Geothermal Update

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

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Key Goals, Objectives, and Priorities

Identify New Geothermal Opportunities

- Lowered risk and cost
- New prospecting workflow/*"Play Fairway"*

Accelerate a Commercial Pathway to EGS

- Frontier Observatory for Research in Geothermal Energy (FORGE)
- Reservoir characterization/creation technologies

Overcome Deployment Barriers

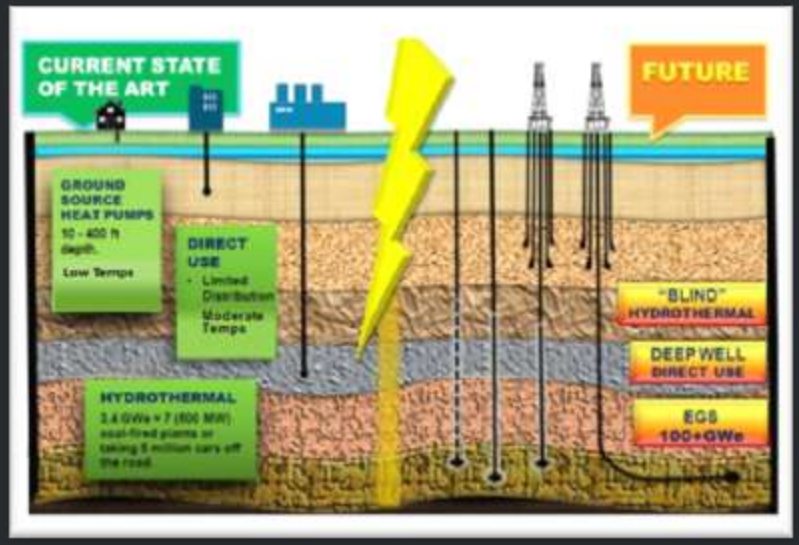
- Regulatory Roadmap: Streamlining
- National Geothermal Data System: Reducing upfront exploration cost

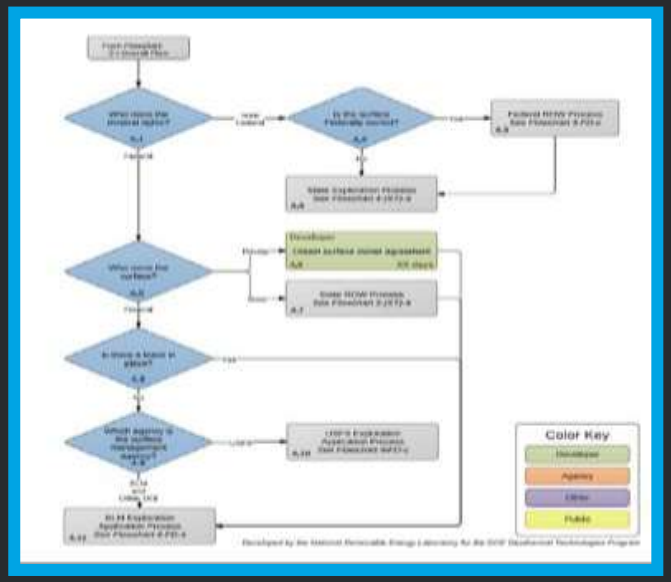
Additive Value

- Co-production and Distributed Power
- Strategic Materials

Subsurface Engineering Crosscut

- Intra- and inter-agency efforts to address common subsurface challenges and better leverage DOE funding





