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Geothermal Power in the U.S. and DOE's Program Activities

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Agenda

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

- How geothermal works
- Geothermal development in the U.S.
- DOE program history
- Resource potential
- DOE's R&D support by resource type

Enel Salt Wells - Courtesy of Enel Green Power – North America

What is a Geothermal Resource?

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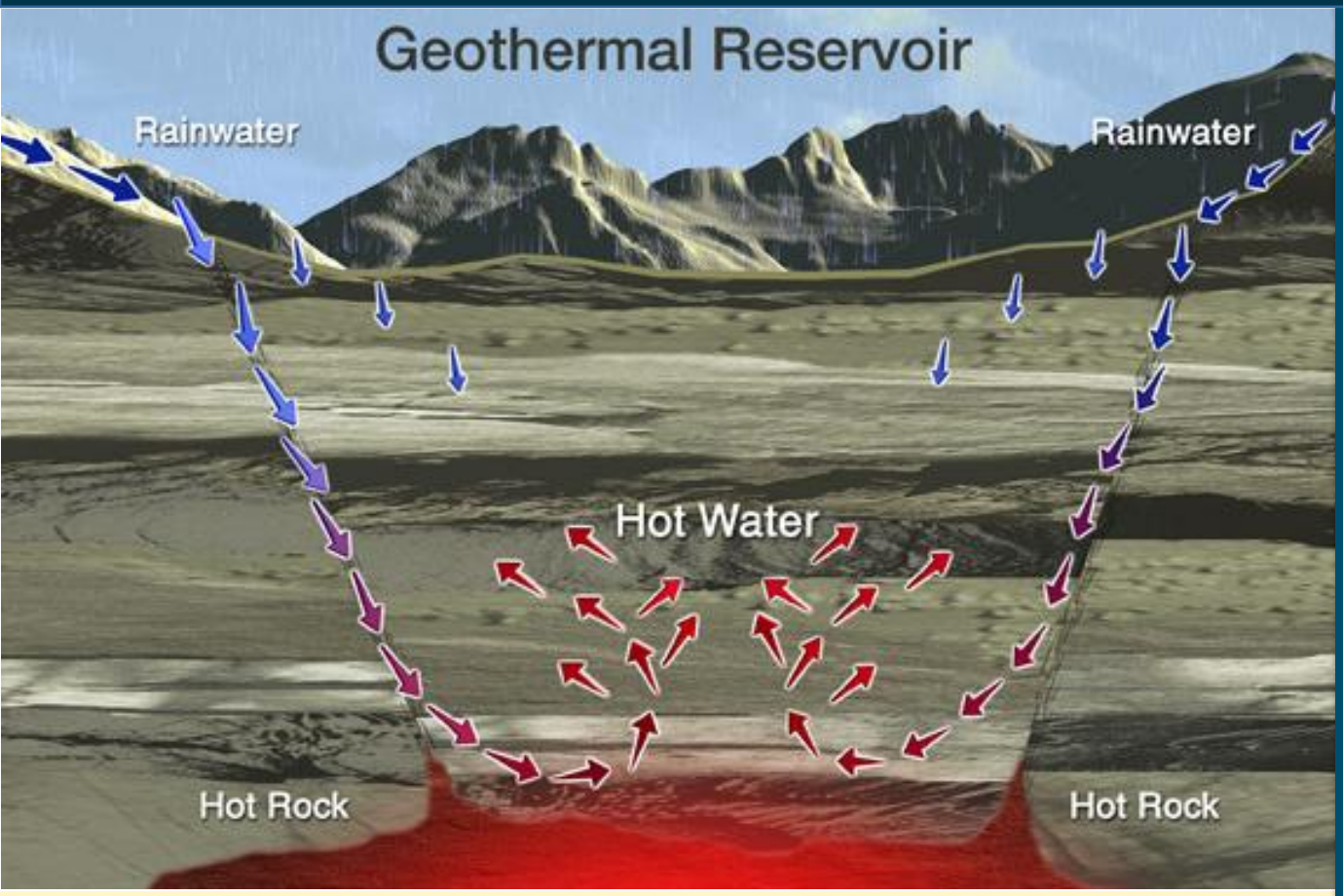
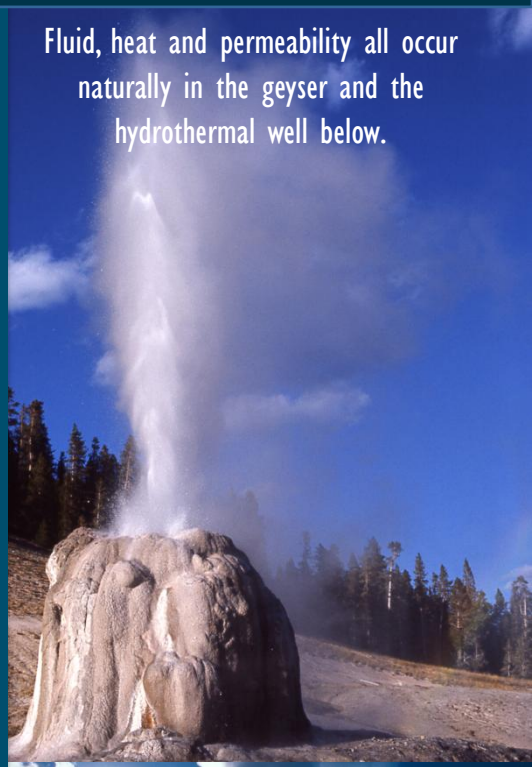
A geothermal resource requires *fluid*, *heat* and *permeability*. Some resources contain all three elements naturally.



Fluid, heat and permeability all occur naturally in the geyser and the hydrothermal well below.



1. *FLUID:* Sufficient fluid must exist naturally or be pumped into the reservoir

2. *HEAT:* The earth's temperature naturally increases with depth & varies based on geographic location

3. *PERMEABILITY*: In order to access heat, the fluid must come into contact with the heated rock, either via natural fractures or through stimulating the rock

How is Electricity Generated?

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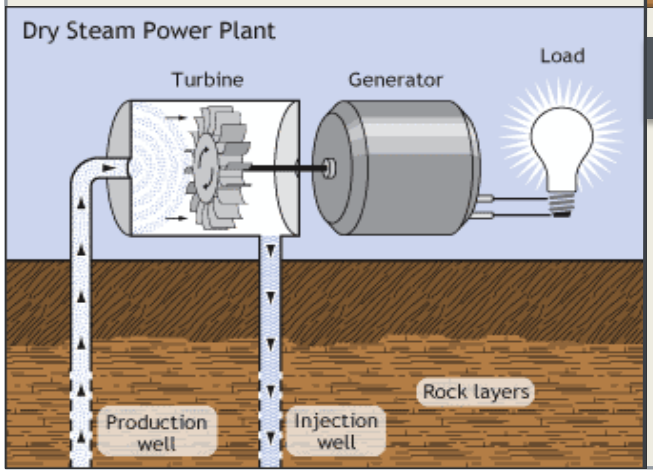
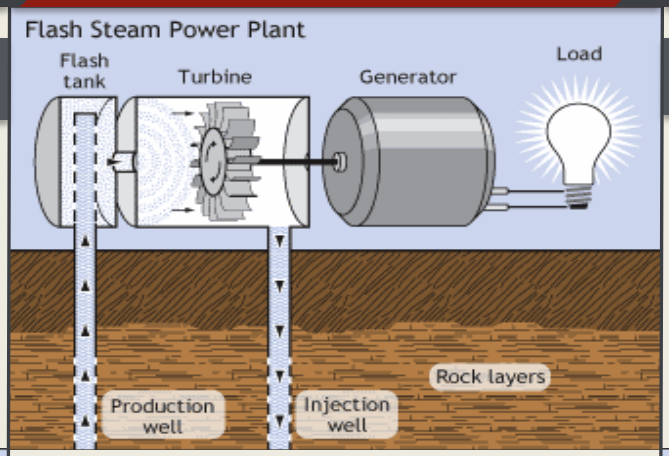
There are three common types of geothermal power plants – *dry steam*, *flash* and *binary*. The type selected in development depends on the type of geothermal resource.

