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

Geothermal Technologies Program Peer Review Program

June 6 - 10, 2011

Bethesda, MD

WELCOME

Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Geothermal Technologies Program

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

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

JoAnn Milliken
Acting Program Manager

Program Peer Review
June 6, 2011

The Past

Geothermal Program History 1976-2012

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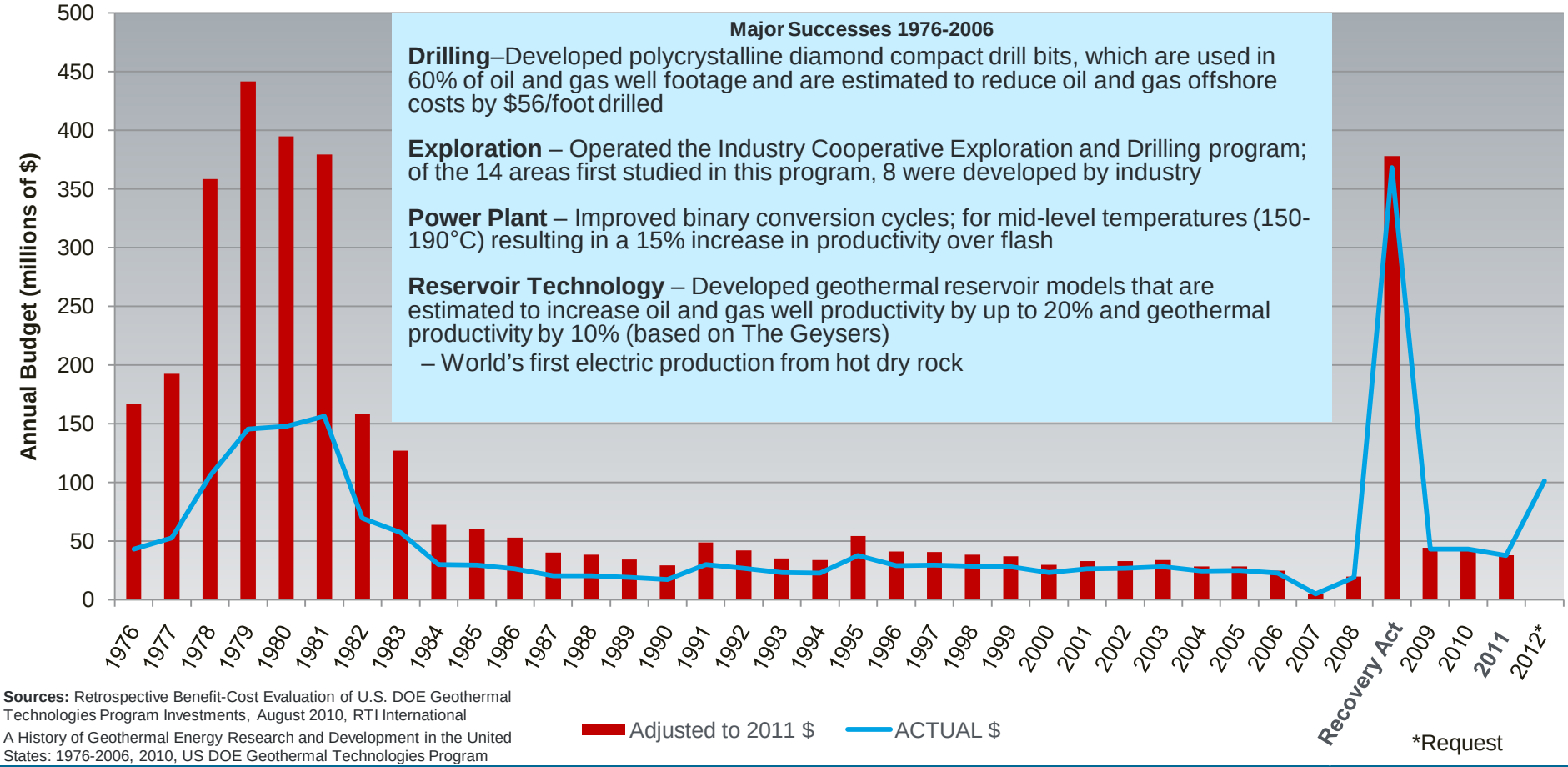
The Geothermal Technologies Program annual budget peaked in the late 1970s, enabling advances in drilling, exploration, power plant systems, and reservoir modeling.