NGDS

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EERE's 5 Core Questions

A Framework for Evaluating GTO Investments

EERE 5 Questions		Applicability to GTO Subprogram Activities
High Impact: Is this a high-impact problem?	☑	EGS is high impact, with a resource potential of 100-500 GWe – enough electricity to power 100 million to 500 million U.S. homes. Blind hydrothermal has the potential for an additional 30 GW while low-temperature resources are more broadly available across the U.S.
Additionality: Will the EERE funding make a large difference relative to what the private sector (and other funding entities) is already doing?	☑	The geothermal private sector is small and risk-averse, with little funding devoted to EGS development, exploration for hidden resources, or low temperature geothermal. The sector is widely operations focused, with little opportunity for innovation without government support.
Openness: Have we made sure to focus on the broad problem we are trying to solve and be open to new ideas, new approaches, and new performers?	☑	GTO seeks feedback on technical direction from geothermal stakeholders and the broader scientific communities including those that work in other subsurface sectors.
Enduring Economic Benefit: How will this EERE funding result in enduring economic benefit to the United States?	☑	Geothermal development–with little to no greenhouse gas emissions–could comprise a significant portion of the U.S. renewable energy supply.
Proper Role of Government: Why is what you are doing a proper high-impact role of government versus something best left to the private sector to address on its own?	☑	The geothermal private sector is not yet equipped to take on the risk of large scale-EGS development and technology optimization or hidden hydrothermal prospect identification.

Geothermal Technology Challenges: *Solvable or "Chasms"?*

Characterizing and Predicting

Efficiently and accurately locate target geophysical and geochemical responses, finding more viable and low-risk resource, and quantitatively infer their evolution under future engineered conditions

Accessing

Safe and cost-effective drilling, with reservoir integrity

Engineering

Create/construct desired subsurface conditions in challenging high-pressure/high-temperature environments

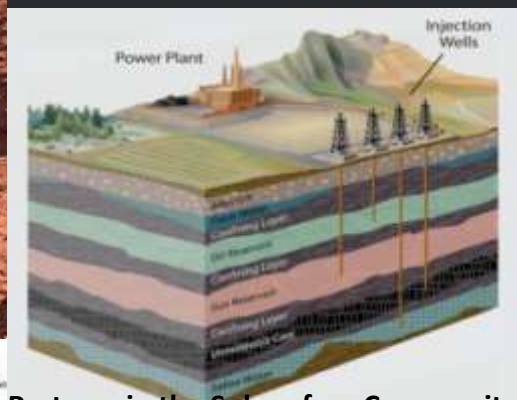
Sustaining

Maintain optimal subsurface conditions over multi-decadal or longer time frames through complex TMHC system evolution

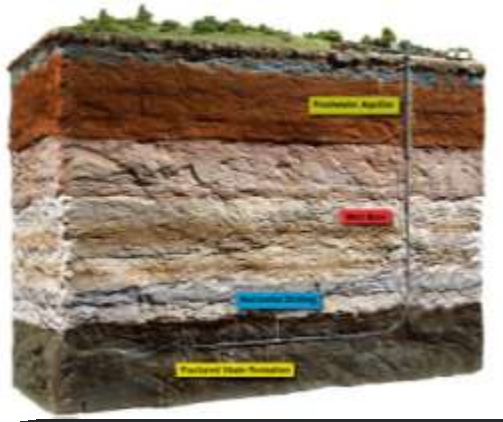
Monitoring

Improve observational methods and advance understanding of multi-scale complexities through system lifetimes

Strong thematic cross-cuts into other subsurface communities – oil and gas, CO_2 sequestration, nuclear waste, storage etc.



Partners in the Subsurface Community



Performance Goals and Metrics

- Reduce the LCOE of newly developed geothermal systems to $.06/kWh by 2030
- Demonstrate the ability to sustain 5MW Enhanced Geothermal Systems (EGS) reservoir by 2020
- Develop near-term exploration tools to lower the upfront risk of exploration
- Initiate activity to extract strategic materials from geothermal brines
- Improve methods to develop and sustain geological heat reservoirs, which will allow geothermal energy to compete equally in the marketplace with conventional electricity sources

Geothermal Program Balance

Transition from Near to Long Term

	Low Temp	Co-Production	Blind Hydrothermal	In- and Near-Field EGS	Greenfield EGS
Timeline	**Near Term**	**Near Term**	**Near to Intermediate**	**Near to Intermediate**	**Long Term**
Strategy	Utilize waste-heat / promote distributed energy	Leverage O&G infrastructure	Promote Sector Growth	Maintain / expand existing fields	Develop replicable model for commercial scale-up
Scale	**100's KW to several MW scale**	**10's-100's MW, aggregate to GWs potential**	**10's GW additional potential**	**5 – 10 GWs potential - low risk**	**10's - 100's GW potential - higher risk**
Constituency	Local and Direct Use	Growing Interest, New Potential Sector	Majority of the Private Sector	Private Sector, very few companies to date	High potential for growth and new entrants resulting from EGS Field Observatory