HIGH | HIGH - MODERATE | MODERATE - LOW

DRY STEAM

Steam from the geothermal source travels directly to a turbine, which drives a generator that produces electricity



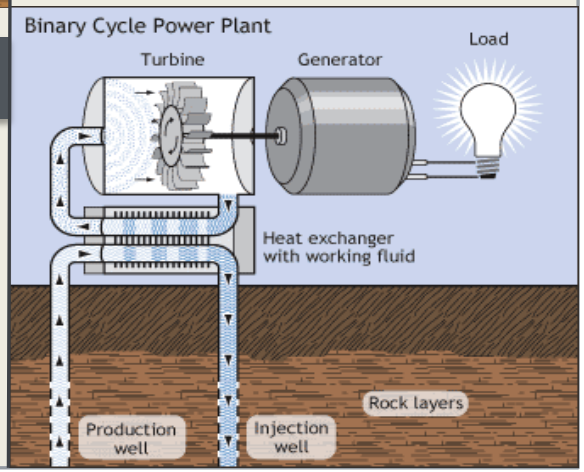


FLASH

Fluid (moderate to high temperatures) is sprayed into a tank held at a much lower pressure, causing some of the fluid to rapidly vaporize; the vapor then drives a turbine

BINARY

Fluid (low to moderate temperatures) passes through a heat exchanger with a secondary fluid with a much lower boiling point; the secondary fluid is then flashed.



Geothermal energy is ***baseload***, ***renewable***, ***domestic*** and ***reduces greenhouse gas emissions***.

The Advantages of Geothermal Energy:

Renewable

Through proper reservoir management, the rate of energy extraction can be balanced with a reservoir's natural heat recharge rate.

Clean

Consumes less water on average over the lifetime energy output than most conventional generation technologies.

Modern closed-loop geothermal power plants emit no greenhouse gases.

Domestic

U.S. geothermal resources can be harnessed for power production without importing fuel.

Baseload

Geothermal power plants produce electricity consistently- High capacity factor

Small Footprint

Geothermal power plants are compact; using less land per GWh than other energy resources

Geothermal in the United States

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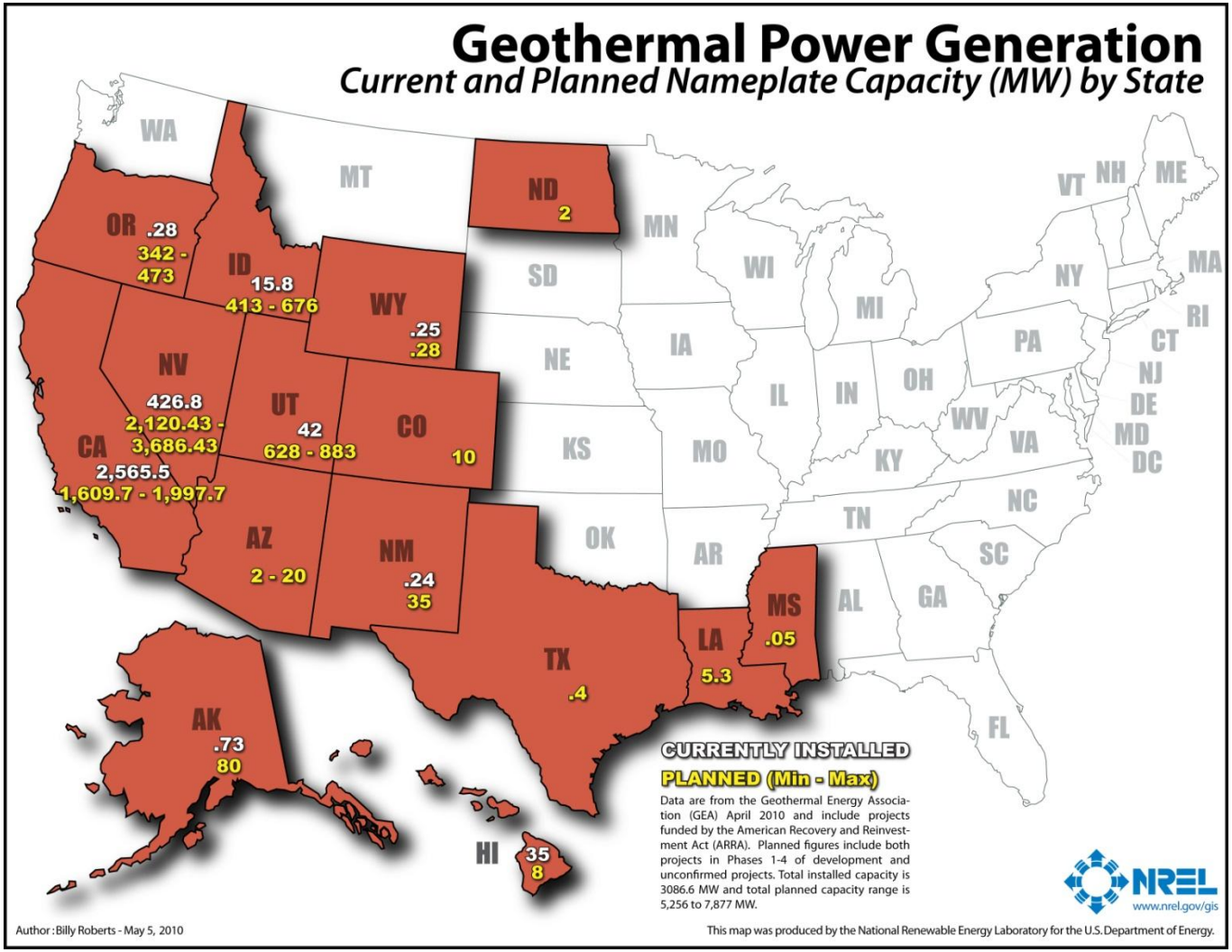
Currently there is approximately 3 GWe of installed geothermal (hydrothermal) in the US, with 98% in California and Nevada. There is 1.6 GWe in development, and geothermal is expanding into new geographic areas.