Annual Budget for the Geothermal Technologies Program 1976 - 2012

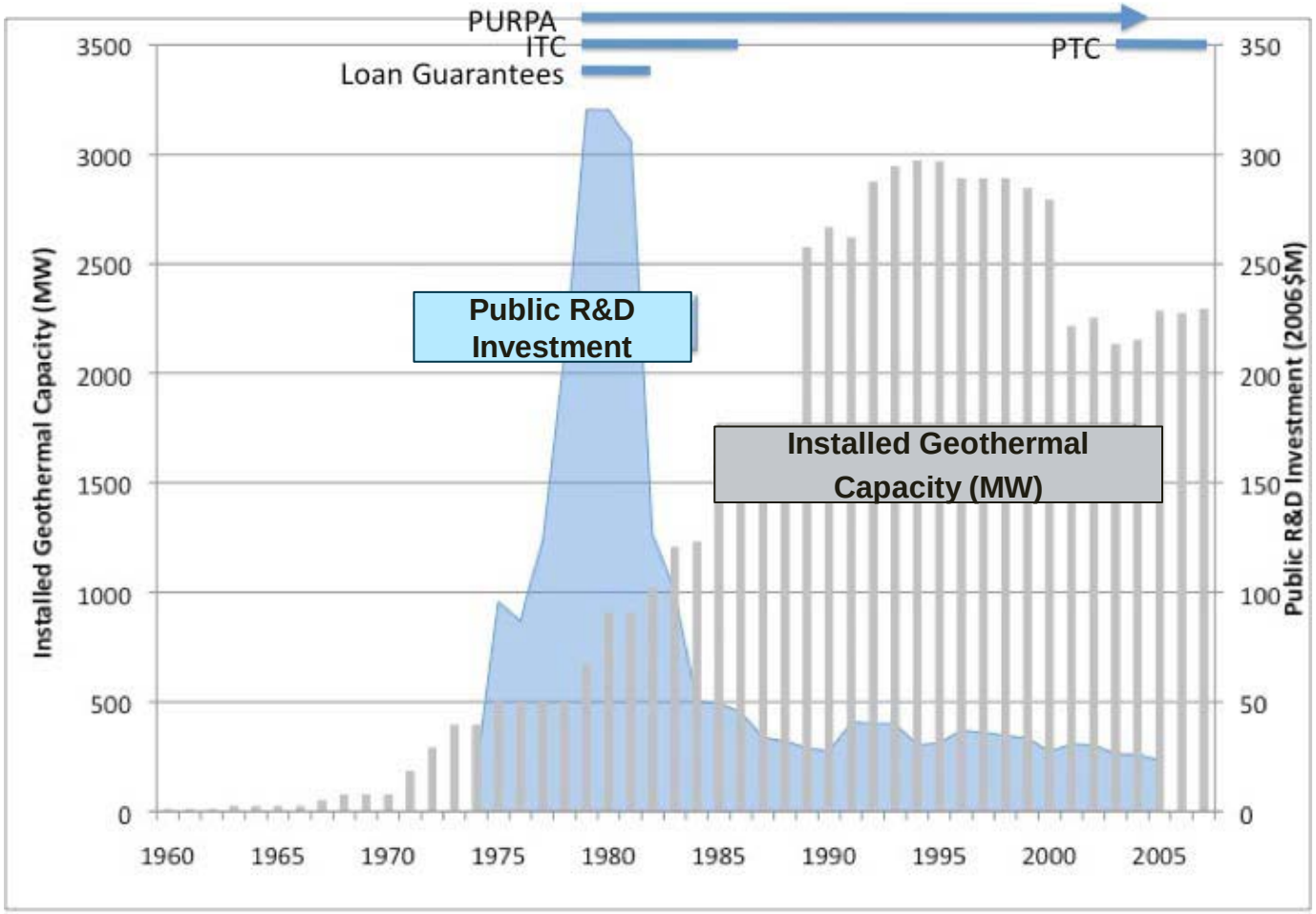


Sources: Retrospective Benefit-Cost Evaluation of U.S. DOE Geothermal Technologies Program Investments, August 2010, RTI International