GTO Operational Space

What's Been Achieved

EGS Demonstration Portfolio Successes

- **The Geysers, CA.** In FY11 and FY12, this demonstration project proves that a man-made reservoir can be created in an unproductive portion of a natural reservoir. First-ever sustained EGS project at commercial scale in the U.S., with the potential to produce 5MW.
- **Desert Peak, NV.** In FY13, this project successfully stimulated an existing sub-commercial well. This project is now connected to the grid, making it the first EGS project in America to generate commercial electricity to the grid, by providing an additional 1.7 MW at the existing wellfield. More projects anticipated at this field as a result.
- **Newberry Volcano, OR.** In FY13, this greenfield project completed reservoir stimulation with a demonstration of new diverter technology used to target stimulation zones within a single well—a first-of-its-kind achievement.


Newberry


The Geysers field


Desert Peak

Desert Peak EGS Demonstration

1st US Grid-Connected EGS Project

> "If we can go to all the hundred or thousands of wells that are unproductive and tinker with them to make them productive, this is a game changer."

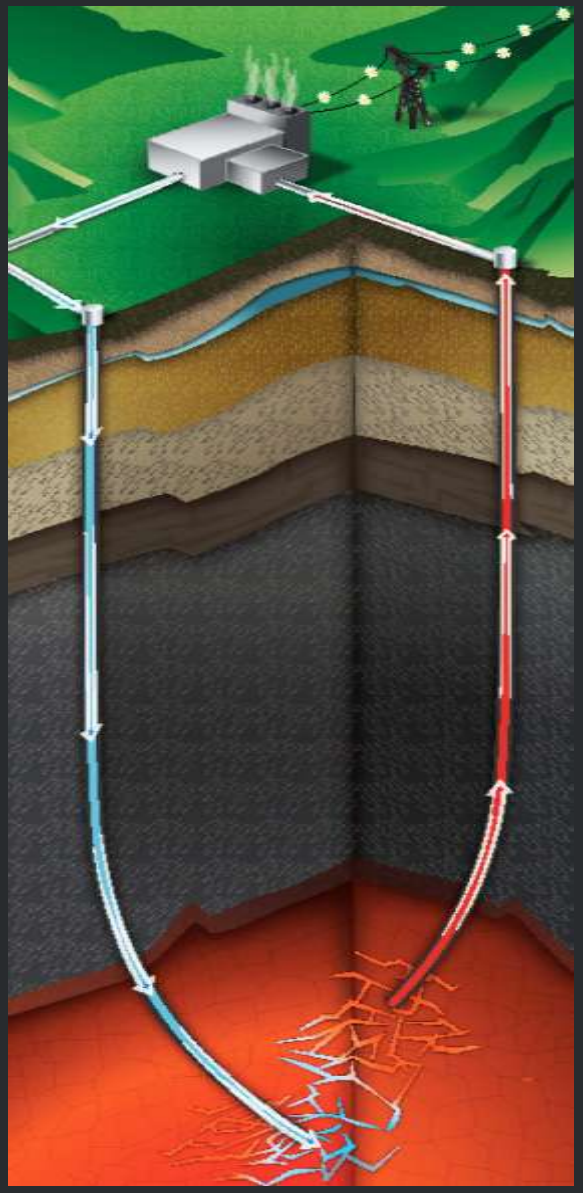
Paul Thomsen, Director of Policy and Business Development, Ormat Technologies
– MIT Technology Review, 4/2013

- Ormat Technologies' Desert Peak EGS project successfully supplied 1.7 MW electricity to the grid – a first-in-the-nation achievement
- DOE invested $5.4 million, with a private costshare of $2.6 million
- Desert Peak represents a near-term opportunity to develop EGS at lower cost and risk; potential for reserve additions at highly competitive costs ($0.02-05/kwh)
- Pathway to larger, more complex and more challenging R&D efforts

> "DOE's Geothermal Technologies Office is changing geothermal development in the U.S."