Geothermal Program History 1976-2012

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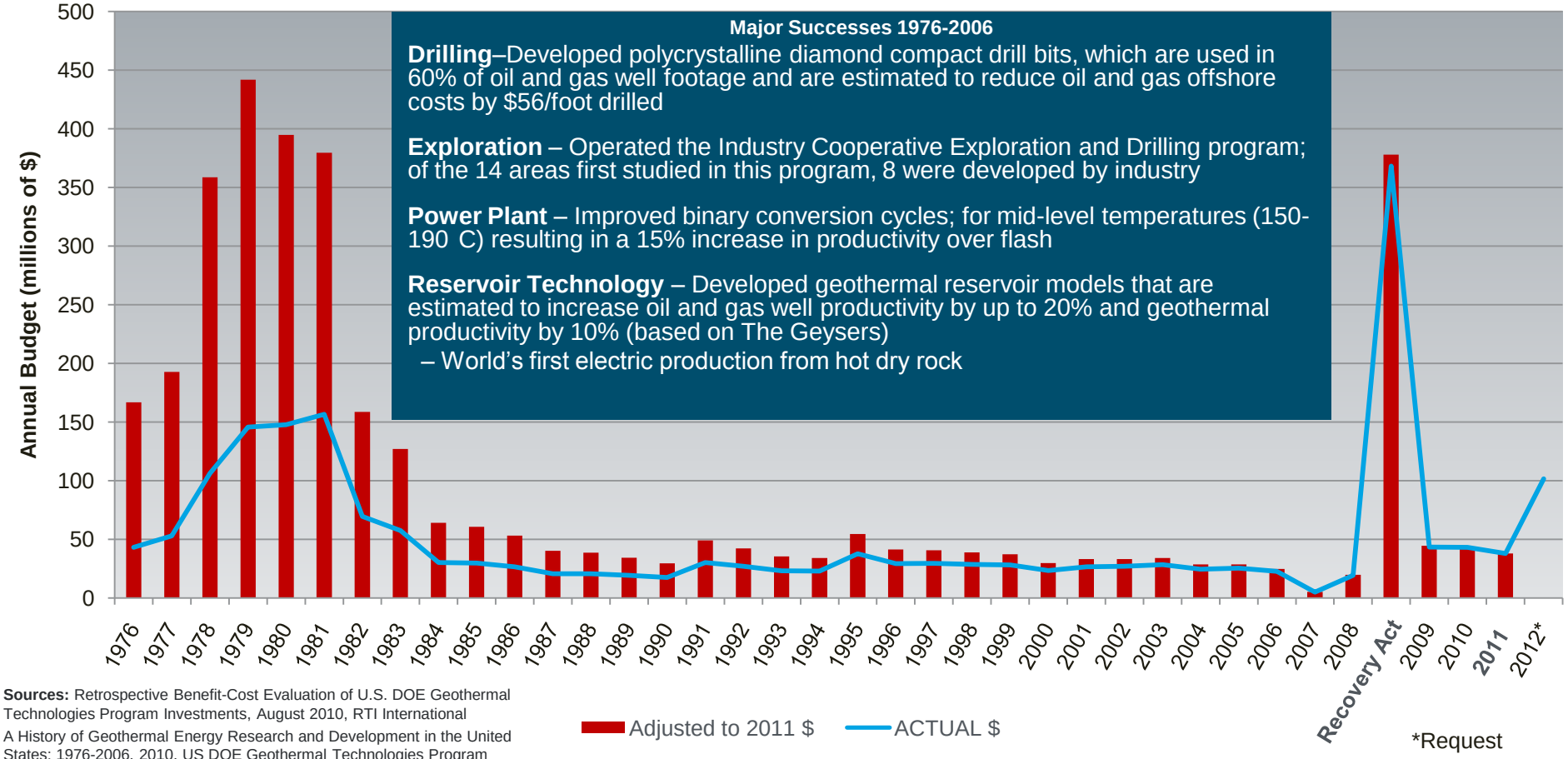
The Geothermal Technologies Program annual budget peaked in the late 1970s, enabling advances in drilling, exploration, power plant systems, and reservoir modeling. Recovery provided a big boost in 2009.

Annual Budget for the Geothermal Technologies Program 1976 - 2012



Major Successes 1976-2006

Drilling–Developed polycrystalline diamond compact 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

Exploration – Operated the Industry Cooperative Exploration and Drilling program; of the 14 areas first studied in this program, 8 were developed by industry

Power Plant – Improved binary conversion cycles; for mid-level temperatures (150-190 C) resulting in a 15% increase in productivity over flash

Reservoir Technology – Developed geothermal reservoir models that are estimated to increase oil and gas well productivity by up to 20% and geothermal productivity by 10% (based on The Geysers)
– World's first electric production from hot dry rock

*Request

Sources: Retrospective Benefit-Cost Evaluation of U.S. DOE Geothermal Technologies Program Investments, August 2010, RTI International

A History of Geothermal Energy Research and Development in the United States: 1976-2006, 2010, US DOE Geothermal Technologies Program

Geothermal ARRA Prime Awardees

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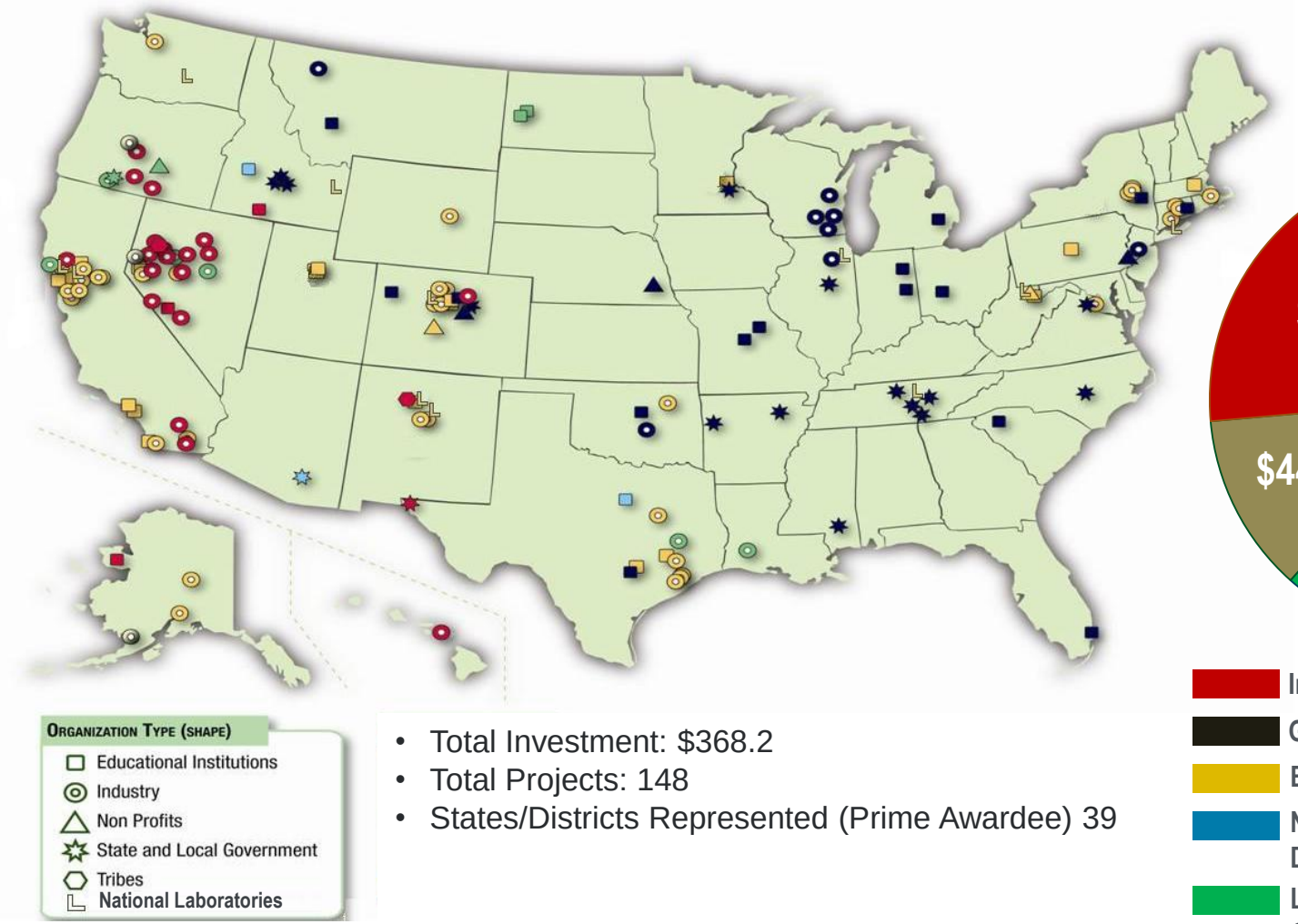
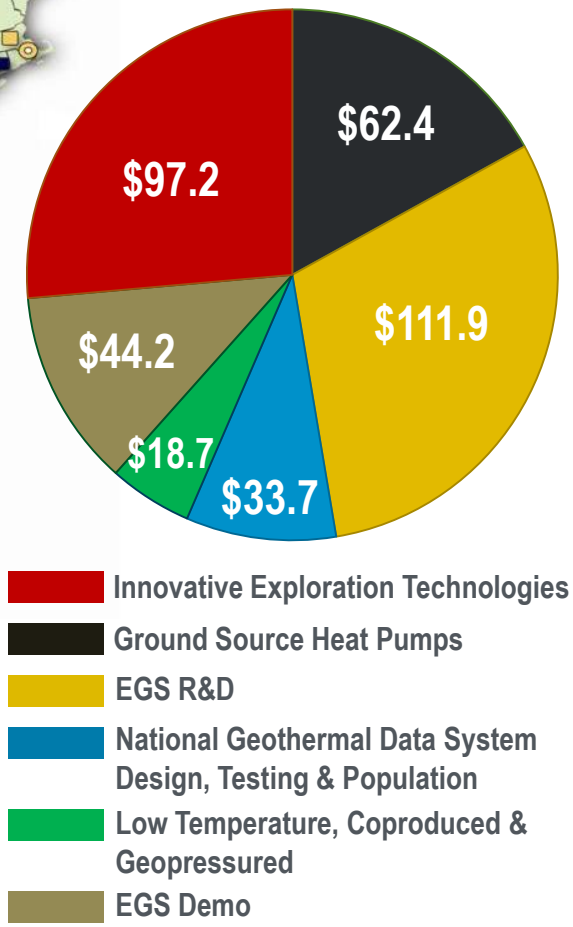
Under ARRA, $368.2 million was awarded to prime awardees in 39 states – demonstrating a national impact.