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

Installed Geothermal Capacity 1960-2007

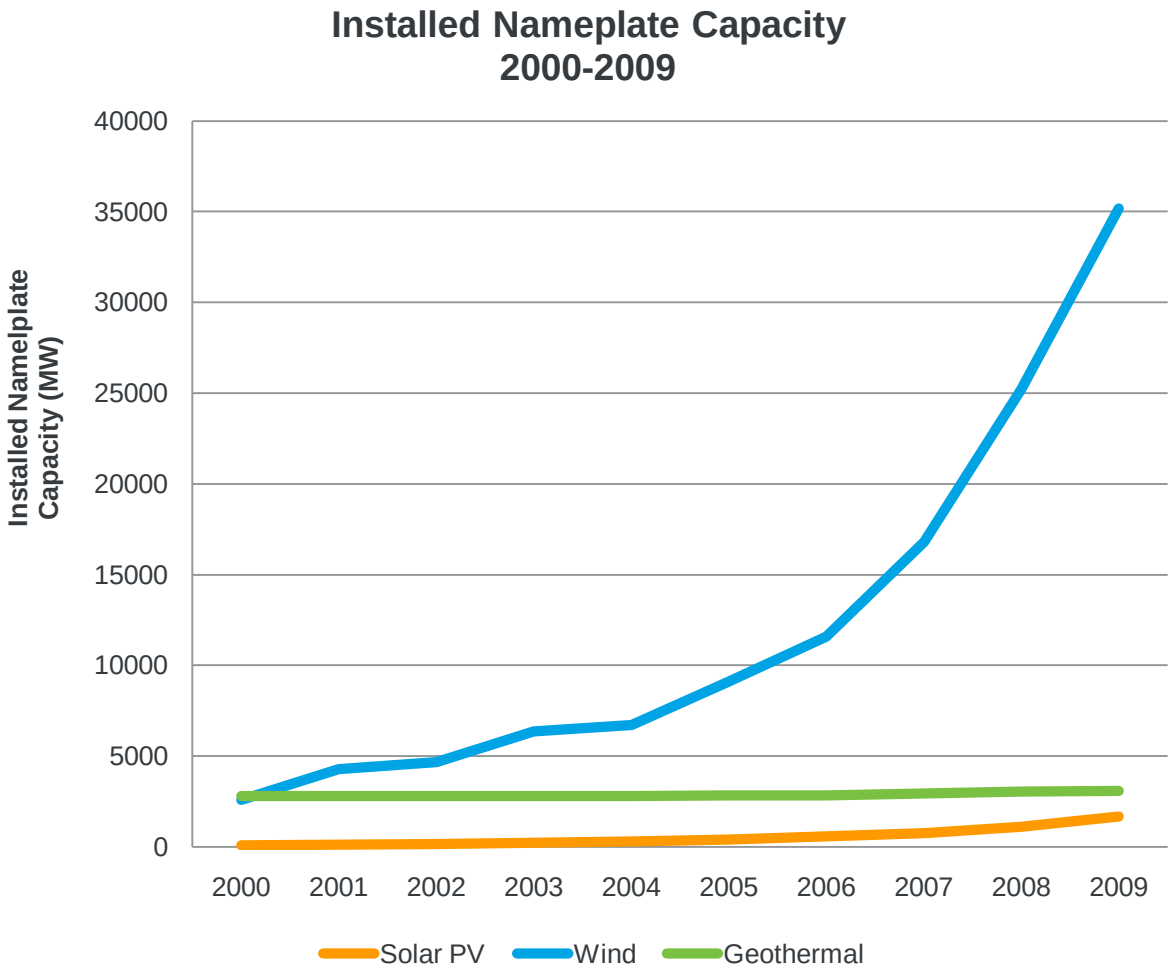
R&D investments and policy drove geothermal energy growth in the 1980s.



From:
Policy Overview and Options for Maximizing the Role of Policy in Geothermal Electricity Development (NREL) September, 2009

Renewable Energy Capacity 2000 to 2009

Annual growth of geothermal capacity lagged behind both solar and wind from 2000-2009.



Nameplate Capacity Annual Increase (Percent Over Previous Year)

Year	Geothermal	Wind	Solar PV
2000	2.20%	2.60%	26.90%
2001	0.00%	65.80%	31.70%
2002	0.00%	9.60%	39.20%
2003	0.00%	35.60%	44.80%
2004	0.00%	5.90%	38.00%
2005	1.10%	35.60%	35.80%
2006	0.10%	26.90%	33.40%
2007	3.70%	45.20%	36.20%
2008	3.50%	50.10%	43.50%
2009	1.50%	39.30%	51.60%

