt;br&gt;Metric: +/- 10% true value; 1 Project / $5,696,835</td>
<td><strong>Temporary sealing of fractures</strong>&lt;br&gt;Metric: Self degrading after 60 days, 300 C, ∆P of 500 psi; 4 Projects / $1,879,000</td>
</tr>
<tr>
<td><strong>Drilling Systems</strong>&lt;br&gt;Metric: crystalline rock, 30 ft/hr for 1000 ft; 9 Projects / $37,720,577</td>
<td><strong>Seismic imaging tools and analysis</strong>&lt;br&gt;Metric: 500 SPS, 24 bit dynamic range, 3-C, 0.5 km between stations, 1 Hz – 1000 Hz sensors, 250 C, 60 dB SNR; 4 Projects / $9,986,158</td>
<td><strong>Zonal Isolation</strong>&lt;br&gt;Metric: Self degrading after 14 days, 300 C, ∆P of 5800 psi; 2 Projects / $2,532,144</td>
</tr>
<tr>
<td><strong>Stimulation Prediction Models</strong>&lt;br&gt;Metric: Location, azimuth and total fractured volume +/- 10% compared to MEQ data; 6 Projects / $6,152,848</td>
<td><strong>High temperature tools &amp; sensors</strong>&lt;br&gt;Metric: 300 C, 3200 psi (10 km); 20 Projects / $29,513,833</td>
<td><strong>Coupled Models (THMQC)</strong>&lt;br&gt;Metric: +/- 10% validation with laboratory experiments; 5 Projects / $5,048,620</td>
</tr>
<tr>
<td><strong>Pumping Technology</strong>&lt;br&gt;Metric: &gt;60 kg/sec production rate; 1 Project / $950,000</td>
<td><strong>Imaging and Modeling Fluid Flow</strong>&lt;br&gt;Metric: Ability to locate and estimate flow rates +/- 10% of true value; 6 Projects / $2,640,297</td>
<td><strong>Smart Tracers and Tracer Interpretation</strong>&lt;br&gt;Metric: fracture surface area (m2), reservoir volume, hydraulic conductivity (m/sec), T; 10 Projects / $8,686,307</td>
</tr>
<tr>
<td><strong>Stimulation Technologies</strong>&lt;br&gt;Metric: 300 C, 3200 psi (10 km), 8760 hrs; 2 Projects / $2,532,144</td>
<td><strong>Establish Inter-well connectivity and sufficient Reservoir Volume</strong>&lt;br&gt;Metric: &gt;60 kg/sec production rate; 1 Project / $950,000</td>
<td><strong>Long Term in-situ sensors</strong>&lt;br&gt;Metric: 300 C, 3200 psi (10 km), 8760 hrs; 2 Projects / $2,532,144</td>
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<td><strong>Low Cost Drilling &amp; Subsurface Characterization</strong>&lt;br&gt;Establish Inter-well connectivity and sufficient Reservoir Volume</td>
<td><strong>Sustaining Production &amp; Long Term In-situ Monitoring</strong>&lt;br&gt;Metric: &gt;60 kg/sec production rate; 1 Project / $950,000</td>
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EGS Test Sites

Key initiative which requires Federal leadership

• **Federal Role:** Ability to test technologies and take technical risks not possible in the private sector

• **Timing:** Need to achieve EGS success more rapidly than possible with our current demonstration portfolio

• **Results:** Well-run test sites focusing on strategic innovation, will quickly optimize the best pathway for EGS success

• **Clarity:** Near-term EGS success will lower risk of this vital resource... allows the private sector to more easily obtain funding and positions EGS as a nationwide resource
Highly likely to be a site with an existing well or well control, subsurface data, permitting etc.

- Tests of Fracturing Geothermal Reservoirs at Shallow or Moderate Depth
- Innovative Techniques to Create Fractures for EGS Demonstration & Test
- Long-Term Tests of Hi-T/Hi-P Tools (user facility)
- Tests of Drill Bits and Drilling Technologies
- Horizontal Drilling—First Ever For Geothermal
**Systems Analysis**

*Request $4M*

*Systems Analysis assesses geothermal resources, cost drivers, barriers, the impact of policy, and progress toward goals.*

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**Current Portfolio**

- Regulatory Roadmap Initiative
- Programmatic Environmental Assessment (EA)
- National Geothermal Data System design, testing and population
- EGS field test site planning, analysis and initial scoping

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**FY13**

- Techno-economic, environmental and financial analysis
- Geothermal data provision
- Intergovernmental and international coordination

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Solutions that increase deployment and decrease risk.
**Scope:**

• Document the regulatory process for geothermal development for:

• **8 states:** California, Nevada, Hawaii, Oregon, Utah, Idaho, Alaska, Montana.

• **3 levels:** Federal, State, County

**Approach:**

• Research *permitting regulations* - develop first draft of flowcharts and supporting documents

• Convene **key agency officials** to review and comment

• Integrate into regulatory roadmap draft. **Deadline: 9/30/2012**

• **Convene key agency representatives (at all levels) and stakeholders to identify areas of concern, bottlenecks, overlaps, differences in implementation, and difficulties in the permitting process. Deadline: October 2012**
Geothermal Portfolio
Technology Drives Value

Performance Monitoring
- Smart tracers
- High temperature sensors
- Improved reservoir analysis

Completion/Stimulation
- Multi-stage fractures
- Fluids and placement
- Water management

Drilling
- Advanced bit design
- Hard rock drilling technologies
- Expandable casing

Subsurface Evaluation
- Seismic and geophysical processing and coupling
- Special core and fluid analyses
- New exploration technologies
- Remote sensing
- Stress field diagnostics

Technical Maturity

Fully Coupled THMC Models
Nanofluids, New Propellants
Rotary Steering, Horizontal Drilling
Cross-well Monitoring

Drilling
- Advanced bit design
- Hard rock drilling technologies
- Expandable casing

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Technical Maturity
• **Potential is huge and remains highly attractive**
  – Opportunity for broad-based implementation of baseload power

• **Balanced Investment Portfolio**
  – Hydrothermal/Exploration Technologies R&D near-term
  – EGS RD&D and demonstrations
  – EGS test sites for long-term goals

• **Reduction of Non-Technical Risks is critical**
  – Carry many of the siting challenges of other energy sources

• **Success is:**
  – ID of more prospects and opportunities
  – Decreased and predictable risk profile
  – Reliable and sustainable business case
“A key mechanism for gaining rigorous, formal and documented evaluation of Geothermal Technologies Program Activities”

- Project evaluations and guidance
- Feedback to principal investigators
- Forum for collaboration and tech transfer
- Complements stage-gate and in-depth project reviews
- Influences operational practices and processes of the Program
- Influences and guides future R&D directions

“Your guidance and feedback are critical to making geothermal a key component of the nation’s energy solutions”
Questions?