- Total Investment: $368.2
- Total Projects: 148
- States/Districts Represented (Prime Awardee) 39



Resource Types and Potential

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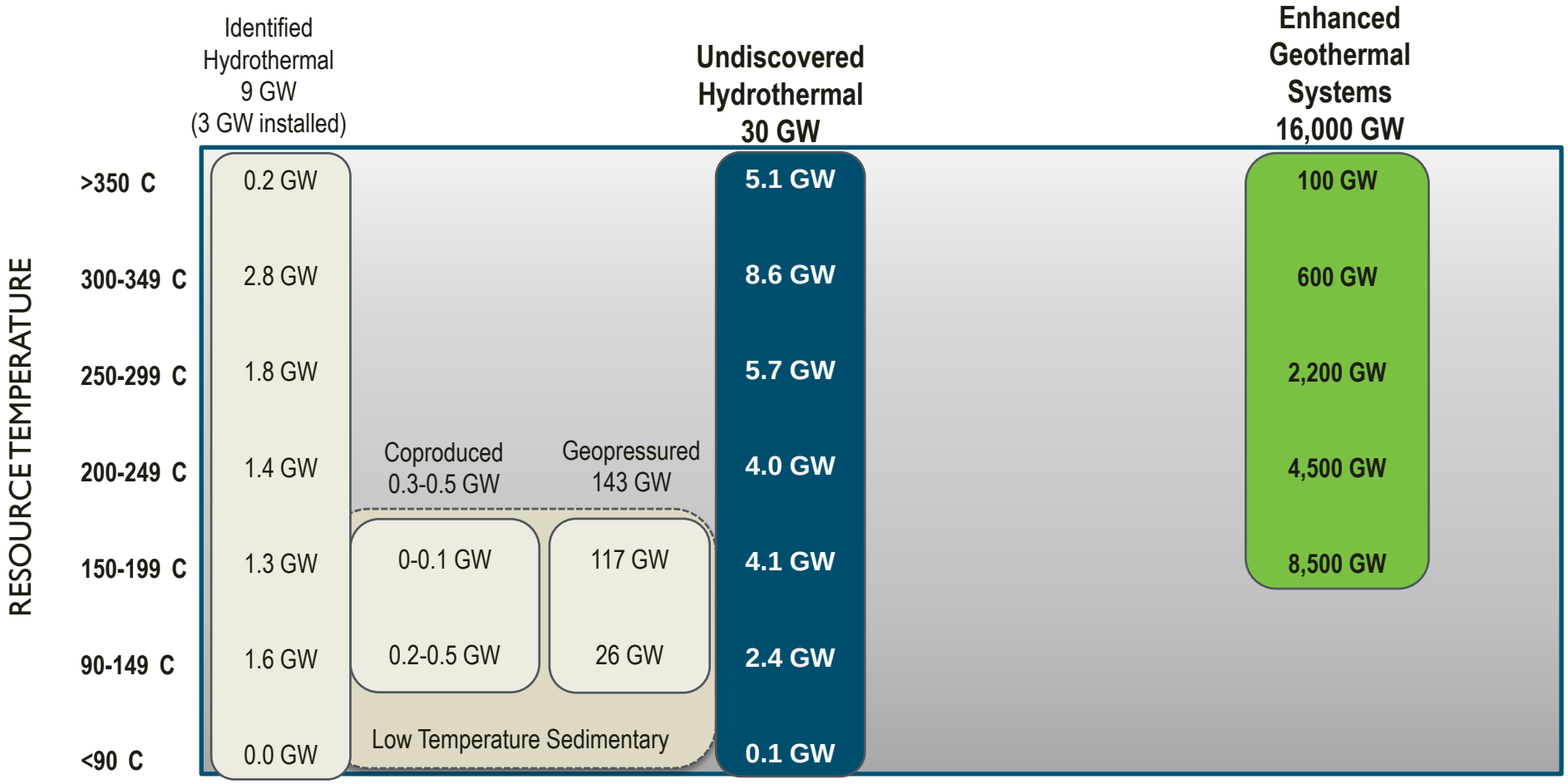
Moving forward, the Program will ***target undiscovered hydrothermal*** and ***enhanced geothermal systems*** (EGS): high-potential areas where technology improvements have the most impact. Generally, economic viability improves as temperature increases.



Hydrothermal Resources

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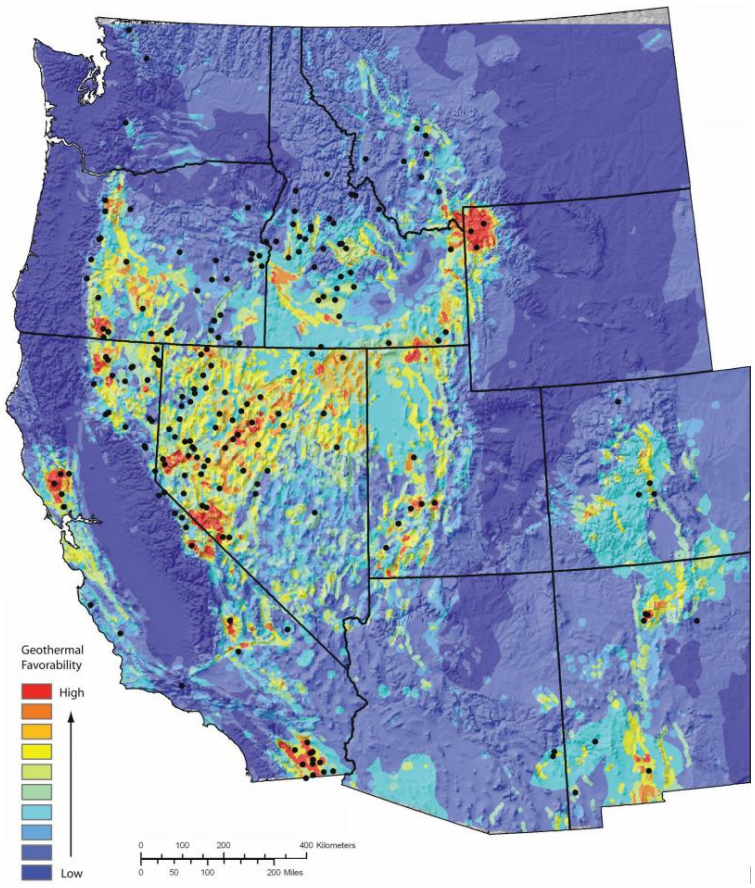
Technology development in exploration tools will ***lower the costs and risks*** associated with confirming the undiscovered resources and will contribute to the geothermal resource available for development.



