

## DOE's Innovative Exploration Technologies Program associated with Conventional Geothermal Systems



**APEC WORKSHOP ON GEOTHERMAL ENERGY DEVELOPMENT**

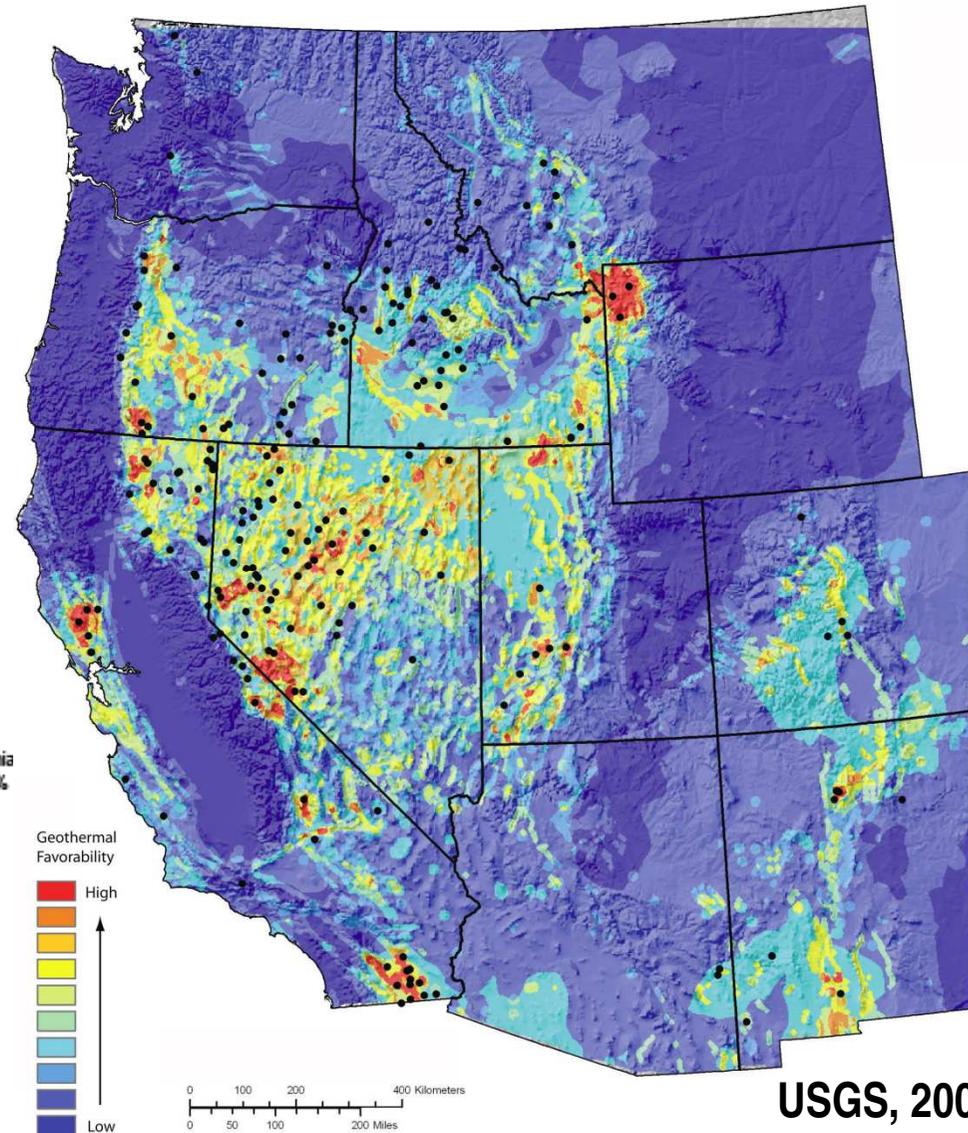
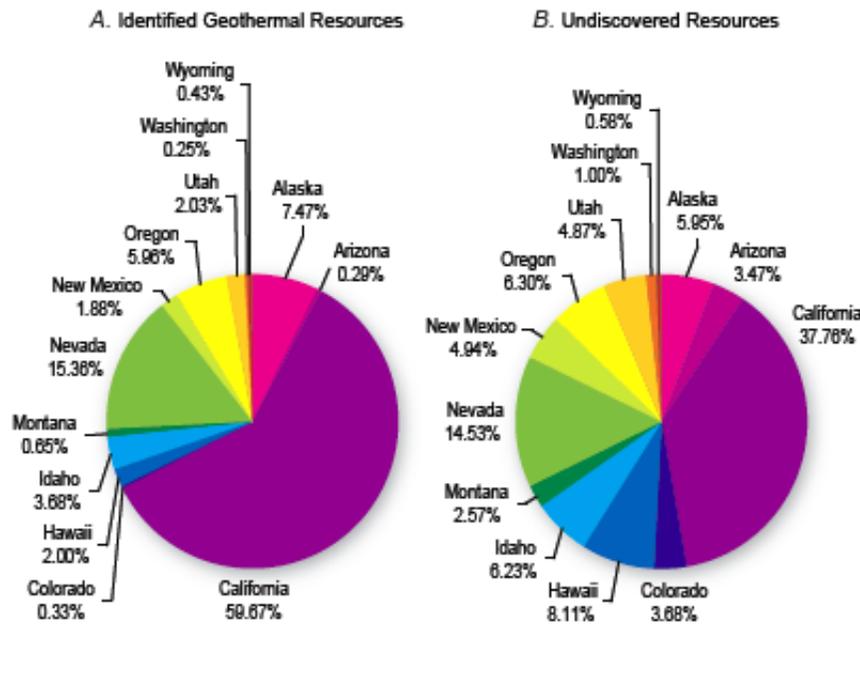
June 25, 2013

Patrick Dobson DOE/LBNL

# Potential Geothermal Resources

## USGS Geothermal Favorability Map

- 9 GWe potential from identified resources (black dots)
- 30 GWe potential from undiscovered resources