The Present

The Recovery Act has provided a much needed boost to geothermal RD&D

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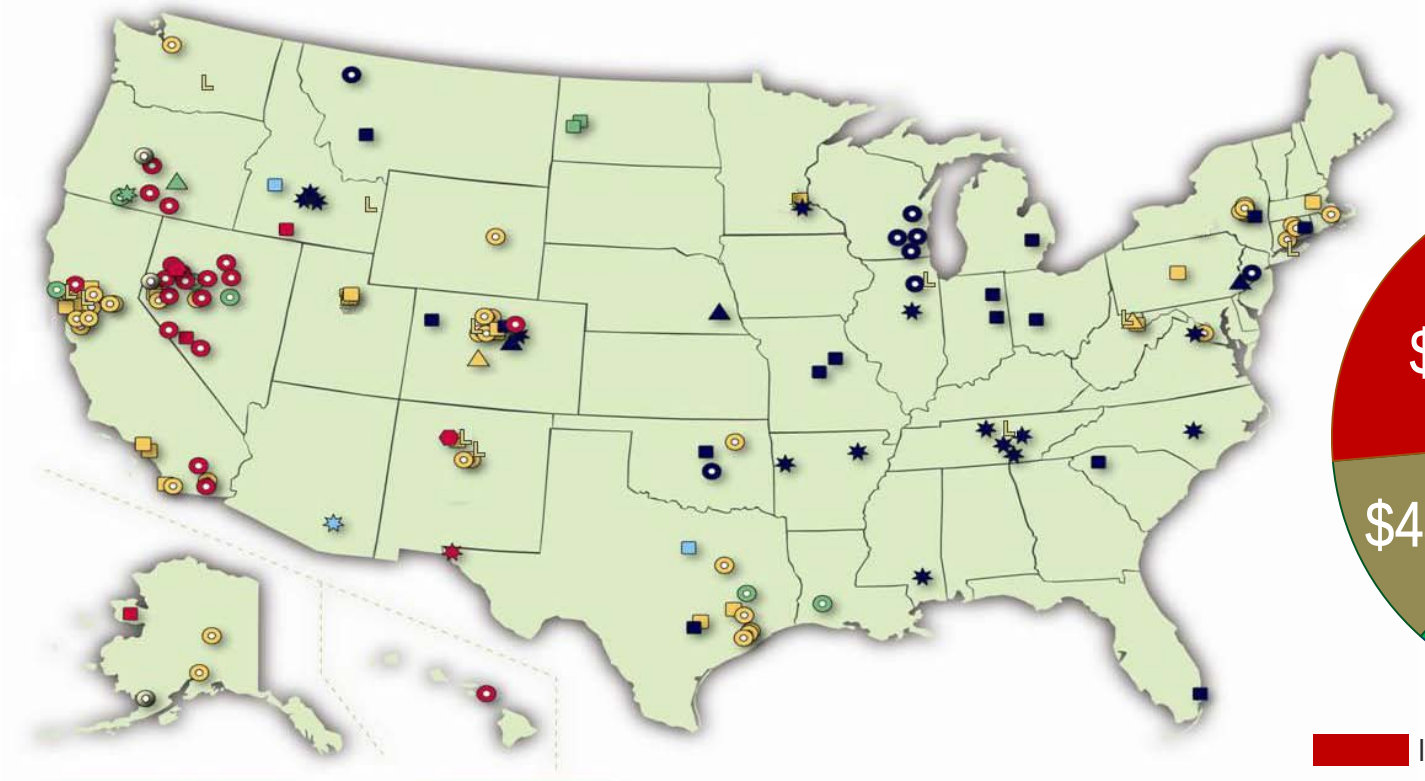
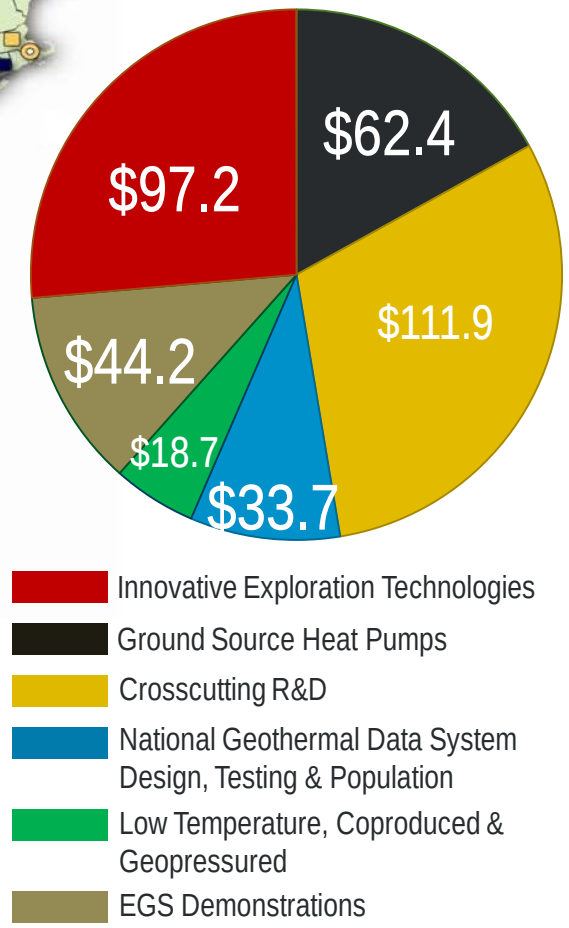
Under Recovery, DOE has invested $368.2 million in geothermal projects in 39 states.



