

# Geothermal Technologies Program

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

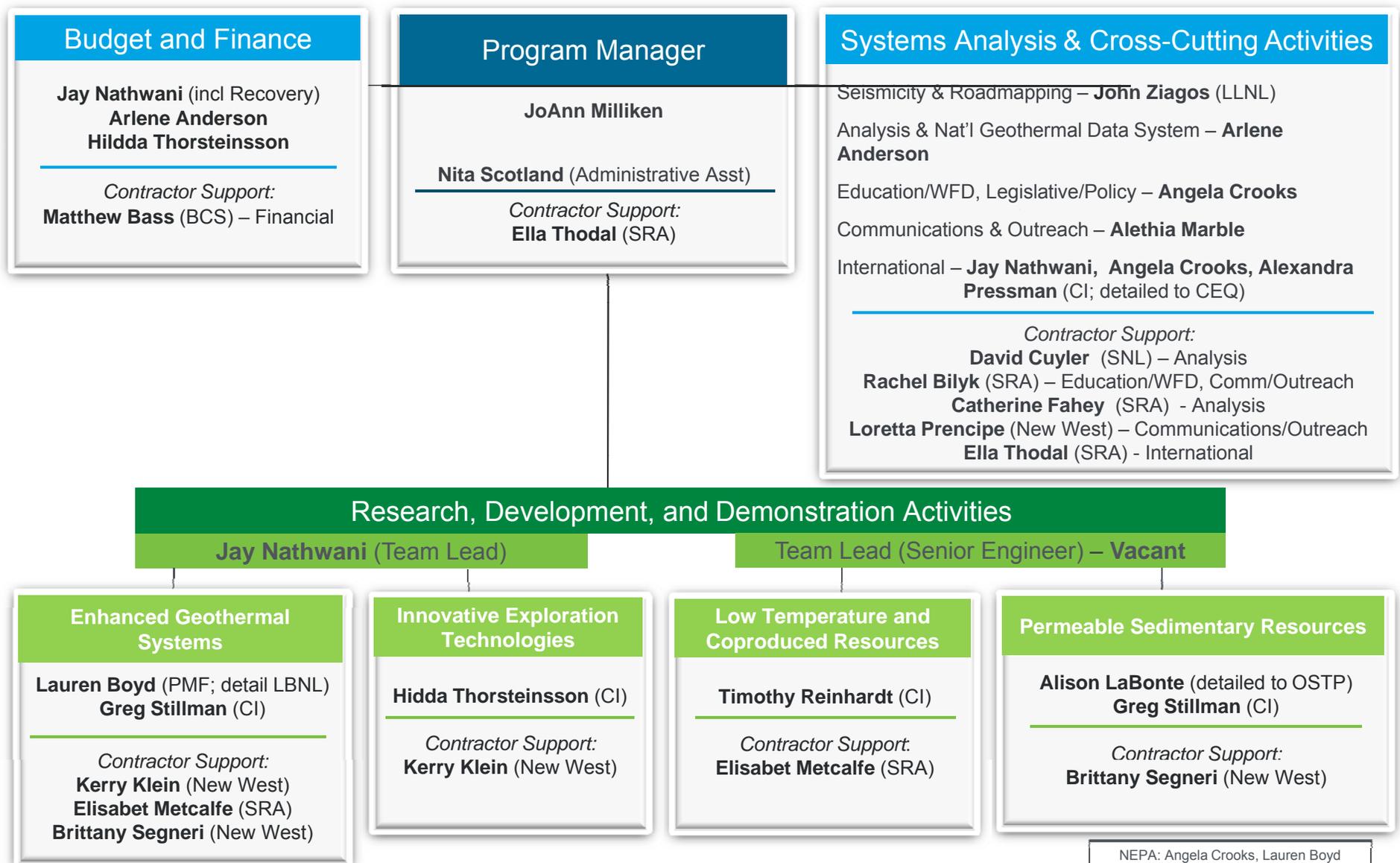


*Enel Stillwater Courtesy of Enel Green Power North America*

For JoAnn Milliken  
Program Manager  
Jay Nathwani

Stanford Geothermal Workshop  
Jan 31, 2011

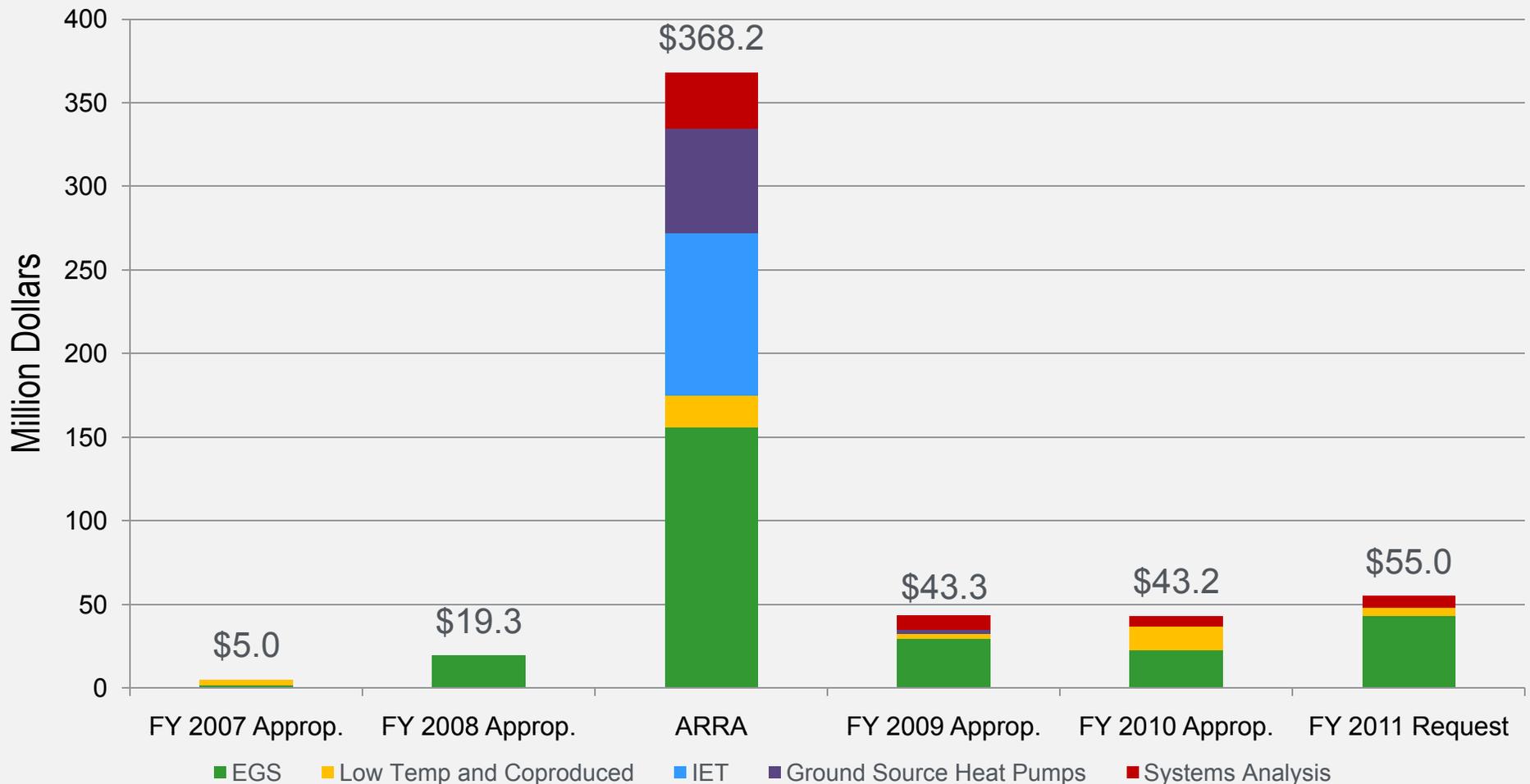
# Program Organization Chart



NEPA: Angela Crooks, Lauren Boyd

# Recent Budget Trend

Program funding was lowest (\$5.0 M) in 2007, but was boosted by \$368.2 M through the American Recovery and Reinvestment Act (ARRA) in 2009.



Under ARRA, \$368.2 million in 148 projects to prime awardees in 39 states – demonstrating a national impact.

# Barriers to Geothermal Development

The Program addresses industry challenges with targeted R&D, demonstrations and cross-cutting efforts.