Defined

- Hot, permeable, convective zones of rock at depth that contain fluid.
- Located in regions proximal to recent tectonic activity (plate boundaries, volcanoes, faults etc.) - e.g.. The western United States

Opportunity

- Currently ***3102 MW*** of geothermal power (from hydrothermal resources) in production in 9 states
- The USGS estimates there is a ***mean of 30 GWe of undiscovered hydrothermal*** in the 13 western states

Challenges

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

Technologies

- New technologies are under development to find hidden resources and to manage power production
    - e.g: Remote sensing, advanced seismic surveys, shallow temperature surveys, advanced drilling, geochemistry (see back-up slides for more information)

Undiscovered Hydrothermal and Innovative Exploration Technologies

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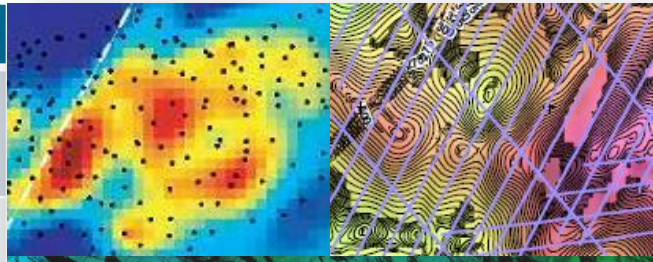
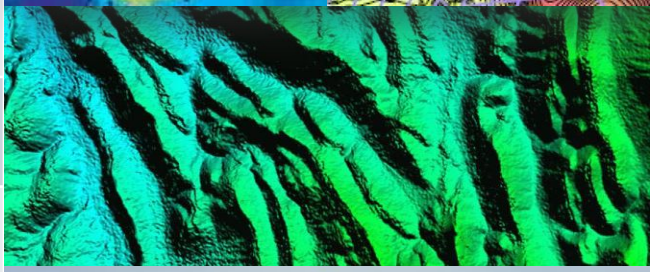
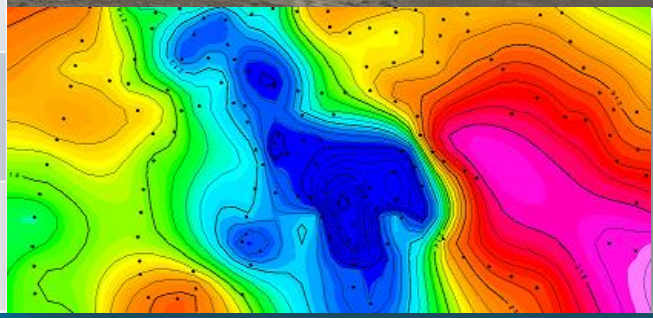
To identify ***undiscovered hydrothermal resources***, the Program is developing new exploration technologies.

Technology	Description
Remote Sensing	Data collected from air/space (LiDAR, InSAR) can be used to **identify surface indicators** of a geothermal resource for large or inaccessible areas
Seismic	A technique used in oil and gas exploration, analyzes **sound waves reflected from geologic features** to improve drilling success
Shallow Temperature Survey	Shallow (2m) temperature readings can be a **quick, cost effective** way to target potential geothermal resources
Stress/Strain Measurements	Mechanical relationships between stress and strain can be used to **predict the orientation of permeable faults** – valuable information when deciding where to drill
Tracers	Tracers can be used to gather data on the **thermal characteristics** of a resource
Drilling	Drilling is the most common method for exploration, but is high cost – these methods look at **improving techniques and reducing costs**
Geochemistry	Sub-soil gas, hydrocarbon, and isotope data can be used to **identify possible up-flow areas** - a simple and cost-effective method to target resources with no surface expression
New Combination of Technologies	Validating combinations of technologies (including those adapted from oil and gas) can **improve the overall exploration well success rate** for a variety of geologic formations