Organization Type (shape)
- Educational Institutions
- Industry
- Non Profits
- State and Local Government
- Tribes
- National Laboratories

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



Recovery Funding Enabled Expanded Geothermal Program Portfolio

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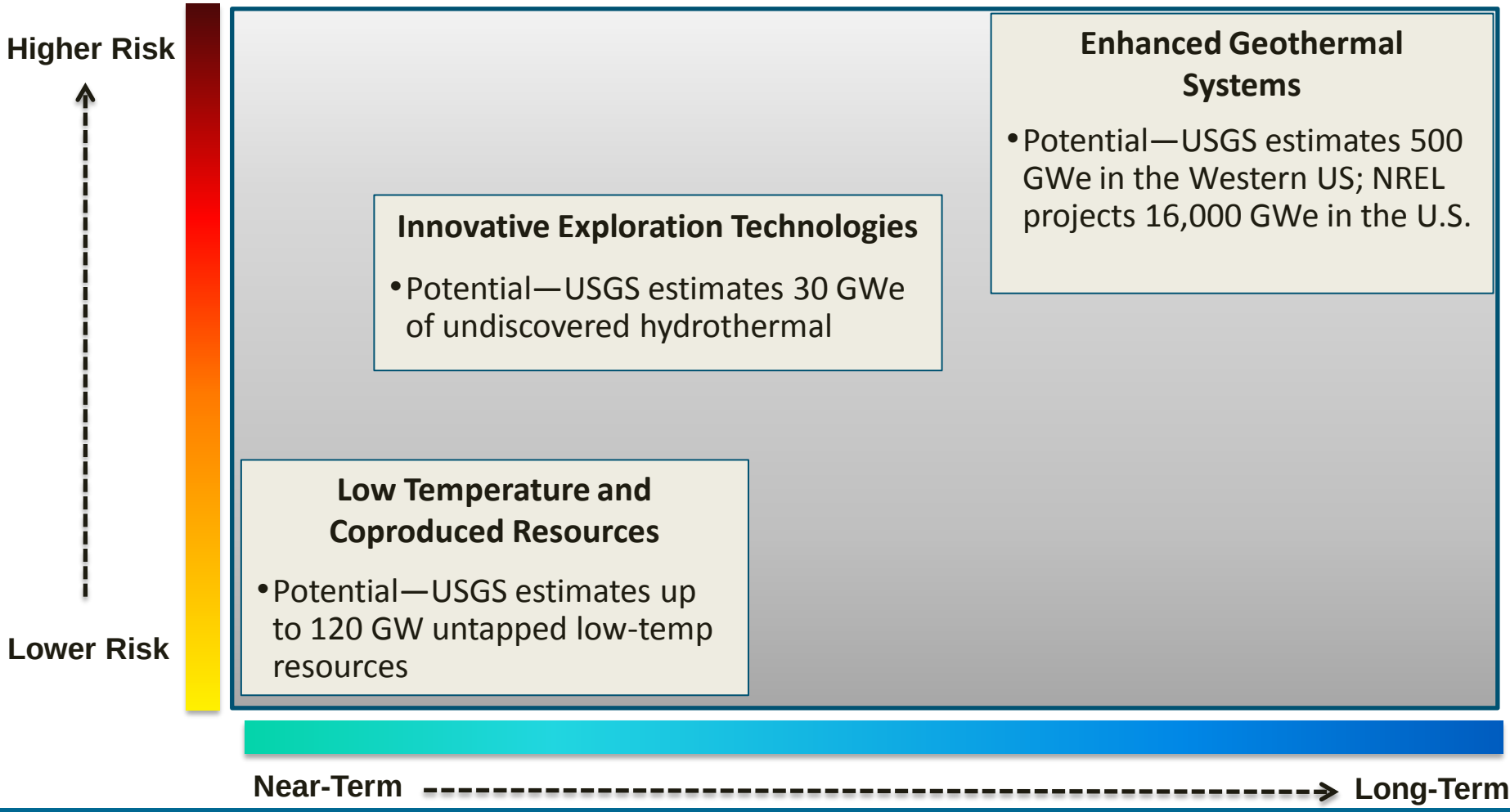
The Program currently supports a diverse portfolio that spans near- to long-term resources and low to high risk technology development. Almost $400 million in Recovery Act funding enabled this strategy.