# Goals of Hydrothermal & Resource Confirmation Program

- Develop advanced exploration tools and technologies through supporting exploration R&D projects to accelerate the discovery and utilization of geothermal resources
  - Improve ability to accurately predict subsurface temperatures
  - Improve ability to identify permeable zones at depth
- Reduce the high level of exploration risk, lower the cost of geothermal power, and increase the economic viability of exploration technologies
- Generate useful data for the National Geothermal Data System
- Exploration R&D projects consist of application of innovative technologies
  - Green field exploration
  - Brown field exploration
  - Expansion of existing geothermal fields
- Other efforts include:
  - Develop exploration best practices and case histories on DOE's Open Energy Information (OpenEI) website
  - Data gap analysis

# Hydrothermal Resource Confirmation

*Innovative Exploration Technologies  
Drilled in 2011*



Energy Efficiency &  
Renewable Energy



NW Geysers, CA



Pyramid Lake



Rye Patch, NV

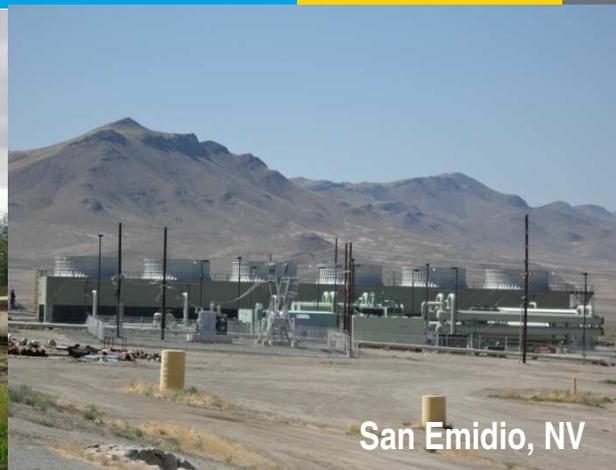
Performer	Project Site	Exploration Technologies	DOE Funds	Awardee Cost Share	TOTAL COST
Geysers Power Company, LLC	Northwest Geyser, CA	Geophysics	\$5,000,000	\$7,130,647	\$12,130,647
Nevada Geothermal Power Company	Crump Geyser, OR	Geophysics	\$1,764,272	\$1,839,271	\$3,603,543
ORMAT Nevada, Inc.	Wister, CA	Geophysics	\$4,911,330	\$5,575,229	\$10,486,559
Presco Energy, Inc.	Pershing County (Rye Patch), NV	Geophysics	\$2,277,081	\$1,934,149	\$4,211,230
Pyramid Lake Paiute Tribe	Pyramid Lake, NV	Geophysics	\$4,845,534	\$0	\$4,845,534
Utah State University	Snake River Plain, ID	Geophysics, Geochemistry	\$4,640,110	\$1,804,488	\$6,444,598

# Hydrothermal Resource Confirmation

*Innovative Exploration Technologies  
Drilling 2012-2013*

U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy



Performer	Project Site	Exploration Technologies	DOE Funds	Awardee Cost Share	TOTAL COST
Utah State University	Snake River Plain, ID	Geophysics, Geochemistry	\$4,640,110	\$1,804,488	\$6,444,598
US Geothermal, Inc.	San Emidio, NV	Geophysics, Remote Sensing	\$3,772,560	\$3,451,878	\$7,224,438
University of Alaska Fairbanks	Pilgrim Hot Springs, AK	Remote Sensing	\$4,274,792	\$1,851,345	\$6,126,137
El Paso County	Ft. Bliss, NM	Geochemistry	\$5,000,000	\$4,812,500	\$9,812,500
Pueblo of Jemez	Jemez Pueblo, NM	Geochemistry	\$4,995,844	\$100,000	\$5,095,844
Oski Energy, LLC	Hot Pot, NV	Geophysics	\$4,214,086	\$3,985,570	\$8,199,656