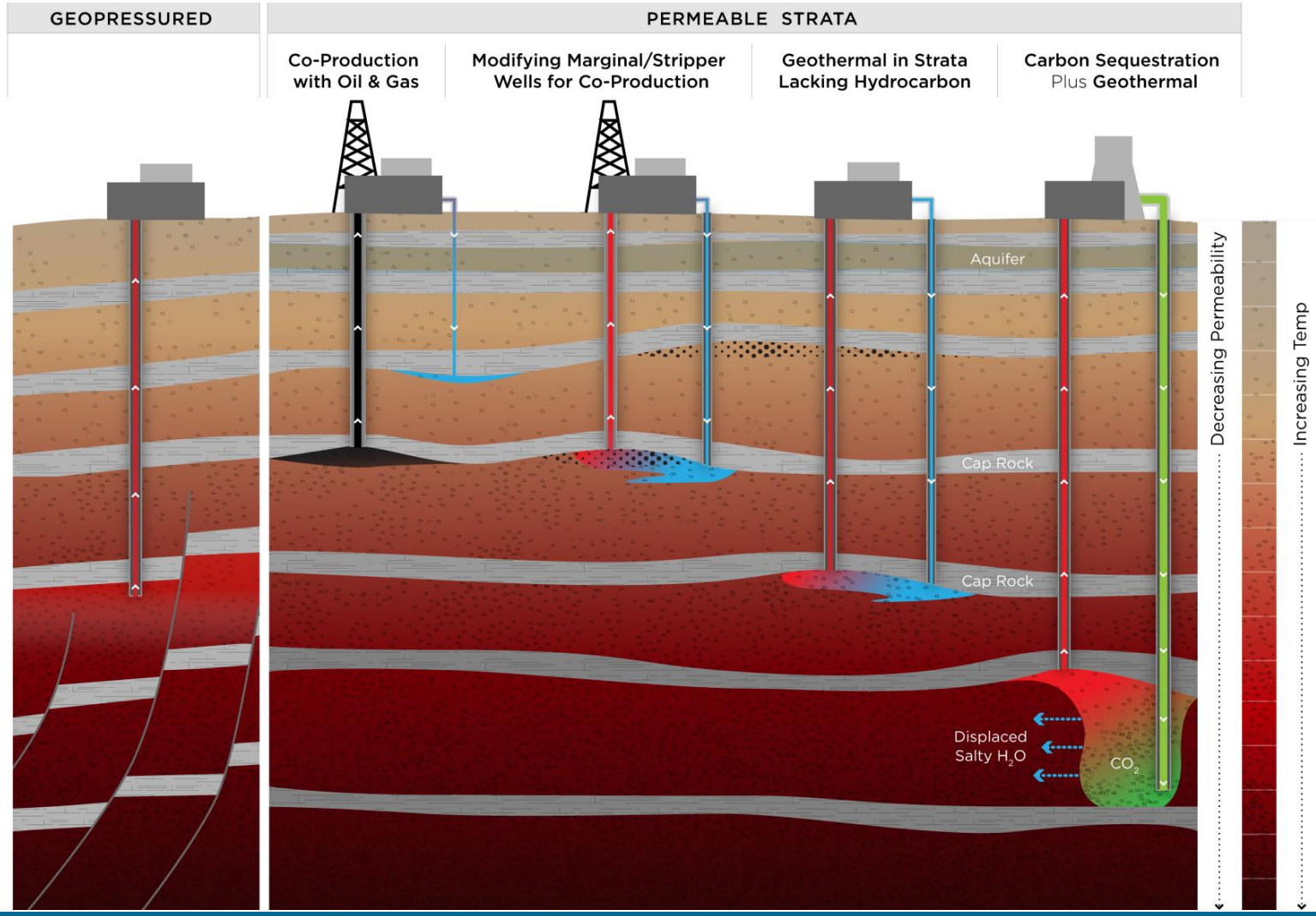






Other Geothermal Resources

In addition to conventional hydrothermal resources, power can be generated from ***low temperature*** , ***geopressured***, ***coproduced*** and other ***permeable sedimentary*** resources.



Low Temperature & Coproduced Resources

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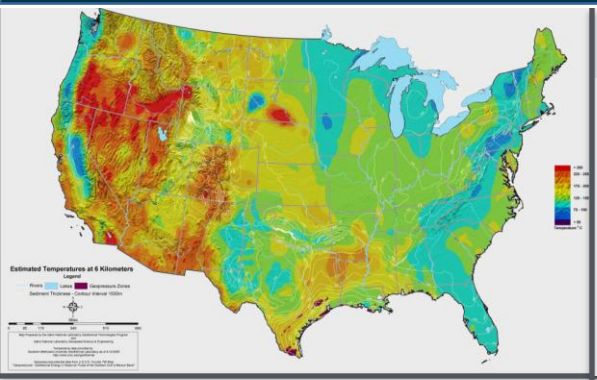
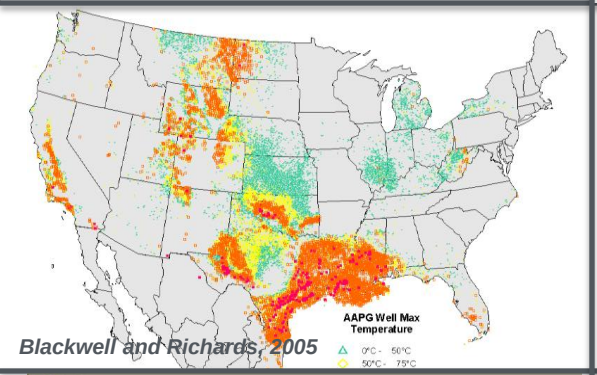
Low temperature, coproduced and geopressured resources are widespread, but have high costs.



Defined

Low temperature resources are hydrothermal resources with temperatures less than 150C.

- They more widely distributed than conventional hydrothermal resources, spreading into the upper Midwest and gulf coast region.

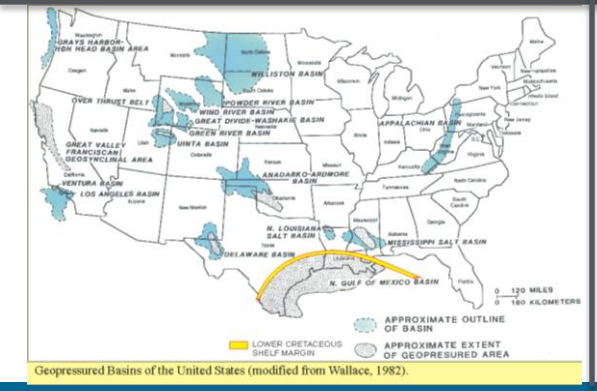


Blackwell and Richards, 2005

Coproduction uses hot water produced as a by-product of oil and gas production to generate electricity.

- The quality of the resource depends on the amount of water produced and the temperature.

Map shows oil and gas well locations and temperatures (red are the hottest, followed by orange, yellow and green).



Geopressured Basins of the United States (modified from Wallace, 1982).

Geopressured resources are reservoirs often associated with gas production that are under a significant amount of pressure.

- Primarily located in the Gulf region, in the lower cretaceous shelf margin (see yellow band on left).

Opportunity

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

Challenges

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

Technologies

- Advanced working fluids
- Cooling systems (air, hybrid)
- High performance heat exchangers
- Fluid reservoir modeling
- Advanced energy conversion systems

Permeable Sedimentary Resources

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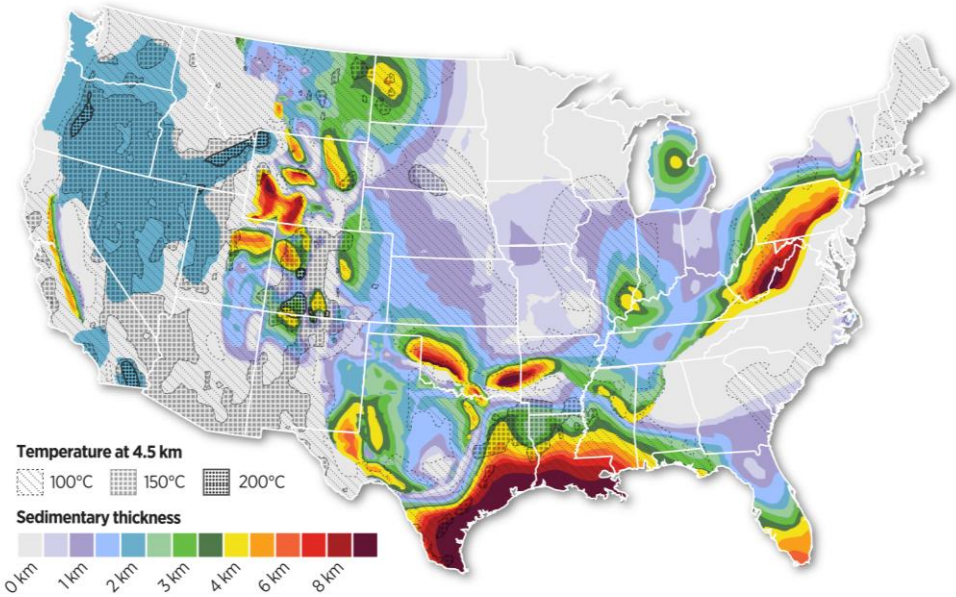
Permeable sedimentary resources are ***widespread*** and can be developed at ***low environmental*** and ***financial risk***.



Economic feasibility is a function of both flow rate and temperature. Generally, optimal flow rates are obtained in shallower sedimentary reservoirs. However, optimal temperatures are obtained at deeper depths.