Lucien Bronicki, Chief Technology Officer, and Ormat Foundation (4/29/13), Ormat Technologies
– Yahoo Stockwatch

Frontier Observatory for Geothermal Research (FORGE)



Promote transformative science and engineering to:

- Validate and optimize enhanced geothermal systems (EGS) technology
- Perfect access and creation of productive and sustainable reservoirs
- Capture and disseminate high fidelity data
- Ensure reproducibility for commercial scale-up

Federal Role:

- Test technologies/take technical risks not possible in private sector
- Work under aggressive timeframe

Direct benefits to multiple areas of subsurface research

Innovative Geothermal R&D with Translational Impacts

1. **Subsurface Characterization** – invented microseismic modeling for reservoir mapping, capitalized on by further investment through DOE's Unconventional Gas Research Programs. Now used by all subsurface communities.
2. **Drilling** –Developed polycrystalline diamond compact (PDC) drill bits, which are used in 60% of oil and gas well footage and are estimated to reduce oil and gas offshore costs by $56/foot drilled.
3. Electric Submersible Pumps (ESP) – Successful development of a high temperature/pressure ESP, through ARRA funding, led General Electric to create a new Artificial Lift business and acquire smaller lift companies to maintain market share .
4. Power Plant – Improved binary conversion cycles; for mid-level temperatures (150-190 C) resulting in a 15% increase in productivity over flash plants
5. **Reservoir Technology** – Developed geothermal reservoir models that are estimated to allow increased geothermal well productivity by 10% and oil and gas well productivity by up to 20% and (based on The Geysers)
6. **In-/Near-Field EGS** – Demonstrated and tested EGS technologies in a near and in-field environment that resulted in additional power of 2-5MW at $0.04/kWh.
7. **Data access** – the NGDS is reducing upfront exploration and development risk by making geothermal data public and interoperable. Earth magazine has referred to this effort as "digitizing the earth," offering leverage to other subsurface sectors.

INNOVATION ⇒ **FURTHER R&D** ⇒ **COMMERCIALIZATION**

e.g., microseismic modeling ⇒ ***DOE Fossil Energy refines seismic mapping techniques*** ⇒ ***Oil and gas community adopts technology as essential fracking tool***

"**DOE's long-term support was critical in the development of commercial tools for microseismic monitoring of fracturing procedures.**"

***NETL**, 2007, DOE's Unconventional Gas Research Programs , An Archive of Important Results*

Key Accomplishments FY 2013

Desert Peak Demonstration Project - Nevada

Completed 8-month, multi-stage stimulation at existing, underperforming well. **Now connected to the grid - first EGS in America to generate commercial electricity** - additional 1.7 MW.

Florida Canyon – Nevada

Geothermal power generation as a byproduct of gold mining, generating electricity for **less than 6 cents/kWh**.

The Geysers EGS demonstration project - California

Successfully drilled a new and distinct reservoir in a very low permeability, high-temperature region, yielding a **commercial-scale 5 MW resource**.

Caldwell Ranch – California

Confirmed an initial 11.4 MW of equivalent steam—50% more than early estimates—from three previously abandoned wells. **First geothermal project where an abandoned steam field has been successfully re-opened for production**.

Geothermal Regulatory Roadmap (GRR)

Online public tool that outlines federal, state, and local regulation for geothermal development in selected geothermal-rich states— **cited in the White House Report to the President, issued in May 2013, as a best practice.**

High performance synthetic diamond (PDC) drill bits

Successfully deployed in hard-rock geothermal wells—particularly suited to harsh downhole environments—and a critical path to reducing costs and risk of geothermal development.

Induced Seismicity Protocol and Best Practices

General guide for geothermal developers to address induced seismicity issues

- DOE commissioned a group of experts to develop an Induced Seismicity Protocol
- This effort engaged the United States and international scientific and industry communities to assess the impacts of induced seismic events.
- DOE released the Protocol in 2012 and adopted its safety guidelines for all DOE-funded EGS demonstration projects.
- The Protocol was well received by the National Research Council (NRC) and recommended as a "best practice" document for use by all other subsurface technologies.