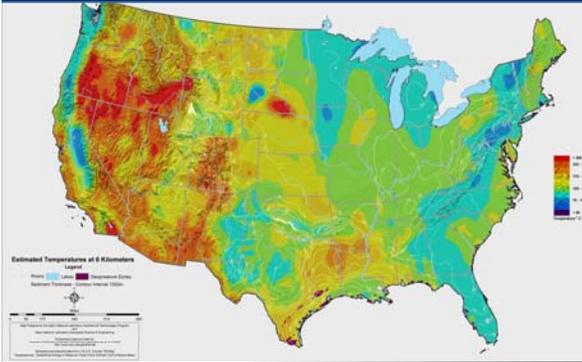
Mission	Lower the cost of electricity and reduce the upfront risk of exploration to establish geothermal energy as a significant contributor to America's future electricity generation.	Vision	<p><b>By 2020, lower the cost of electricity and reduce the upfront cost of electricity to:</b></p> <ul style="list-style-type: none"> <li>▪ Assist in reaching installed capacity of 12 GWe – a fourfold gain from 2010</li> <li>▪ Expand geothermal energy into new regions across the U.S., spurring the economy and creating high-quality green jobs nationwide.</li> </ul>
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Barriers	Approach
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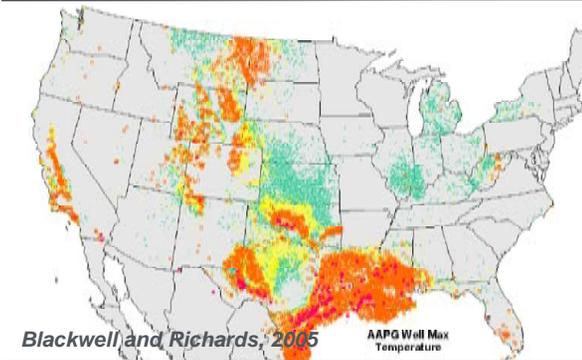
Low Temperature and Coproduced Resources	
<ul style="list-style-type: none"> <li>• Industry lacks experience and knowledge.</li> <li>• Current power conversion technology is relatively inefficient in lower temperature ranges.</li> </ul>	<ul style="list-style-type: none"> <li>• Advance working fluids, air cooling and high-performance heat exchangers.</li> <li>• Demonstrate revolutionary technology to lower costs and spur industry buy-in.</li> </ul>
Innovative Exploration Technologies	
<ul style="list-style-type: none"> <li>• The high cost and risk of exploration drilling hampers industry growth.</li> </ul>	<ul style="list-style-type: none"> <li>• Improve technologies, such as 3D seismic and remote sensing, to lower upfront risk and locate undiscovered hydrothermal resources.</li> <li>• Validate new technologies to better understand well characteristics at depth without drilling.</li> </ul>
EGS	
<ul style="list-style-type: none"> <li>• Induced seismicity must be understood as a tool and a potential hazard; effective mitigation measures must be developed.</li> <li>• Reservoirs must be engineered so that flow rates remain high while thermal drawdown is limited.</li> <li>• Inter-well connectivity is critical yet difficult to demonstrate.</li> </ul>	<ul style="list-style-type: none"> <li>• Develop tools and models that better characterize fractures and fracture networks.</li> <li>• Advance high-temperature and high-pressure tools, sensors and equipment.</li> <li>• Gain public support through experience and better scientific understanding of induced seismicity.</li> </ul>
Cross-cutting	
<ul style="list-style-type: none"> <li>• Industry and policy-makers lack publically available, consistent and reliable geothermal data.</li> <li>• There is a need to train and maintain the next generation's workforce.</li> </ul>	<ul style="list-style-type: none"> <li>• Assess and classify resources in all 50 states.</li> <li>• Educate students and train a skilled a new generation of geothermal workers.</li> <li>• Collaborate with domestic (e.g., USGS, BLM) and international agencies.</li> </ul>

# Low Temperature and Coproduced Resources Subprogram

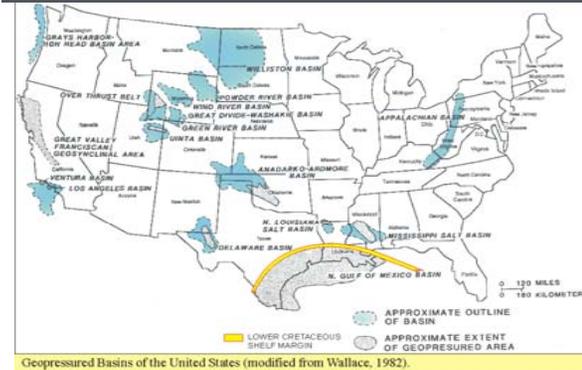
This subprogram aims to reduce costs of low temperature and coproduced resources and enable 3 GW by 2020.



**Low temperature** geothermal resources are more widely distributed than conventional hydrothermal resources, spreading into the upper Midwest and gulf coast region.



In **coproduction**, hot water is a by-product of oil and gas wells. The quality of the resource depends on the amount of water produced and the temperature. See left for oil and gas well locations and temperatures (red are the hottest, followed by orange, yellow and green).



**Geopressured** wells are primarily located in the Gulf region, in the lower cretaceous shelf margin (see yellow band in the map at left).