Defined

- Like coproduction, these resources are located in sedimentary basins – they are relatively hot (<180C), have high permeability, and often contain in-situ fluids

Opportunity

- Can leverage oil and gas infrastructure and exploration data
- Stimulation is not required – lowering costs and risks from induced seismicity
- May be possible to conduct heat extraction in tandem with carbon capture and sequestration by using CO_2 as a working fluid

Challenges

- Controlling the boundary of a reservoir is necessary to prevent loss of geothermal fluid and ensure groundwater integrity

Technologies

- High temperature modifications of oil and gas technologies
- Working with very high flow rates of hot brine that may contain sand
- Controlling reservoir boundaries
- Understanding rock and fluid or CO_2 interactions

Enhanced Geothermal Systems (EGS)

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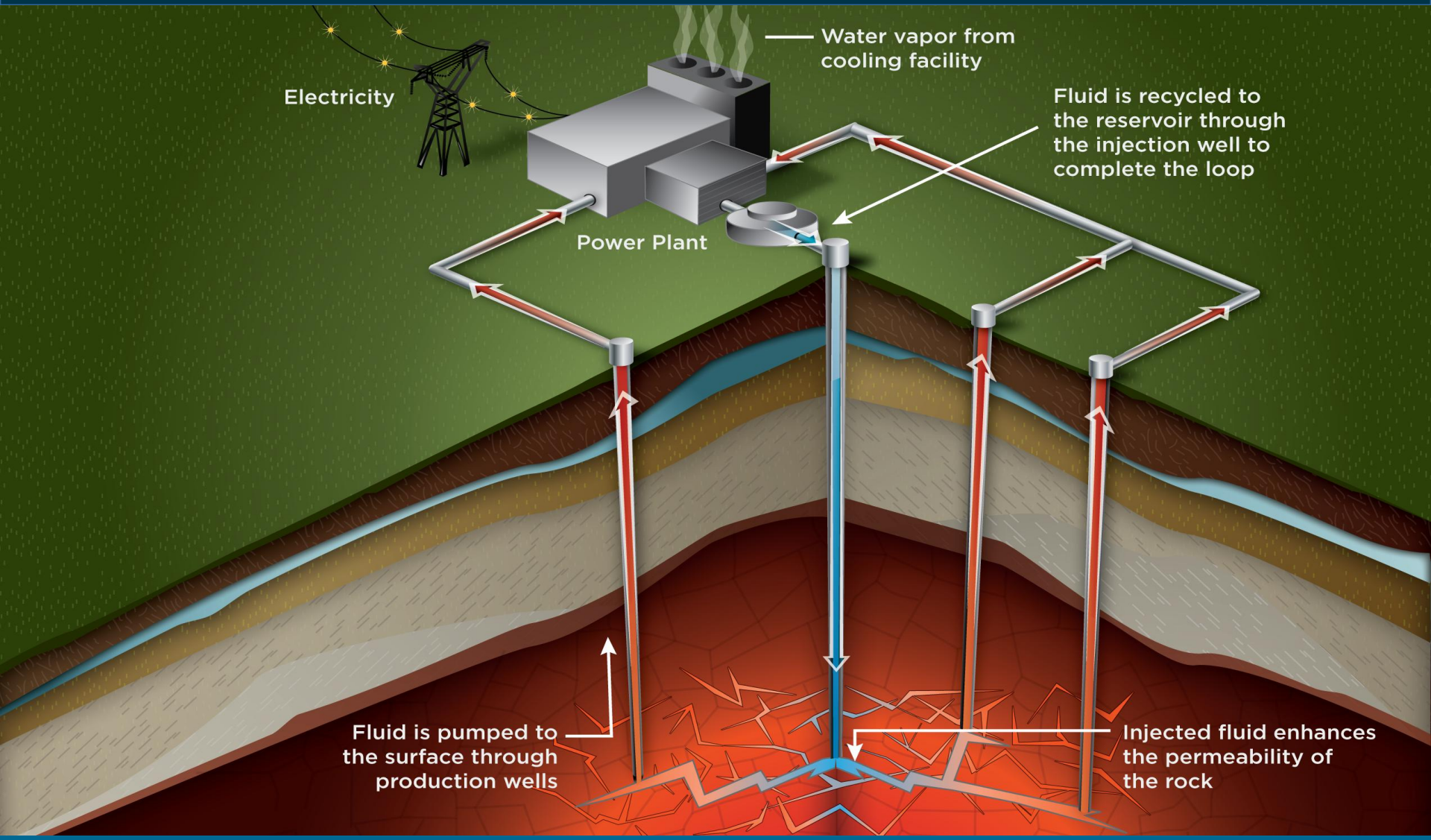
EGS uses advanced technologies to access the heat of the earth and produce electricity.



EGS Resource

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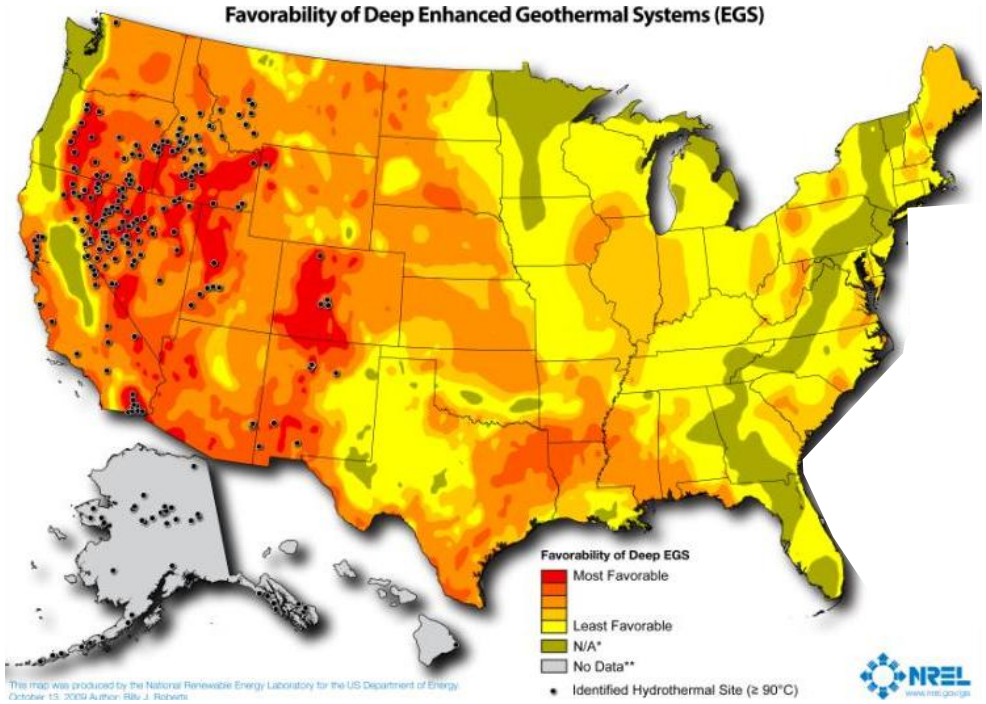
While EGS has an ***enormous resource potential***, challenges such as ***reservoir engineering*** and ***induced seismicity*** must be addressed.

Defined

- EGS systems have access to heat depending on depth, but lack two or both of the other ingredients necessary for a viable hydrothermal resource-permeability, and/or the presence of fluid.