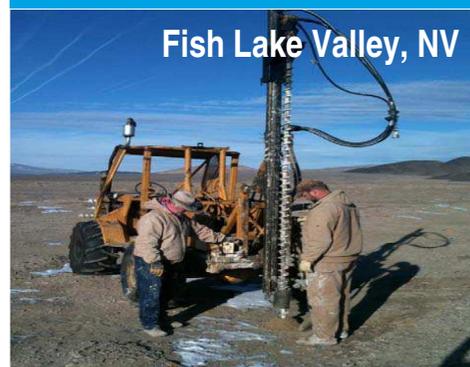
# Hydrothermal Resource Confirmation

*Innovative Exploration Technologies*

*Projected Drilling 2013-2014*

U.S. DEPARTMENT OF  
**ENERGY**

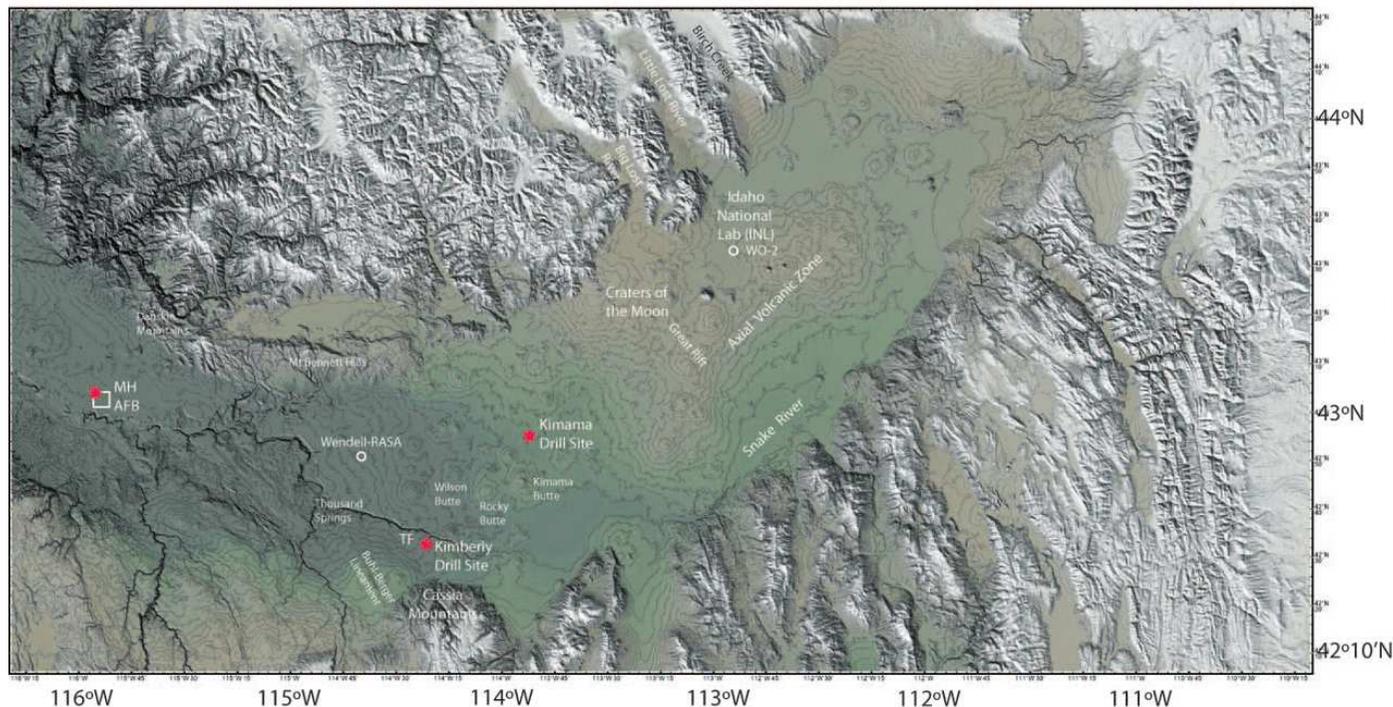
Energy Efficiency &  
Renewable Energy



Performer	Project Site	Exploration Technologies	DOE Funds	Awardee Cost Share	TOTAL COST
Nevada Geothermal Power Company	Pumpnickel, NV	Geochemistry	\$1,597,847	\$1,597,847	\$3,195,694
ORMAT Nevada, Inc.	Glass Buttes, OR	Remote Sensing	\$4,475,015	\$4,050,500	\$8,525,515
Ram Power, Inc. (Sierra Geothermal)	Silver Peak, NV	Remote Sensing	\$5,000,000	\$7,356,546	\$12,356,546
Ram Power, Inc. (Sierra Geothermal)	Alum, NV	Remote Sensing	\$5,000,000	\$7,356,546	\$12,356,546
University of Kansas Center for Research Inc.	Fish Lake Valley, NV	Geochemistry	\$2,299,237	\$1,943,282	\$4,242,519
Flint Geothermal LLC	Western Colorado	Remote Sensing	\$4,778,234	\$3,007,300	\$7,785,534
ORMAT Nevada, Inc.	Maui, HI	Remote Sensing, Geochemistry	\$4,377,000	\$4,327,260	\$8,704,260
Davenport Power, LLC	Newberry Volcano, OR	Geophysics	\$5,000,000	\$7,830,425	\$12,830,425

### 3 wells drilled to evaluate region with elevated heat flow

- **Kimama** - 1912 m hole with 98 C BHT, penetrated mostly basalt, with thick cold aquifer down to 960 m
- **Kimberly** – 1958 m hole with thick isothermal section (55-60 C) below 400 m, penetrates margins of silicic caldera
- **Mountain Home** – 1821 m hole with artesian flow of 129 C from fluid entry at 1745 m; well penetrates basalts and lacustrine sediments