## Key Elements

These resources include:

- Low temperature (under 150° C) hydrothermal
- Resources coproduced with oil or gas
- From geopressured wells

## Opportunity

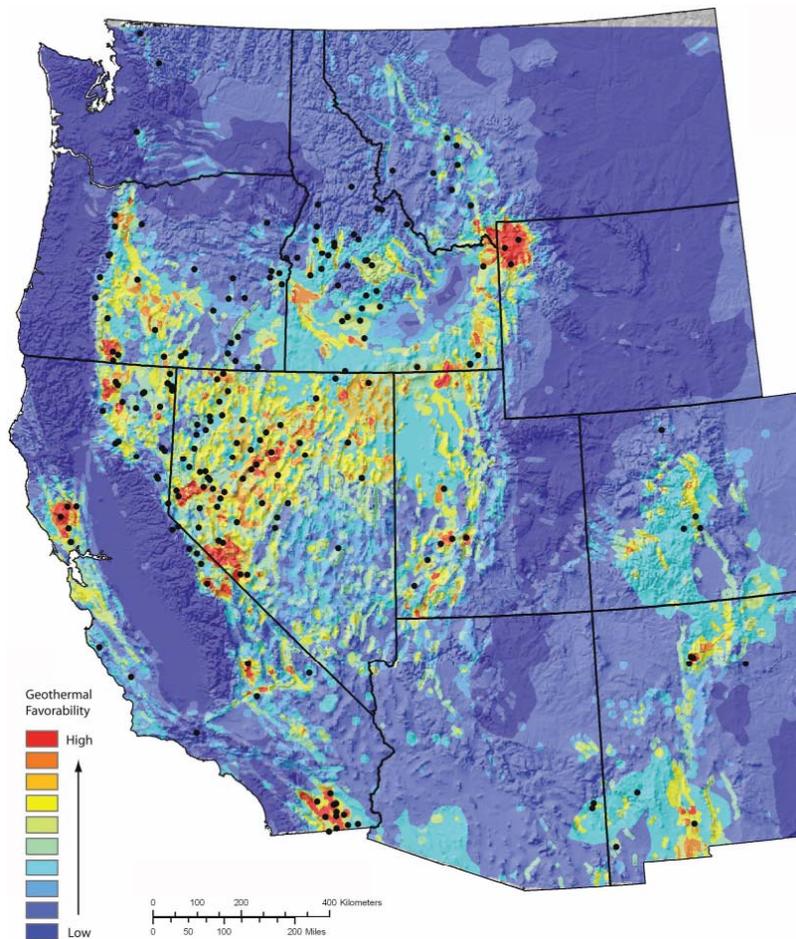
These largely untapped resources can open up new geographic areas to geothermal development and bring more MW online in the near-term.

## Challenges

High LCOE, coupled with relative inefficiency of current technology in lower temp regimes, prevents industry buy-in.

# Innovative Exploration Technologies (IET)

Improving exploration tools will lower the costs and risks associated with confirming the undiscovered resources and will contribute to the geothermal resource available for development.



## Key Elements

- Improving tools such as remote sensing, seismic and geothermometers will help geothermal developers locate and confirm geothermal resources

## Opportunity

- The USGS estimates there is a mean of 30 GWe of undiscovered hydrothermal in the 13 western states
- Once confirmed, these resources can be brought online with existing technologies
- Tools developed can be used for other geothermal resources to manage the resource and optimize power production

## Challenges

- The exploration phase of geothermal development is extremely costly and high risk
- Some resources show no surface expression, making them difficult to confirm

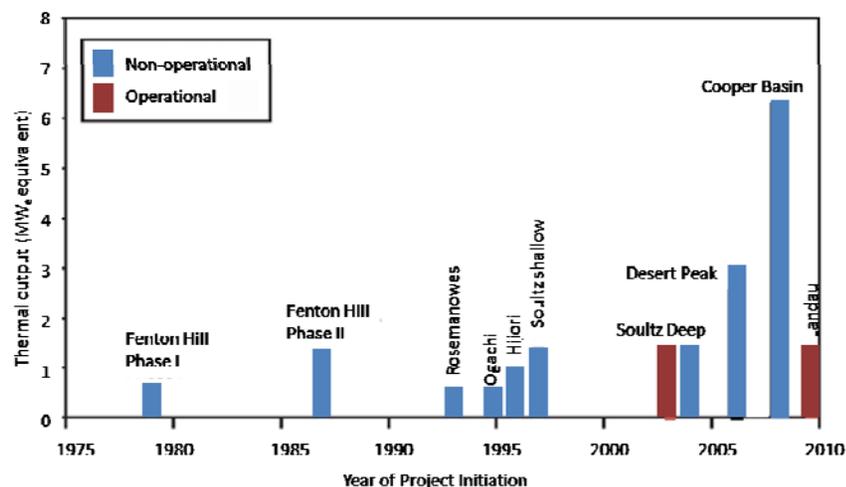
By 2020 add 1 GWe of hydrothermal capacity confirmed using innovative exploration technologies

# Enhanced Geothermal Systems

Goal: Demonstrate the ability to create an EGS reservoir capable of producing 5 MWe by 2020

