Accelerate Near Term Hydrothermal Growth

- Lower hydrothermal exploration risks and costs.
- Lower hydrothermal cost of electricity to 6 cents/kWh by 2020.
- Accelerate the development of 30 GWe of undiscovered hydrothermal resources.

Secure the Future with Enhanced Geothermal Systems (EGS)

- Demonstrate that Enhanced Geothermal Systems are technically feasible by 2020.
- Lower EGS cost of electricity to 6 cents/kWh by 2030.
- Accelerate the development of 100 GWe by 2050 (MIT) and ultimately demonstrate the full scale of geothermal resource potential.
Benefits of the Program
Value Added Through Federal Role

• **Increased Speed of Innovation**
  – Advance innovation at a high rate, to achieve development and power generation targets

• **Reduced Exploration & Development Risk and Cost**
  – Tools and technologies which can both lower costs, and identify new resources

• **Information**: National Geothermal Data System and Geothermal Data Repository benefit entire US Geothermal Industry
  – One-stop source for all existing public data
  – Rapid evolution from concept, to exploration and development

• **Technology and System Validation to Increase Investor Confidence**
  – Increased and more favorable funding to private sector

• **Is it enough?**
  – Not yet: Getting to targeted scale, will still require dramatic change
Over 25 years of government and private investment in shale gas RD&D and supporting policy mechanisms were necessary to have a “material impact”*

EGS is arguably in the same techno-commercial space that shale gas was prior to validation. Challenges include the rate of advancement and innovation, and ability of the sector to run with game-changing technical advances.

Hydrothermal and Resource Characterization

**TRL Context**

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

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

**Energy Conversion**
- Coproduction demonstrations
- Thermodynamic cycles
- Operation and maintenances
- Low temperature demonstrations

Note: not all entities listed
Enhanced Geothermal Systems

**TRL Context**

### TRL 2-3
- Reservoir Characterization
  - Fracture characterization - Seismic
  - Drilling
  - Stress orientation and magnitude (minifrac)

### TRL 4-6
- Reservoir Creation
  - Stimulation technologies
  - Zonal isolation
  - MEQ Imaging

### TRL 7-8
- Reservoir Sustainability
  - Reservoir monitoring
  - Coupled reservoir modeling
  - Fluid imaging (neutron and joint inversion)

*Note: not all entities listed*
Portfolio Highlights

Perma Works LLC
Well Monitoring Systems for EGS
Principal Investigator: Randy Normann

- Partnered with Sandia National Laboratories
- Developing new digital pressure/temp/flow (PT-Flow) tool capable of operation at 40k psi and 300°C
- Potentially capable of permanent installation in the wellbore for long-term reservoir monitoring
- Currently, conducting long-term lab tests of individual components

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Solder Prototype 300°C-500°C (Photo provided by Perma Works LLC)
Portfolio Highlights

Sandia National Laboratories

Technology Development and Field Trials of EGS Drilling Systems

Principal Investigator: David Raymond

- Partnership between SNL, Navy Geothermal Program, Barber Drilling, and NOV Reed Hycalog. Drilling in granite in the Chocolate Mountains (NE of Salton Sea)

- Successful deployment of high performance synthetic diamond drill bits in hard-rock geothermal wells

- Project targeting longer bit life and increased penetration rates – significant impact on drilling cost reduction

- Initial data indicates good performance (~30 ft/hr vs. ~10 ft/hr with roller bits), additional analysis and R&D to follow

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(Photos provided by SNL)
Simbol Materials

Technologies for Extracting Valuable Metals and Compounds from Geothermal Fluids

Principal Investigator: Stephen Harrison

- Successfully scaled up laboratory process for making a lithium extraction material
- Currently running a pilot plant that filters 20 gallons/minute
- Plan to develop processes to cost-effectively extract additional materials (manganese, zinc, potassium, cesium, and rubidium) from geothermal brines
- A commercial plant, near Salton Sea, will begin construction in late 2012

Portfolio Highlights

Lithium Extraction Demonstration Plant
(Photo provided by Simbol Materials)

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Portfolio Highlights

**Lawrence Livermore National Lab**

*Predicting Stimulation Response Relationships for Engineered Geothermal Reservoirs*

*Principal Investigator: Charles Carrigan*

- Developing a computational test bed to produce realistic models of engineered geothermal system (EGS) stimulation-response scenarios
- Successfully modeled a 10% enhancement in a stimulated fracture network
- Model and simulations demonstrate how a propagating hydrofracture is affected by a pre-existing fracture network

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**Portfolio Highlights**

**Lawrence Livermore National Lab**

**Predicting Stimulation Response Relationships for Engineered Geothermal Reservoirs**

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**Hydrofracture allowing interaction with pre-existing fracture network**

