Geothermal Technologies Office
Stanford Geothermal Workshop
February 11-13, 2013

Doug Hollett, Director
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy
Geothermal Program: Key Goals and Objectives

Creating Impact

**Increased Focus**

- **Identify New Geothermal Opportunities**
  - Lowered risk and cost
  - New prospecting workflow

- **EGS R&D and Underground Field Observatory**
  - New techniques and technologies

- **Non-Technical Barriers**
  - Regulatory Roadmaps and Optimization

- **Project Synergies**
  - Co-Production and Distributed Power
  - Strategic Resources
Energy Efficiency & Renewable Energy

Geothermal Technologies Office

What’s new?

• EGS Demonstrations (3) and R&D successes
  – EGS underground field observatory in planning stages

• Projects:
  – ~100+ MW of new hydrothermal capacity
  – NGDS, Regulatory Roadmap, Induced Seismicity Protocol

• Personnel:
  – New Staff: Josh Mengers (PMF); Dan King (AAAS); Chris Richards; Jodi Deprizio; Steve Hanson; Sharon Cosgrove
  – Leadership: Eric Hass (Hydrothermal), Lauren Boyd (EGS), Margaret Schaus (Operations), Jay Nathwani (Chief Engineer)

• Forums:
  – Workshop planned to better inform the Program – mid 2013
  – Student competition starting shortly

• Increasingly looking at impact – areas or topics which are transformational and can make a significant difference will be funded
## Geothermal Program Balance
### Transition from Near to Long Term

<table>
<thead>
<tr>
<th></th>
<th>Low Temp</th>
<th>Co-Production</th>
<th>Hydrothermal</th>
<th>EGS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Timeline</strong></td>
<td>Current</td>
<td>Near Term</td>
<td>Near to Intermediate</td>
<td>Long Term</td>
</tr>
<tr>
<td><strong>Strategy</strong></td>
<td>Distributed Energy</td>
<td>Leverages O&amp;G investment</td>
<td>Sector Growth</td>
<td>Transformation</td>
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<tr>
<td><strong>Scale</strong></td>
<td>100's KW to several MW scale</td>
<td>10's-100's MW scale, aggregate to several GW potential</td>
<td>10's GW additional potential</td>
<td>10's - 100's GW potential, but high risk</td>
</tr>
<tr>
<td><strong>Constituency</strong></td>
<td>Local or Rural, Direct Use</td>
<td>Growing Interest, New Potential Sector</td>
<td>Majority of the Private Sector</td>
<td>Fewer Players</td>
</tr>
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</table>

- **Constituency**: Local or Rural, Direct Use
- **Strategy**: Distributed Energy
- **Scale**: 100's KW to several MW scale
- **Timeline**: Current
- **Strategy**: Leverages O&G investment
- **Scale**: 10's-100's MW scale, aggregate to several GW potential
- **Timeline**: Near Term
- **Strategy**: Sector Growth
- **Scale**: 10's GW additional potential
- **Timeline**: Near to Intermediate
- **Strategy**: Transformation
- **Scale**: 10's - 100's GW potential, but high risk
- **Timeline**: Long Term
Geothermal Potential by 2030

Pathway to Growth

Program Focus

In the pipeline

- Existing Capacity
- Power Plant Construction Phase (GEA)
- Confirmation Phase (GEA)
- Discovery Phase (GEA)
- Coproduced
- Blind Hydrothermal
- EGS

Identified Resources

- P95: 7.9 GWe
- mean: 9 GWe
- P5: 16 GWe

Undiscovered Hydrothermal

- P95: 3.7 GWe
- mean: 30 GWe
- P5: 73 GWe

EGS

- P95: 728 GWe
- mean: 518 GWe

Installed Capacity (GWe)

- 2006: 35
- 2009: 30
- 2012: 25
- 2015: 20
- 2018: 15
- 2021: 10
- 2024: 5
- 2027: 0
- 2030: 0

Year


Resource Potential (GW)

from USGS, 2008
Geothermal power plants brought online/expanded in 2011-12 (126.85 MW)

- **San Emidio Expansion**
  - U.S. Geothermal (12.75 MW)

- **Florida Canyon Mine**
  - Electratherm (0.1 MW)

- **Tuscarora Power Plant**
  - Ormat (18 MW)

- **Beowawe Power Plant**
  - Terra-Gen (1.9 MW)