## Global Status

Worldwide Attempt at EGS Projects



## GTP Demonstration Projects

Recipient	Project Sites	Status
Ormat Technologies, Inc. (\$4.3M)	Desert Peak, Nevada	Stimulation Phase 3-chemical stimulation
Geysers Power Company, LLC (\$5.7M)	The Geysers, California	Drilling complete, installing infrastructure, discovered the hottest well in US (~750°F)
University of Utah (\$8.9M)	Raft River, Idaho	Induced Seismicity report draft under review
Ormat Technologies, Inc (\$3.4)	Bradys Hot Springs, Nevada	Building geologic and structural 3-D model
AltaRock Energy Inc. (\$21.4M)	Newberry Volcano, Oregon	Completing EA
TGP Development Co. (\$10.4M)	New York Canyon, Nevada	Waiting for FONSI from DOE
NakNek Electric (\$12.4M)	NakNek, Alaska	Financial difficulties; cleaning and logging next month

## Technical Barriers and Needs

- Interwell connectivity
- Reservoir creation – fracturing
- Sustain reservoir flow rate
- Defined and controlled reservoir boundaries
- Fracture stimulation modeling
- Excessive well construction time (e.g. drilling and casing) & material cost (trouble costs high @ 4X hydrothermal)
- Environmental issues including seismicity and water use

## Supported by R&D Activities

- Temperature-hardened submersible pumps
- Induced Seismicity
- Zonal isolation tools
- Monitoring (smart tracers), and logging tools
- Coupled models to predict reservoir developments and performance

## Game Changing Breakthroughs

- Advanced drilling techniques (e.g. spallation) to reach 3 to 5x current speed through hard geothermal rock
- Validation of CO<sub>2</sub> as a working fluid

EGS barriers are common across all geothermal resources

# EGS Subprogram Goals

This subprogram aims to demonstrate the ability to create an EGS reservoir capable of producing 5MW by 2020 and sustain a 5 MW EGS reservoir for 5 years by 2025.

- **Reduce high level of risk** during early stages of EGS development
- **Resolve** key component R&D challenges
- **Demonstrate** the ability to create an EGS reservoir capable of producing 5 MW by 2020
- **Sustain** a 5 MW reservoir for 5 years by 2025
- **Demonstrate and validate** stimulation techniques that sustain fluid flow and heat extraction rates.
  - **Validate EGS** reservoir creation through demonstration projects in a variety of geologic environments
  - **Optimize** reservoir flow rates and thermal drawdown to enable long-term, economical energy production



Through the SBIR/STTR programs, the Program supports small businesses and invests in technologies to advance geothermal.

## Small Business Innovation Research (SBIR) Program and the Small Business Technology Transfer (STTR)

Administered by the U.S. Small Business Administration (SBA) Office of Technology to ensure that the nation's small, high-tech, innovative businesses are a significant part of the federal government's research and development efforts.

In FY 2010, the Geothermal Technologies Program contributed \$786,000 to the SBIR program and \$94,000 to the STTR program for geothermal projects.

<b>Phase I</b>	Advanced Cooling Technologies, Inc.	Vortex Enhanced Direct Contact Heat Exchanger for Geothermal Cooling
	HiFunda, LLC	High-Reliability Cements for Enhanced Geothermal Systems
	NanoSonic, Inc	High Performance Hybrid Polyorganosiloxane Cements for Enhanced Geothermal
	United Silicon Carbide, Inc.	High Temperature Smart Sensor for Downhole Logging and Monitoring
	Weston Geophysical Corp.	Improved Time-Dependent Seismic Monitoring Systems for Enhanced Geothermal Reservoir Characterization
<b>Phase II</b>	MagiQ Technologies	Seismic Sensor
	Physical Optics Corporation	Fiber Optic High Temperature Seismic Sensor
<b>Phase III</b>	Composite Technology Development, Inc.	Improved High-Temperature ESP Motor Lead Extension Cables for Reliable Geothermal Power Production

The Program addresses induced seismicity by establishing and updating clear protocols and best practices, performing R&D, and collaborating both domestically and internationally to build a strong knowledge base.

## Policies

- Instituted interim DOE policy for EGS demonstration projects
- Require seismic instrumentation and monitoring of all EGS sites

## Deliverables and Events

- Feb 2010 Workshop: Research & Technical Needs
- June 2010 Workshop: Induced Seismicity Protocol Review
- Developing Best Practices for EGS

## Collaborations

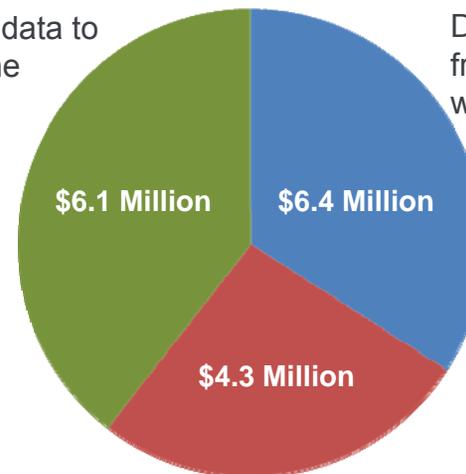
- Leading update of IEA-GIA Induced Seismicity Protocol
- Initiating IPGT working group to collaborate on Induced Seismicity R&D with Australia, Iceland and Switzerland
- Participation in European Commission's GEISER Induced Seismicity Workshops
- Participating in interagency effort for comprehensive NAS study

## FRACTURE CHARACTERIZATION (7 Projects, 2008-2013)

Using microseismic data to better understand the characteristics of reservoir fractures.