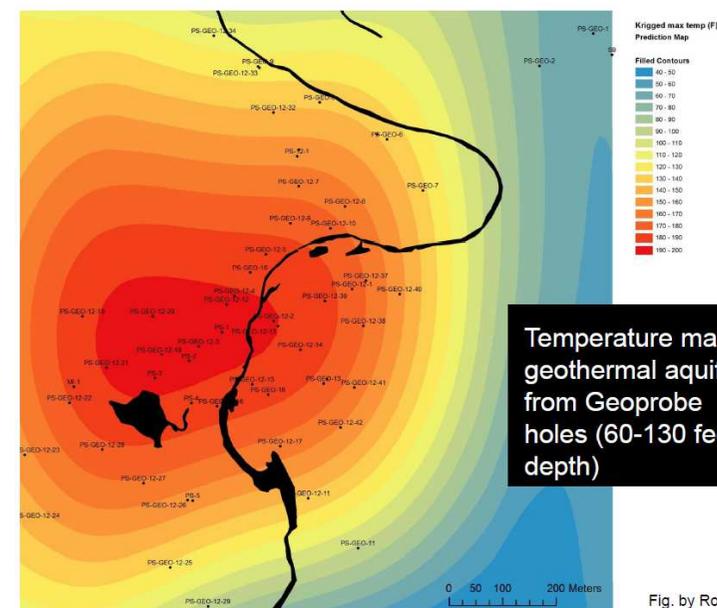
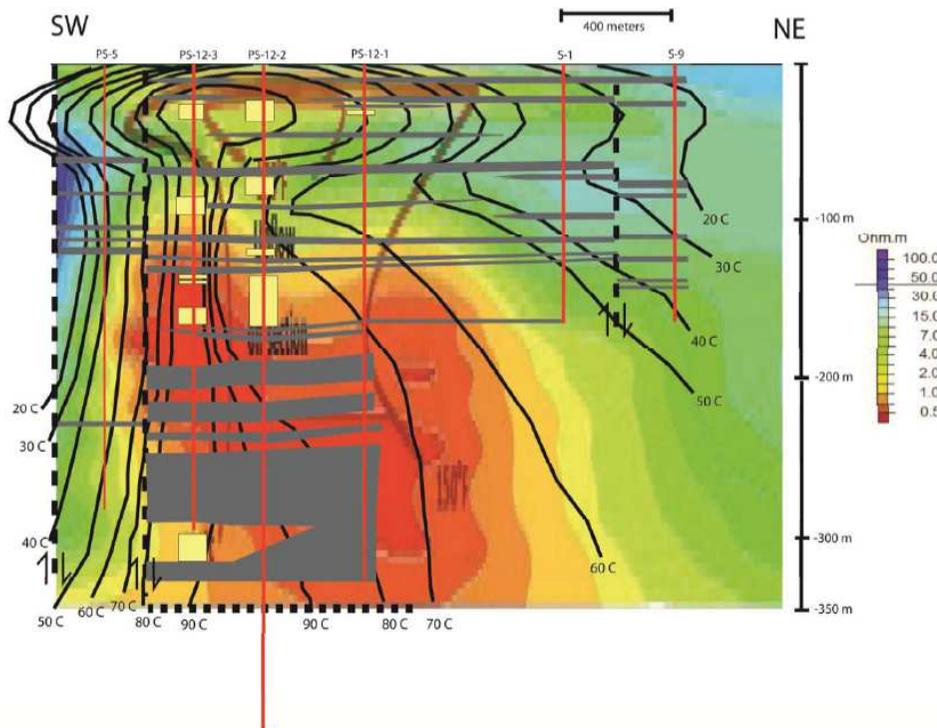
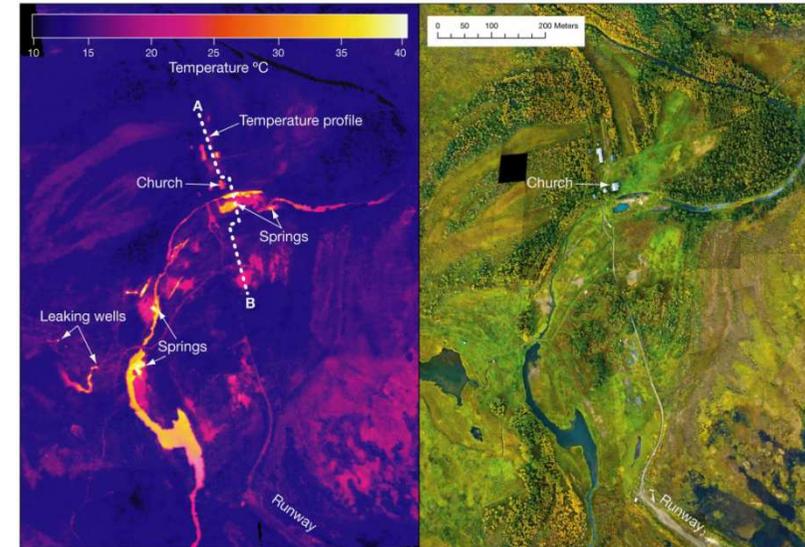
**Artesian flow at Mtn. Home**

**Shaded relief  
topographic map of  
Snake River Plain**

# Pilgrim Hot Springs, AK

## University of Alaska, Fairbanks

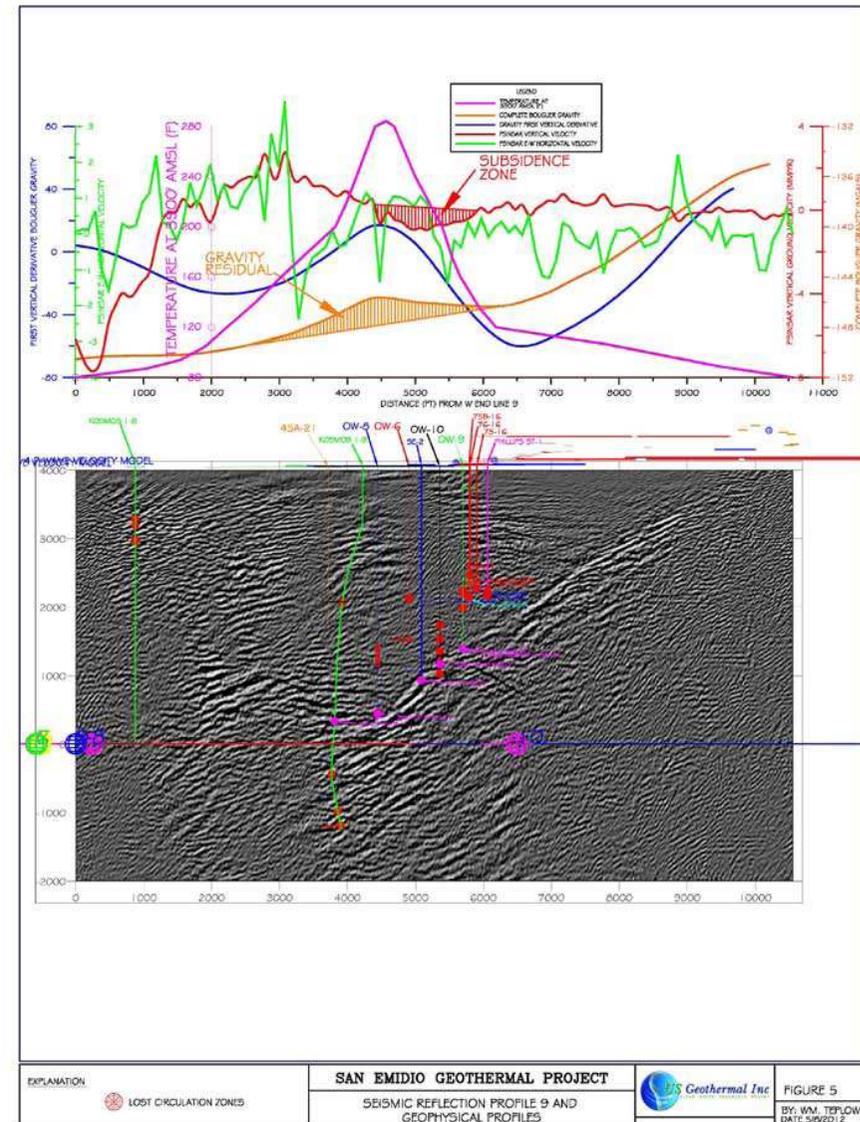
- Forward looking infrared (FLIR) airborne survey used to identify extent of hot springs and hot ground
- Geoprobe holes (20-40 m) used to identify shallow outflow plume, pinpoint upflow location for deeper drilling targets
- Integrated geophysical data (MT, gravity, magnetics) with geology