- **McGinness Hills Power Plant**
  - Ormat (30 MW)

- **Hudson Ranch Plant**
  - Energy Source (49.9 MW)

- **Puna Plant Expansion**
  - Ormat (8 MW)

- **Dixie Valley I Power Plant**
  - Terra-Gen (6.2 MW)

- **Nevada: 68.95 MW**
- **California: 49.9 MW**

**Geothermal Power Plants**

2011-2012
Geothermal Projects
Phase III and IV Development

Developers*
- CalEnergy
- Chena Hot Springs
- Cyrq Energy
- ElectraTherm
- Enel North America
- Gradient Resources
- Kodali, Inc.
- OIT
- Ormat Technologies
- Ram Power, Inc.
- RMOTC
- Surprise Valley Electric
- Terra-Gen
- U.S. Geothermal

Phase III
~750 MW
(Planned Capacity Addition)

Phase IV
~200 MW
(Planned Capacity Addition)

Phase III: Permitting and Initial Development
Phase IV: Resource Production and Power Plant Construction

*Nevada Developers in bold.

SOURCE:
Budget Overview
Challenging but a good path forward

Dollars in Millions

<table>
<thead>
<tr>
<th></th>
<th>FY 07 Approp.</th>
<th>FY 08 Approp.</th>
<th>FY 09 Approp.</th>
<th>FY 10 Approp.</th>
<th>FY 11 Approp.</th>
<th>FY 12 Actual</th>
<th>FY 13 Request</th>
<th>FY 13 CR Budget</th>
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<tbody>
<tr>
<td>EGS</td>
<td>$5.0</td>
<td></td>
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<td></td>
<td></td>
<td>$65.0</td>
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<tr>
<td>Low Temp and Coproduced</td>
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<td>TBD</td>
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<td>Innovative Exploration Technologies</td>
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<tr>
<td>Systems Analysis</td>
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<td>Ground Source Heat Pumps</td>
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FY13 funds to date have been $10.5M for a CR through March; remaining funding not yet known.
## Core Program Focus

### EGS Demonstration Projects

<table>
<thead>
<tr>
<th>Performer</th>
<th>Project Site</th>
<th>Site Information</th>
<th>Stimulation Timeline</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>Successful stimulation completed- additional work underway</td>
<td>$ 4.3 M</td>
</tr>
<tr>
<td>Geyser Power Company, LLC</td>
<td>The Geyser, CA</td>
<td>Reopen two existing wells to deepen for injection and stimulation</td>
<td>Successful 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>Initiating in early FY13</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 Brady’s geothermal field</td>
<td>Initiating in early FY13</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>Initial data indicates successful stimulation</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>Project on Hold</td>
<td>$ 12.4 M</td>
</tr>
</tbody>
</table>
Current EGS Demo Schedule
Spring 2013

DESERET PEAK
Phase 1: $3.9 M
Planning, permitting, well characterization & rework
Phase 2: $3.9 M
Chemical & hydraulic stimulation
Phase 3: $0
Flow & tracer testing

CALPINE
Phase 1: $4.8 M
Modeling, permitting, wellbore readiness
Phase 2: $1.4 M
Stimulation & analysis
Phase 3: $0
Long-term injection & monitoring

RAFT RIVER
Phase 1: $5.3 M
Planning, permitting, well characterization, geologic model
Phase 2: $1.9 M
Thermal & hydraulic stimulation
Phase 3: $0.2 M
Long-term data collection & monitoring

BRADY’S
Phase 1: $0.9 M
Planning, permitting, geologic structure model
Phase 2: $1.4 M
Stimulation
Phase 3: $1.1 M
Flow & tracer testing, pipeline construction

ALTA-ROCK
Phase 1: $2.1 M
Planning, permitting, well-bore readiness
Phase 2: $18.7 M
Perm seismic array, stimulate & test well, drill & stim two production wells, system circulation testing
Phase 3: $0.7 M
Long-term data collection & monitoring

NAKNEK
CDPs: $5.3 M
Permitting, well characterization, design & drilling, geologic model, stimulation plan
Phase 1: $1.7 M
Permitting, seismic array, resource model, simulation plan
Phase 2: $6.6 M
Chemical / hydraulic stimulation
Phase 3: $9.3 M
Permitting, production well design, drillin, testing & analysis
Phase 4: $0.7 M
Permitting, circulation testing & monitoring
Enhanced Geothermal Systems (EGS)
Facies Concept – A Continuum

Greenfield:
No existing geothermal development or infrastructure

In-Field
Located within an unproductive portion of an operational hydrothermal field

Near Field/Field Extension
On the margins of existing hydrothermal fields
OUR VISION:

Increased success at Demo projects

Near term use on margins of existing fields as reservoir enhancement tool (many in NV!)