## STIMULATION PREDICTION MODELS (6 Projects, 2008-2013)

Developing models to predict fracture patterns and fluid flow within the engineered reservoir.



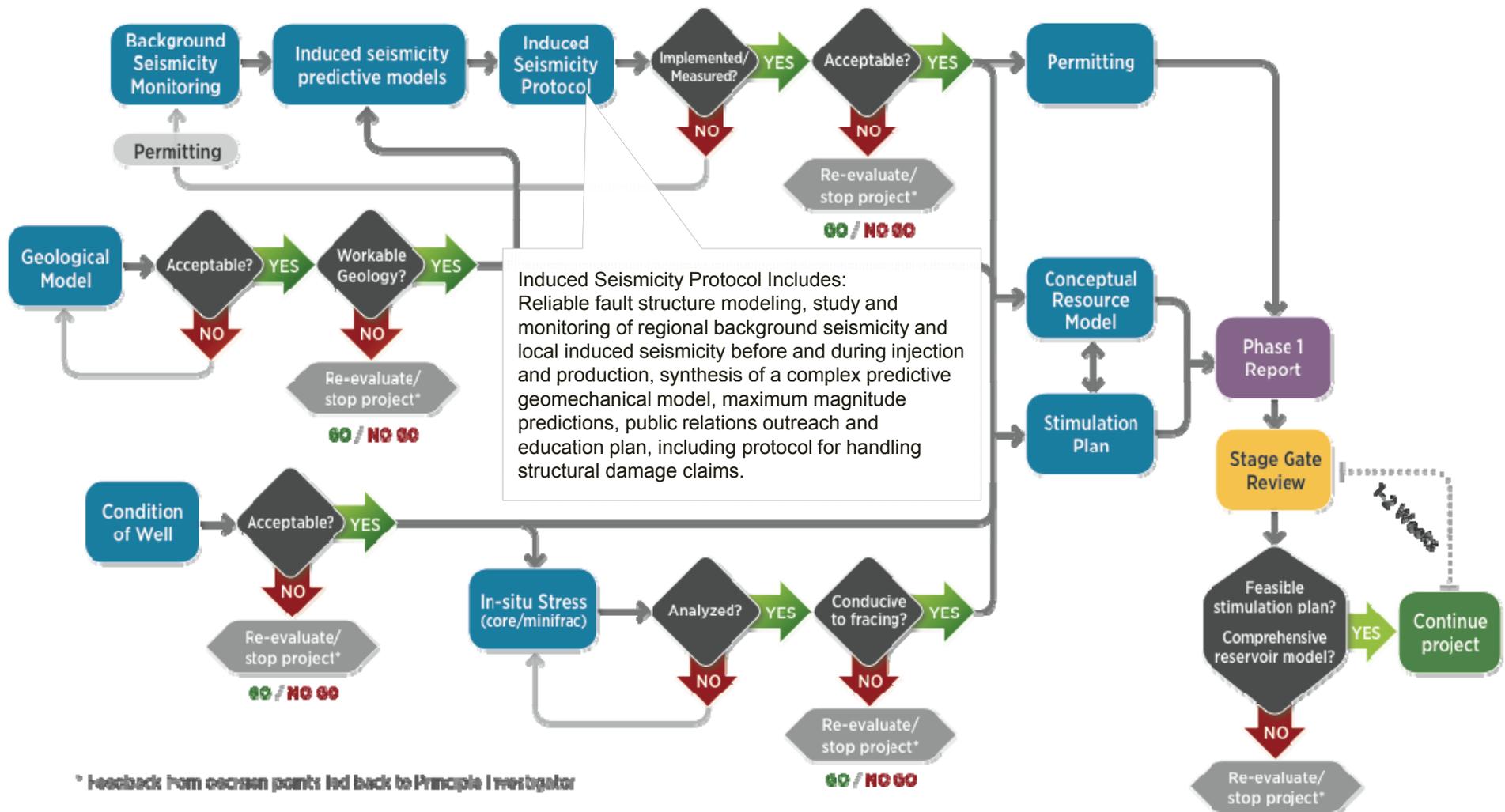
## INDUCED SEISMICITY (4 Projects, 2010-2013)

Developing more accurate methods of locating and evaluating microseismic activity associated with reservoir creation.