Temperature map of geothermal aquifer from Geoprobe holes (60-130 feet depth)

Fig. by Ronald Daanen

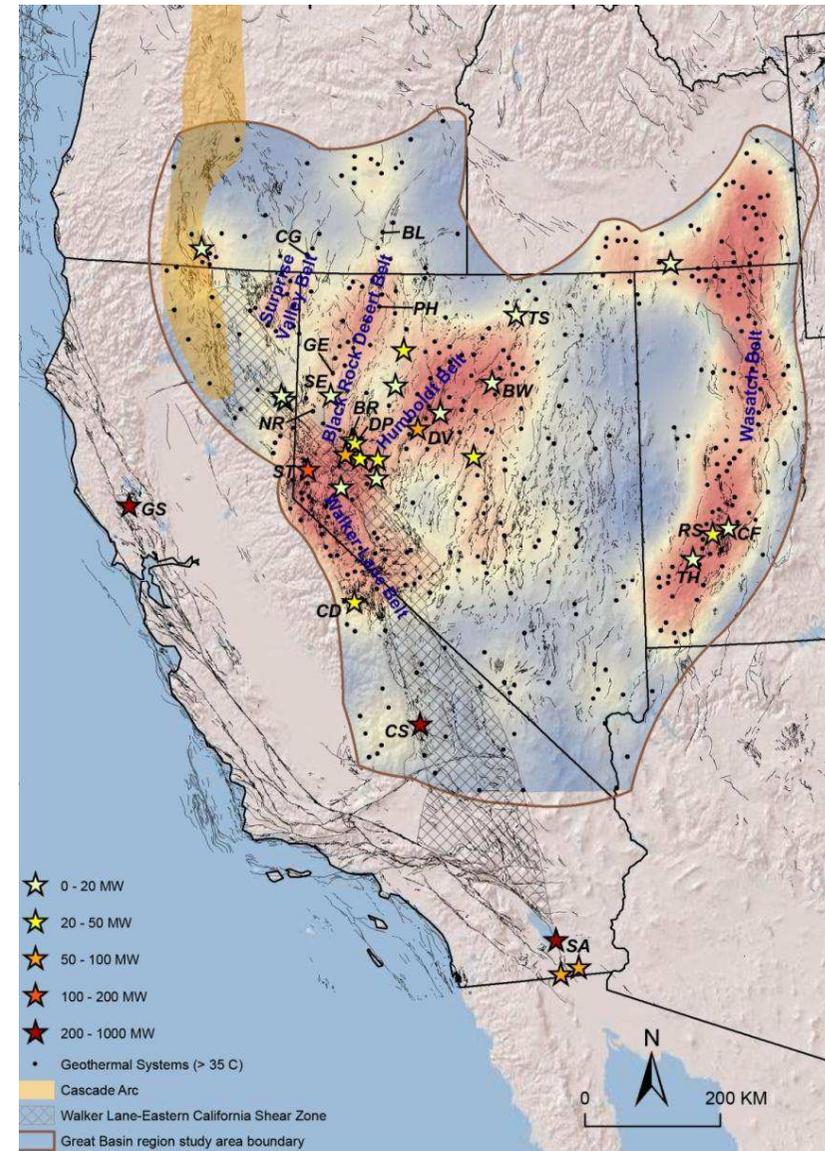
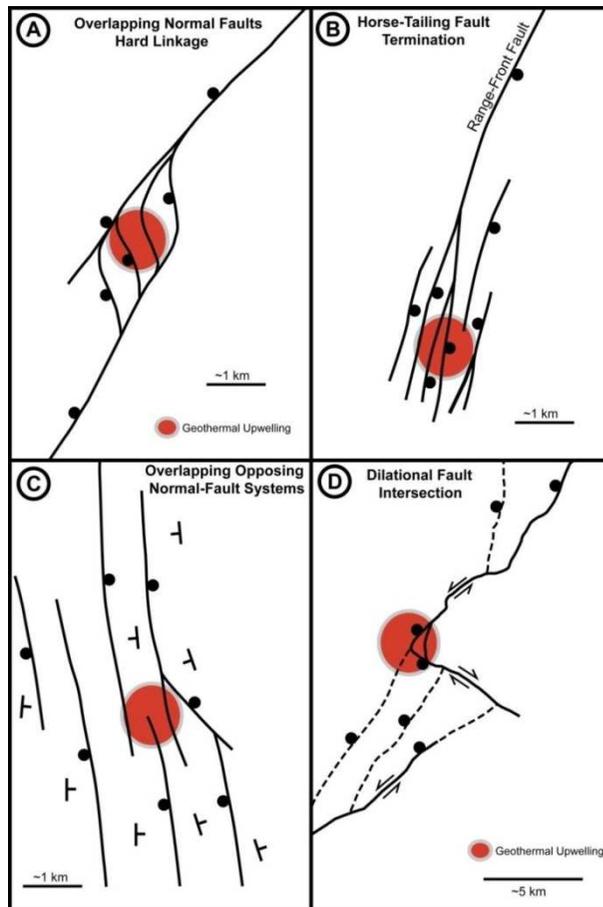
- Used structural kinematic analysis, PSInSAR, gravity, magnetics, and reflection seismic techniques to identify and map Large Aperture Fractures (LAFs) and identify drilling targets
- Key accomplishments:
  - 4 out of 5 wells encountered commercially exploitable permeability and temperature
  - Added 2 MWe to currently operating wellfield
  - Expanded possible southern resource area by 2.6 km<sup>2</sup>
  - Found resource with temperatures 6 to 11 C higher than previously observed