Widespread deployment as routine reservoir enhancement tool at existing and fields in development

Preparedness - strategy, funding, oversight
**How It Works**

Man-made reservoir is created in hot rock that has insufficient natural permeability or fluid saturation.

Fluid is injected into the subsurface under carefully controlled conditions, causing pre-existing fractures to re-open, creating permeability.

Fluid is then circulated throughout the now-fractured rock and heat transported to the surface, where electricity is generated.

**Benefits**

*A potentially important contributor to the US energy portfolio*

- Baseload, non-intermittent energy source
- Minimal, environmental footprint, low emissions, and virtually carbon-free
- An incredible 100+ GW potential

**EGS Field Lab**

- Enable cutting-edge research, drilling, and testing.
- Directly benefit existing technologies in all areas of research in the geothermal space.
- Ultimately validate and optimize EGS technology into a replicable model for commercial scale-up.

**Reservoir Access**

New well geometries and concepts, optimized drilling

**Reservoir Creation**

Characterize local stress, zonal isolation, novel fracturing methods, increase fractured volume per well

**Productivity**

Increase flow rates without excessive pressure needs or flow localization

**Sustainability**

Maintain productivity with minimal thermal drawdown and water losses

**BARRIERS**

- Hard/Hot-rock drilling, completion technologies
- Horizontal wells – a first for geothermal
- Rotary steering
- Stress-field diagnostics
- Smart tracers
- Advanced Reservoir Modeling
- Zonal Isolation
- High-T sensors
- Cross-well monitoring
- Diverter technologies

**SOLUTIONS**
**Ideal Characteristics:**

**Technical**
- Well characterized: 1-2 prior wells
- Hi T, some fractures, moderate permeability and porosity

**Logistics**
- Existing or nearby infrastructure/assets
- Permitting pathway
- Minimal on-site facilities
  - NOT a long-term, permanent facility
**Challenges**

**Innovative Solutions**

1. **Faster, More Efficient Drilling Technologies**
2. **Advanced Downhole R&D**
3. **Measurement /Assessment Tools**
4. **Seismic Modeling, Monitoring & Protocols**

**Barriers**

1. High Cost of Drilling
2. Creating a Reservoir
3. Subsurface Characterization
4. Sustained Reservoir Production
5. Risk Management & Mitigation
EGS Underground Field Observatory
A few of the scientific challenges

1. What are the critical characteristics of natural hydrothermal reservoirs that must be translated to EGS for a reservoir to sustainably produce heat for 20-30 years? How can hydrothermal reservoirs be improved for optimal heat extraction?

2. What are the observational limits for imaging fracture creation and propagation?

3. Are there novel materials that could be emplaced in the reservoir to improve sustainability?

4. Are there novel methods for permeating a rock matrix far field from the borehole?
Pathway to Transformative Change

Shale Gas: Technology Innovations
Spawned Sector Transformation

Potential for similar impact in Geothermal using broadly comparable technologies

Barnett: High-rate slick-water fracs
2-4 OGIP recovery

Barnett: Horizontal well
2-4 stimulations per well
5-8% OGIP recovery

Barnett: Horizontal well
6-8 stimulations per well
8-12% OGIP recovery

Barnett: Improved Petrophysics
16 stimulations
12-30% OGIP recovery

Sources: Lippman Consulting, Inc. 2011. Technology advances from King, 2012 (SPE 152596)
Position all major initiatives for initiation and execution over next 2 years

- **EGS Field Observatory:**
  - Competitive Solicitation end FY13

- **Horizontal well Project**
  - 1st activity Q4 2013

- **Play Fairway mapping**
  - 1st go-by completed 2013

- **Regulatory Roadmap**
  - Completion Q2 and support optimization
  - 5 of 10 white papers on key topics

- **Strategic Materials**
  - Project kickoff with key agency stakeholders

- **DOE-DOD collaboration**
  - Site selection and path forward

- **Oil and Gas Co-Production deployment**
  - Equipment in the field Q3, first data by year end