Favorable EGS locations have high temperatures near the surface, and may be near existing hydrothermal plants

Opportunity

- Heat is present almost everywhere at depth
- EGS can provide emission-free baseload power across the U.S. by stimulating pre-existing fractures and creating a man-made reservoir 2-10 km below the surface

Challenges

- Geothermal reservoirs must be engineered so that flow rates remain high while thermal drawdown is limited
- Establishing a connection between wells is critical yet difficult to demonstrate
- Induced seismicity must be understood both as a tool and a potential hazard; effective mitigation measures must be developed

Technologies

- **Accessing Hot Formation**: drilling technologies, high temperature high pressure tool and sensor development, high temperature component coatings
- **Create the Reservoir:** stimulation technologies, zonal isolation, fracture characterization/fluid flow
- **Sustain the Reservoir:** alternative heat transmission fluids, long term monitoring technologies, improved plant design

EGS Demonstration Projects

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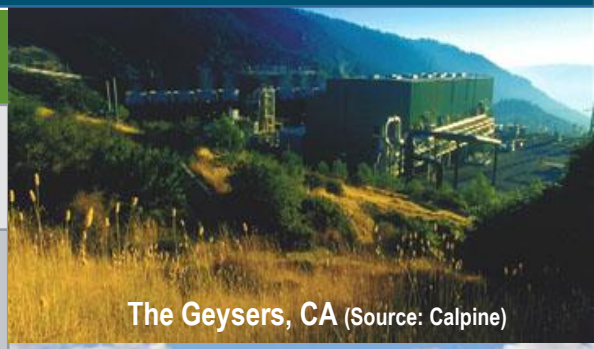
With the goal of demonstrating a 5MW reservoir by 2020, the Program has seven EGS demonstration projects in a variety of geological environments.

Recipient	Project Site	Site Information	Update
Ormat Technologies Inc.	Desert Peak, NV	Adjacent to existing hydrothermal sites	Completed a 4 stage stimulation. Met with team on July 1 to design the next stimulation stage.
Geysers Power Company, LLC	The Geysers, CA	Two existing wells will be reopened and deepened for injection and stimulation	Initiate final modifications and testing of Prati 31 and 32 July 11; Injection scheduled first week of August
University of Utah	Raft River, ID	Improve the performance of the existing Raft River geothermal field	NEPA approval granted July 7 for well rework, simulation and monitoring. Well will be re-opened early August.
Ormat Technologies Inc.	Bradys Hot Springs, NV	Improve the performance of the existing geothermal field	Developing a structural model to develop a stimulation plan.
AltaRock Energy Inc.	Newberry Volcano, OR	High potential in an area without existing geothermal development	Submitted draft Induced Seismicity Protocol which comprises a key part of their Environmental Assessment, to be submitted July 29.
TGP Development Co.	New York Canyon, NV	Site adjacent to existing hydrothermal sites and shows high temperatures at shallow depths	Drilling continues in Coyote Canyon: estimated completion is August 15.
NakNek Electric Association	NakNek, AK	Located in remote location in Alaska without existing geothermal development	Evaluating the condition of well in order to determine a path forward


The Geysers, CA (Source: Calpine)

Raft River, ID (Source: US Geothermal)

NakNek, AK (Source: NEA)

Other Program Areas

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Systems Analysis (GTP)

- Resource assessment and classification: USGS
- Links to high quality data: National Geothermal Data System www.geothermaldata.org
- Costs: INL's Geothermal Electricity Technologies Evaluation Model (GETEM) analyzes cost and performance of geothermal projects
- Environmental impacts: ANL is performing lifecycle analysis, including evaluating greenhouse gas emissions and water use

International Activities (GTP)

- Collaborating with Iceland, Switzerland and Australia on the International Partnership for Geothermal Technology
- Working with several countries through the IEA Geothermal Implementing Agreement
- Working with the European Commission's GEISER project to address induced seismicity

Education and Workforce Development (GTP)

- Student Competition (NREL)
- National Geothermal Academy (UNR)
- Geophysical field camp (CSM)
- Research experiences for undergrads (NSF)
- Post-doc fellowships (ORISE)

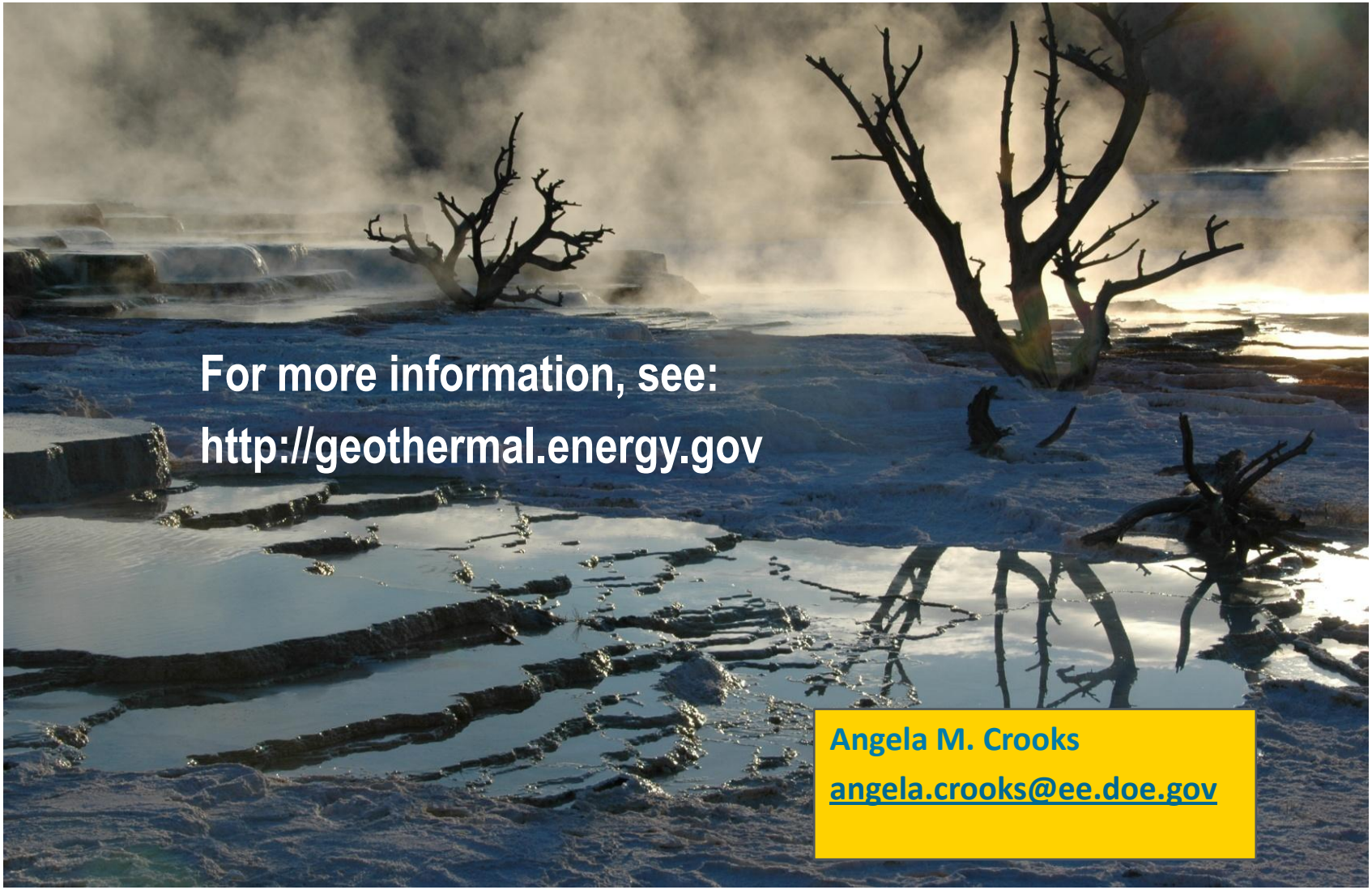
SBIR/STTR: Small Business Innovation Research/Small Business Technology Transfer

- U.S. Small Business Administration program ensures that small high-tech, innovative businesses are included in federal R&D
- GTP contributed $94,000 to projects in FY10

ARPA-E: Advanced Research Projects - Energy

- Invests in pre-commercial, high-impact technologies.
- $9.14 M to further low-contact drilling technology, allowing for rapid and sustained penetration of ultra-hard rock formations

Thank you for your attention



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