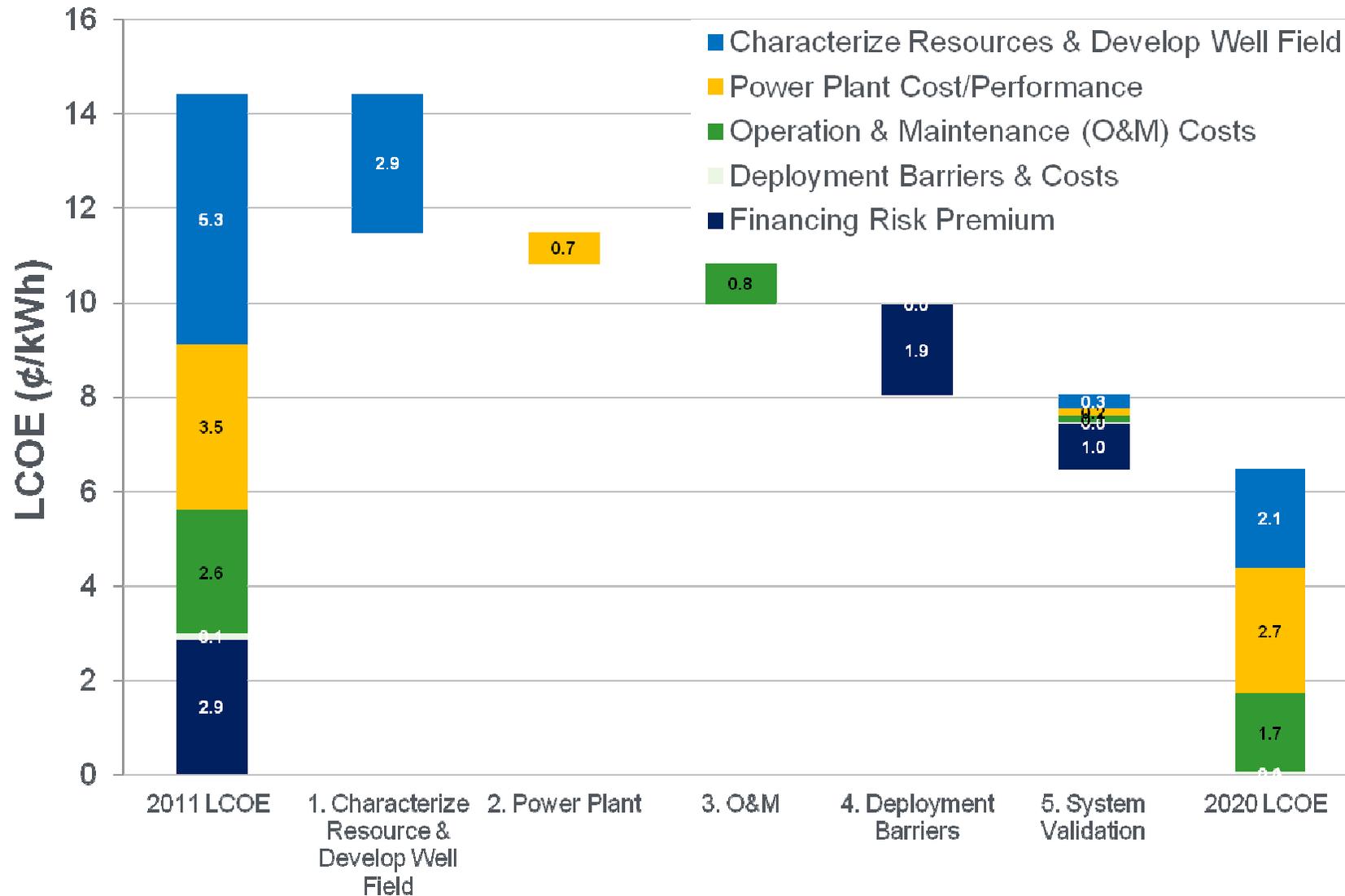
# Structural Controls of Geothermal Systems (Faulds, 2013)

Geothermal 'fairway' of high fracture permeability and fluid flow where:

- Co-location of critically stressed fault segments
- High fault intersection density



# Hydrothermal Cost-Reduction Cascade



# Information Collection, Sharing, and Analysis OpenEI and NGDS

## GEOTHERMAL ENERGY

Geothermal Home

Overview Technologies Resources Market Data Geothermal Topics Data Resources Financing Permitting & Policy Links

### Geothermal Energy



The Sierra Nevada Mountains provide a spectacular backdrop for a cooling tower array at the ORMAT Mammoth Geothermal Power Plant in Central California.

**Geothermal energy** is heat extracted from the Earth. A wide range of temperatures can be suitable for using geothermal energy, from room temperature to above 300° F.<sup>[1]</sup> This heat can be drawn from various depths, ranging from the shallow ground (the upper 10 feet beneath the surface of the Earth) that maintains a relatively constant temperature of approximately 50° to 60° F, to reservoirs of extremely hot water and steam located several miles deep into the Earth.<sup>[2][3]</sup>

Geothermal reservoirs are generally classified as either low temperature (<302°F) or high temperature (>302°F). Commercial electricity production normally requires a high-temperature reservoir capable of providing hydrothermal (hot water and steam) resources, called **hydrothermal reservoirs**.<sup>[1]</sup>

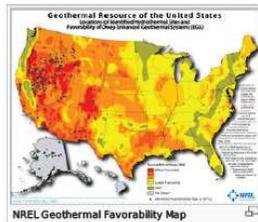
Geothermal is distinct from other renewables such as solar or wind because it is a considered a "baseload" technology, providing electricity 24 hours a day, 365 days a year.<sup>[4]</sup>

### Geothermal Resources

In 2008, scientists with the U.S. Geological Survey (USGS) completed an assessment of the geothermal resources in the U.S., which indicated:

- 9,057 MWe of identified geothermal resource
- 30,033 MWe of undiscovered potential
- 517,800 MWe of EGS potential

Visit the Geothermal Resources page to view other resource assessments that have been conducted.