Total funding for Induced Seismicity Projects - \$18.8\* M, including \$2M in funds for EGS demo monitoring and other IS activities at Lawrence Berkeley National Lab.

# EGS Demonstration Induced Seismicity Stage Gate

DOE-funded EGS demonstration projects must comply with a series of technical stages gates, including compliance with the induced seismicity protocol.



The Systems Analysis subprogram answers important questions to reduce barriers to geothermal development.

## What is the supply potential?

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- Coproduced
- Low Temperature
- Geopressured
- Hydrothermal: Estimated 6 GW identified, 30 GW undiscovered
- EGS: Estimated 16,000 GW

## How do we reduce the upfront risk of development?

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- Develop National Geothermal Data System linking high-quality data sets. See [www.geothermaldata.org](http://www.geothermaldata.org)
- Populate data by linking to high quality data sets in partnership with all state geological surveys, Southern Methodist University and all awardees.
- Evaluate and share exploration best practices

## What is new?

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- Geothermal Vision Study

## How do we describe the resource?

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- In partnership with USGS, DOE is developing a geothermal resource assessment and classification.

## What are the costs?

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- INL's Geothermal Electricity Technologies Evaluation Model (GETEM) analyzes cost and performance of geothermal projects

## What are the environmental impacts?

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- ANL is performing lifecycle analysis, including evaluating greenhouse gas emissions and water use

The ARPA-E program makes investments in pre-commercial, high-impact technologies.

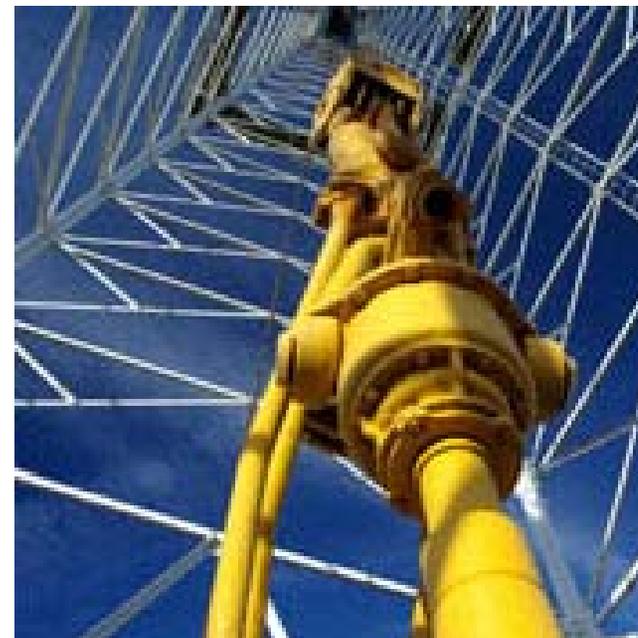
## Advanced Research Projects Agency – Energy (ARPA-E)

Administered by the DOE to develop transformational technologies to:

- Reduce dependence on foreign energy imports;
- Reduce emissions (including greenhouse gasses);
- Improve energy efficiency and
- Improve U.S. leadership in developing and deploying advanced energy technologies

## Foro Energy Hybrid Thermal-Mechanical Drilling Technology

- Geothermal energy project funded in 2009
- \$9,141,300 to further low-contact drilling technology
- Goal of project to enable more economical EGS wells
- Expected to allow for rapid and sustained penetration of ultra-hard rock formations



# Loan Guarantee Program

The DOE's loan guarantee program provides loans to a variety of electricity generation projects. To date, over \$180 million has been awarded/conditionally awarded to two geothermal projects, both under section 1705.

- The Loan Guarantee Program addresses the high cost and difficulty securing financing when deploying new energy projects, both for innovative and commercial technologies.
- Under **1703**, Congress appropriated \$51.0B from FY 2007 and FY 2009 for **innovative** renewable energy generation and manufacturing, bio fuels and transmission. Applications accepted on a rolling basis until December 2010, or until funds are no longer available. Applicants are responsible for providing the credit subsidy.
- Under ARRA (**1705**), an additional \$48.6B was appropriated for **conventional** renewable energy systems and electric power transmission. Includes \$4B for credit subsidy. Construction must begin by September 30, 2011.
- Two geothermal projects have been selected for loan guarantees:



Nevada Geothermal Power Company: \$78.8M (closed)  
Awarded September, 2010  
49.5 MW power plant in Nevada



US Geothermal, Inc: \$102.2M (conditional)  
Awarded June, 2010  
22 MW power plant in Oregon

# Grant in Lieu of Tax Credit

Under this program, the Treasury can make direct payments in lieu of tax credits to companies that create and place in service renewable energy facilities. As of December, 2010, \$262.9M has been awarded to geothermal projects.