(Photo provided by LLNL)

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Portfolio Highlights

U.S. Geothermal

Finding Large Aperture Fractures in Geothermal Resource Areas Using a Three-Component Long-Offset Surface Seismic Survey

Principal Investigator: William Teplow

- Completed Geophysical Exploration (Dilatational fault mapping, Seismic reflection, Gravity, PSInSAR, 3D seismic refraction, Shallow temperature survey)
- The combination of techniques developed in Phase 1 appears to be an effective methodology for identifying drilling target wells.
- Commencing Phase II based on promising results: Temperature Gradient Wells are currently being drilled in the southern resources area

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Large Aperture Fracture (LAF) in Range Front Fault
San Emidio North, Wind Mountain Mine Pit
(Photograph provided by U.S. Geothermal)
Nanofluids offer improved efficiency of ORC systems without major modifications to equipment or operating conditions.

- Better thermal conductivity
- Improved heat transfer coefficient

Metal Organic Heat Carrier (MOHC) nanomaterials augment nanofluid performance.

- Boost heat carrying capacity per kg
- Increase effective latent heat of vaporization
- Can be designed for complex interactions

Techno-economic analysis underway.

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First demonstration of a nanofluid undergoing multiple vaporization-condensation cycles without change.

(Photo provided by PNNL)
AltaRock

EGS Demonstration at Newberry Volcano

Principal Investigator: Susan Petty

- BLM Environmental Assessment (EA) process underway: public comment period closed January 25
- AltaRock and partners have worked to characterize the EGS resource at Newberry through development of a comprehensive geologic model, characterization of in situ stresses, induced seismicity and geomechanical analysis

**Portfolio Highlights**

Well 55-29, Newberry, OR
(Photo provided by AltaRock)

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Realizing the Full Potential of Geothermal

Adapted from Chad Augustine, NREL

All numbers quoted come from the USGS 2008 Resource Assessment
Energy Efficiency & Renewable Energy

EGS Resource and Reserve Space
Moving from Potential to Confirmation

**Resource:**
Thermal energy in rock 3-10 km & ≥150 °C

Accessible resource:
< 7 km depth

Useful Resource:
< 5 km

What is the realistic geothermal resource and reserve range?

**Geology:**
Rock properties, temperature, depth, k, ϕ, fracture spacing, stress regime

**Technology:**
Stimulation, monitoring, seismic imaging, fracture characterization

“Resource”

“Economic Reserve”

Reduce costs
Increase efficiency
Lower risk
Validate technology
Geothermal Technologies

Program Direction

- **Potential is huge and remains highly attractive**
- **Technical headroom exists**
- **Non-Technical risks are definable and manageable**
- **Success is:**
  - Decreased and predictable risk profile
  - Commercial and sustainable scale
  - Business case which industry can use for funding
- **Increased Focus FY12 thru FY14**
  - EGS test sites concept
  - Identification of new geothermal prospects
  - Programmatic EA
  - Funding leverage and interagency co-operation
  - O&G strategic engagement
Geothermal Technologies Program 2012 Peer Review
The Westin Westminster Hotel
Westminster, Colorado

- Principal investigators will present the results of their projects for peer review
- Approximately 169 projects will be presented, representing a total DOE investment over $340 million
- Learn and network with other stakeholders and program staff

For more information and to register, visit: geothermal.energy.gov/peerreview
Growing Technical and Staff Capabilities of the Program

• Postings coming soon for Physical Scientist and Subsurface Engineer
  • www.usajobs.gov

• Post Doc Research opportunities to work on collaborative applied research with the host facility, and the EERE Program sponsoring the award. Awards administered by Oak Ridge Institute for Science and Education (ORISE) in collaboration with EERE - **Deadline May 1, 2012.**
  • www.eere.energy.gov/education/postdoctoral

• Summer internship open - **Closing date Feb 21, 2012.**
  – For Physical Science and Engineering Positions, apply here:
    • http://usajobs.gov/GetJob/ViewDetails/307544100

• Volunteer internship open; contact the program office or:
  • http://www1.eere.energy.gov/office_eere/careers/internships_fellowships.html#volunteer

Program Updates

• Roadmaps (9) – comments - **needed by March 1, 2012**

• IS Protocol
“This country needs an all-out, all-of-the-above strategy that develops every available source of American energy – a strategy that’s cleaner, cheaper, and full of new jobs.”

“Nowhere is the promise of innovation greater than in American-made energy.”

“…Government support is critical in helping businesses get new energy ideas off the ground.”

“…I’m proud to announce that the Department of Defense, the world’s largest consumer of energy, will make one of the largest commitments to clean energy in history – with the Navy purchasing enough capacity to power a quarter of a million homes a year.”

“…Double-down on a clean energy industry that’s never been more promising.”