### Geothermal Market Data



An engineer inspects the blades of a backup turbine at a Northern California Power Agency (NCPA) geothermal power plant at The Geysers.

In 2012, the Geothermal Energy Association reported a global installed geothermal capacity of 11,224 MW, and a U.S. installed geothermal capacity of 3,187.<sup>[5]</sup> Geothermal energy accounts for approximately 3% of renewable energy-based electricity consumption in the United States.<sup>[6]</sup>

Find more information on Installed Geothermal Capacity, Geothermal Generation, and Planned Geothermal Capacity.



National Geothermal Data System

Search site or data

Search Site  
 Search Data

Use Data
Publish Data
Developers
Events
About

Welcome to NGDS, information for discovery, evaluation, and development of geothermal resources.

NGDS is your source for access to information resources on geothermal energy from a national network of data providers. Data are contributed by academic researchers, private sector participants, and state and federal agencies, primarily the Department of Energy. Access, view, and download data with this free and [easy online search tool](#).



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NGDS Featured in May 2013 Scientific American article

[Decades-Old Documents Could Speed Discovery of Geothermal Wells](#)

**HELP**

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**SHARE DATA**

Becoming a data provider to the NGDS is simple. To learn more about contributing your project's data to the DOE Geothermal Data Repository, data interchange formats, and data services follow the links below.

- [Contribute to DOE Geothermal Data Repository](#)
- [Register Data](#)

**PARTICIPANTS**

  
 Association of American State Geologists

  
 Southern Methodist University

  
 U. S. Geological Survey

[Full list of contributors](#)

<http://geothermaldata.org>

[en.openei.org/wiki/Gateway:Geothermal#](http://en.openei.org/wiki/Gateway:Geothermal#)

# Workshop Results

## Priority technology needs (1 of 2)

### **CROSS-CUTTING**

- Conceptual Models
- Structural Evaluation of Geothermal Systems
- 3D Visualization and Modeling Software
- Database of Case Histories and Analysis Tools
- Geothermal Potential Maps

### **GEOLOGY/STRUCTURE STRESS/STRAIN**

- Core Log Analysis
- Stress/Strain Data Mapping
- Basic Geologic Setting and Permeability
- Coupled Transport Modeling
- District Mapping
- Rock Property Data-Data Set

### **NON-INVASIVE GEOPHYSICS**

- Gravity Tools and Techniques
- Inverse Methods
- Seismic (reflection seismic, passive, source)
- EM Improvements
- 3D EM Interpretation Techniques
- High Density Data Acquisition Instruments

# Workshop Results

## Priority technology needs (2 of 2)

### **INVASIVE GEOPHYSICS**

- Well Logging Tools
- Crosshole/Downhole Techniques
- Vertical Seismic Profiling (VSP)
- EM Improvements
- Heat Flow Logging