- Under ARRA (section 1603) the Treasury can make grants to renewable energy facilities in lieu of Investment Tax Credits (ITC) or Production Tax Credits (PTC). Geothermal facilities can apply for awards of 10-30% of eligible costs.
- Under Section 707 of the Tax Relief, Unemployment Insurance Reauthorization and Job Creation Act of 2010, this program was extended to projects placed in service after 2011 but only if construction of the property began during 2009, 2010 or 2011.
- Applications are accepted on a rolling basis, with a final deadline of October 12, 2012.
- State, Federal and local governments as well as tax-exempt applicants are not eligible.

## Awards under 1603 as of December 20, 2010

NGP Blue Mountain	NV	\$	57,872,513.00
Enel Salt Wells, LLC	NV	\$	21,196,478.00
Enel Stillwater, LLC	NV	\$	40,324,394.00
Geysers Power Company	CA	\$	2,224,148.00
ORNI 18	CA	\$	108,285,626.00
Thermo No. 1	UT	\$	32,990,089.00
<b>Total</b>			<b>\$262,893,248.00</b>



From <http://www.ustreas.gov/recovery/1603.shtml>

The IET Roadmap addresses the question: How can we advance geothermal exploration technologies to significantly lower exploration risk and cost?

## Examined five technology areas:

1. Geology
2. Geophysics
3. Geochemistry
4. Remote sensing
5. Cross cutting



## Identified nine technology solutions:

1. Next-generation geophysical air borne data
2. Multi-physics models
3. Improved thermodynamic data
4. Development of advanced geothermometers
5. Stress/strain data mapping
6. High resolution remote sensing data and reliable automated processing methods
7. 3-Dimensional modeling techniques (software)
8. Multi-disciplinary conceptual models
9. Create case study examples of geothermal systems in different settings

**Draft published for  
comments February 4, 2010  
on the GTP webpage:**

[http://www1.eere.energy.gov/geothermal/pdfs/iet\\_needs\\_assessment\\_draft.pdf](http://www1.eere.energy.gov/geothermal/pdfs/iet_needs_assessment_draft.pdf)

# Joint Carbon Sequestration & Geothermal Energy Workshop

In June 2010, GTP and the Office of Fossil Energy participated in a workshop to identify geosciences research themes common to both CS and Geothermal Energy and expand the stakeholder community to accelerate progress in critical research areas.

Process: DOE's Office of Fossil Energy, Energy Efficiency and Renewable Energy, and Office of Science funded a two day workshop with three breakouts:

- Subsurface characterization and development
- Reservoir management challenges, particularly in geomechanics and geochemistry
- Science needs for predictive modeling

Results: Example areas with high value for collaboration across programs

- Developing screening criteria based on better regional characterization data
- Determining what level of site characterization prior to ground breaking is crucial, and what can be gathered via monitoring after development period has begun.
- Improved understanding of fundamental and coupled processes (especially geochemical reactions and multiphase flow of water-CO<sub>2</sub>) and their incorporation into reservoir models
- Characterizing heterogeneity, quantifying uncertainty, and risk (e.g. seismic and containment)

Deliverable:

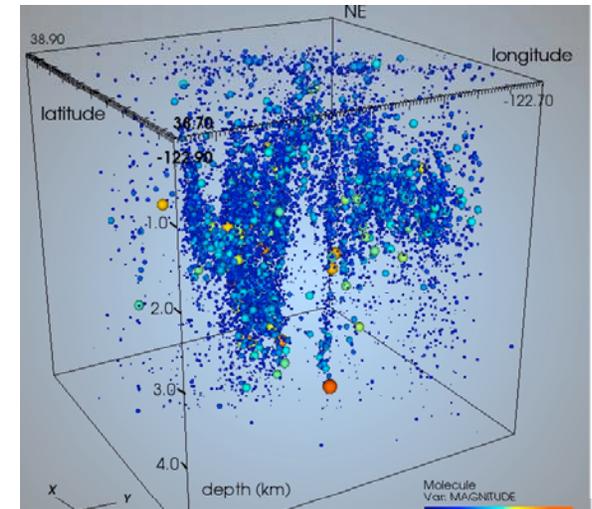
Electronic publication of the report by March, 2011

# EGS Induced Seismicity Roadmap

An Induced Seismicity Roadmap for the EGS Subprogram is in progress and will be published by April, 2010.

## Process:

- Convene several workshops to engage experts in industry, government, academia and national laboratories.
- Final workshop with a small, focused group to:
- Capitalize on previous workshops and expert judgment to reach agreement upon an overall strategic framework for the IS Roadmap.
- Write draft IS Roadmap including vision, mission, program elements and crucial research themes.
- Next steps: focused workshop review, GTP final review, available to stakeholders.



## Results:

- Focused IS workshop held October 2010
- First draft written from workshop notes completed, December 2010
- Major GTP edit completed January 2011

**Deliverable:** Electronic publication of the report by April, 2011