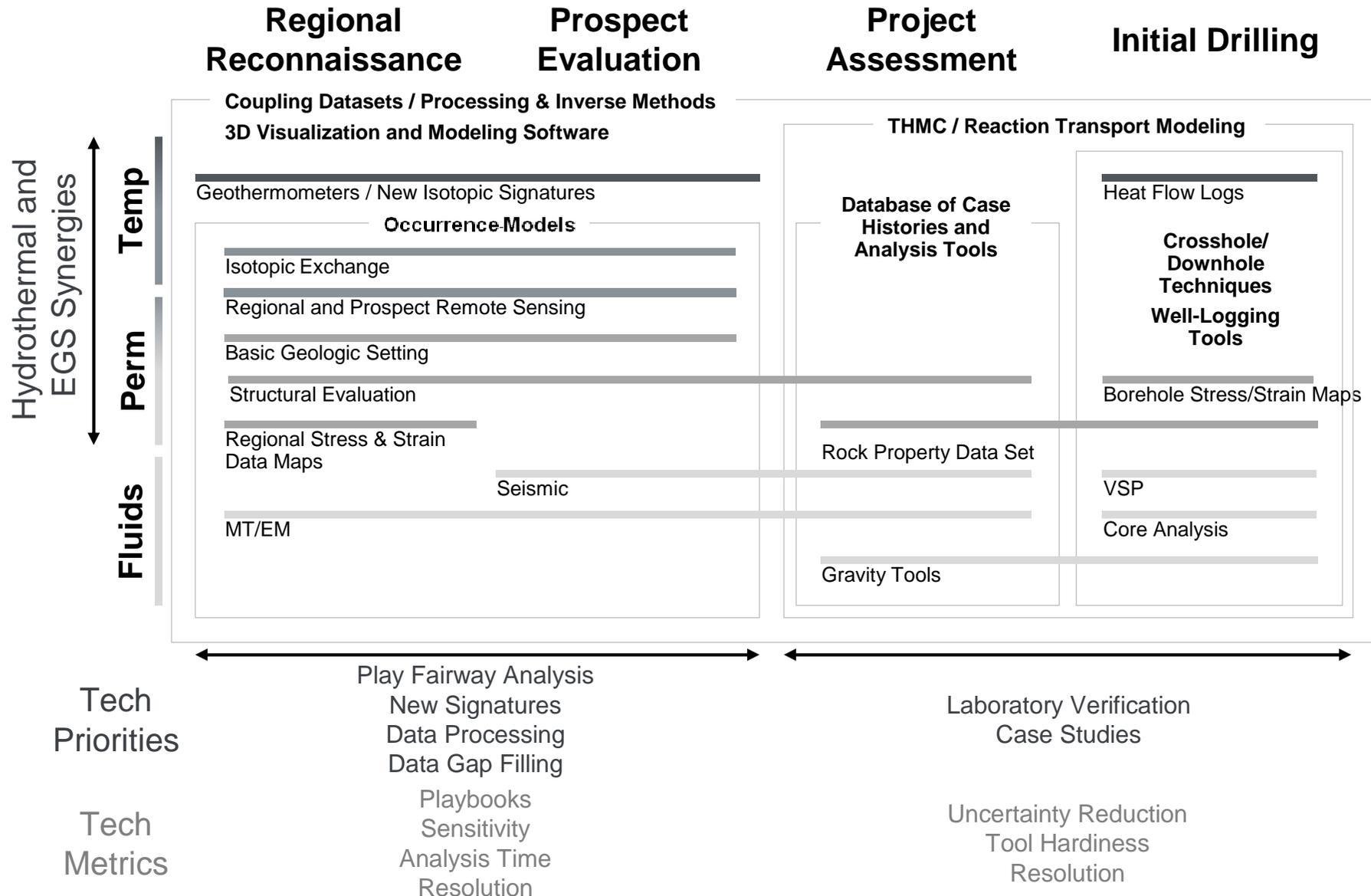
### **AIRBORNE EXPLORATION**

- MT/EM Tools/AFMAG
- Gravity Tools
- Regional Remote Sensing Data Collection
- Synthesis of Multiple Data Sets
- Processing Methods
- Single Source Database

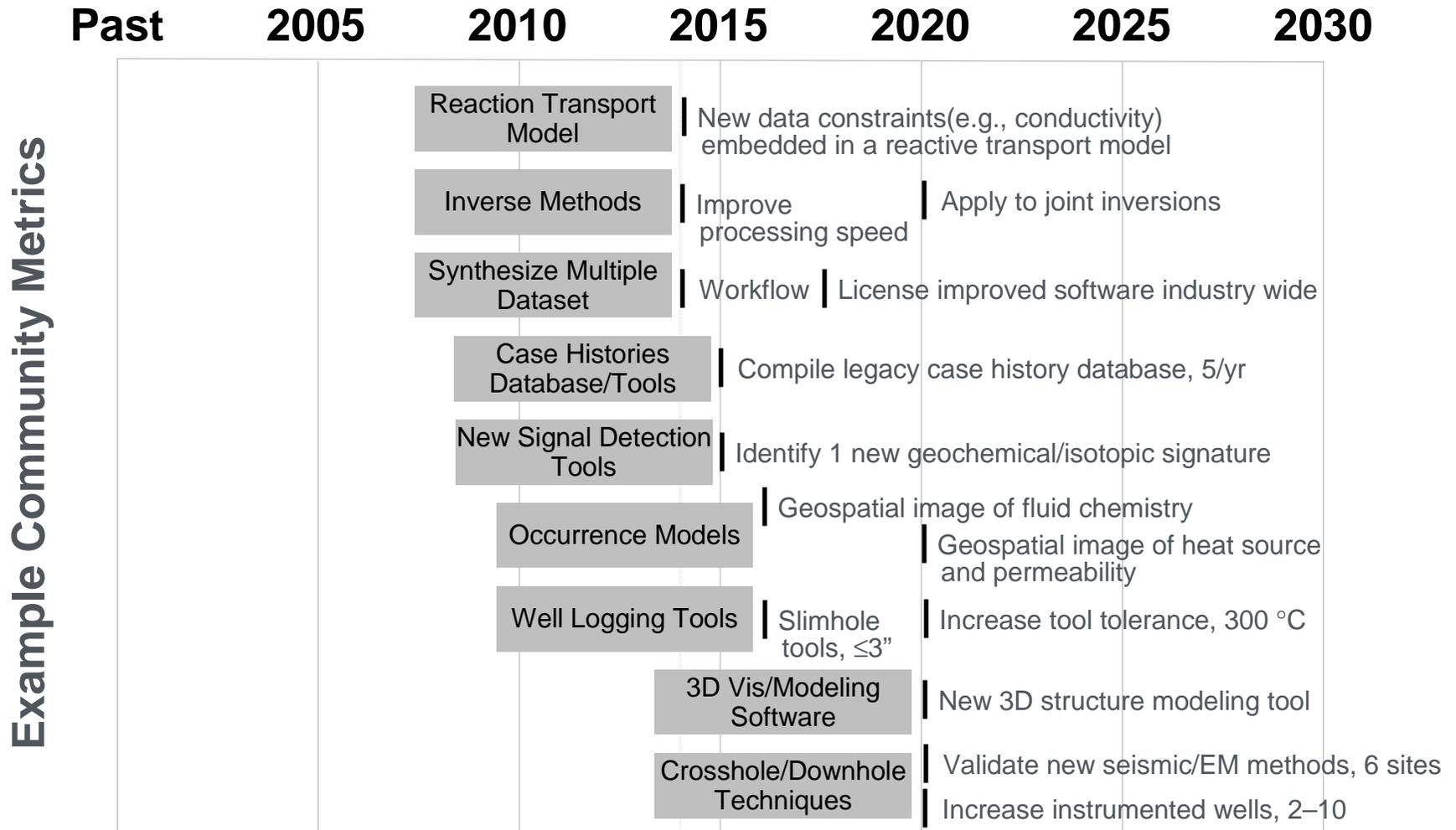
### **GEOCHEMISTRY**

- Reaction Transport Modeling
- Isotopic Exchange/Permeability Distribution
- New Signal Detection Tools
- Geothermometers
- Fracture Detection Tools
- Improved Consistent Thermodynamic and Kinetic Database

# Technology Needs Categories and Priorities



# Workshop Results Metrics proposed



# Concluding Remarks

- DOE's Hydrothermal & Resource Confirmation Program has supported many field R&D projects over the past 3 years to test innovative exploration technologies
  - Identify and develop blind hydrothermal resources
  - Lower exploration risk
  - Lower geothermal power cost
- Data collection and analysis critical to maximizing project benefits
- Roadmapping work used to identify technology barriers, focus future R&D efforts of program
- Many aspects of this program are applicable to EGS, coproduction, and low temperature resources