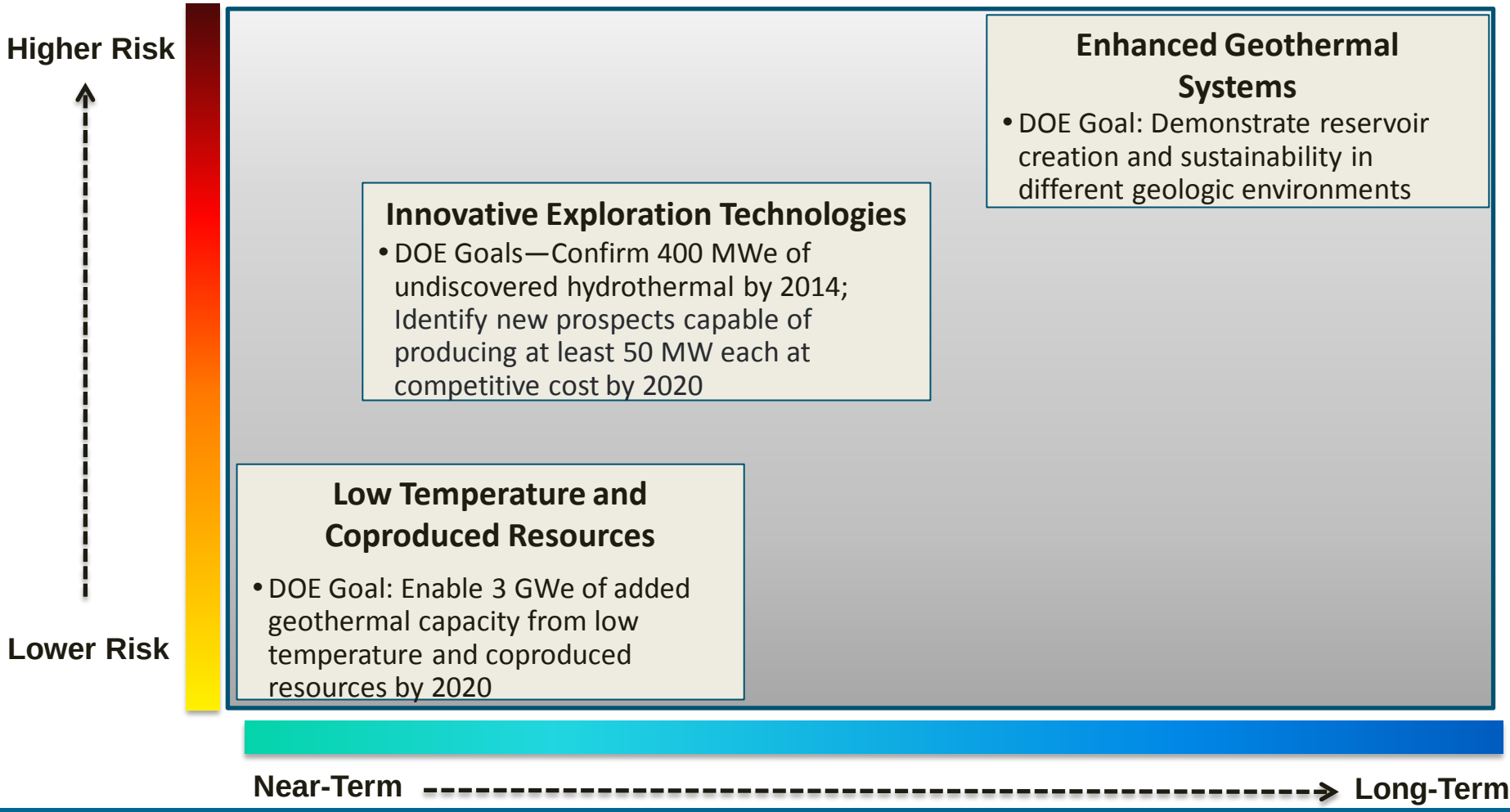
Current program pathways to increase geothermal power generation



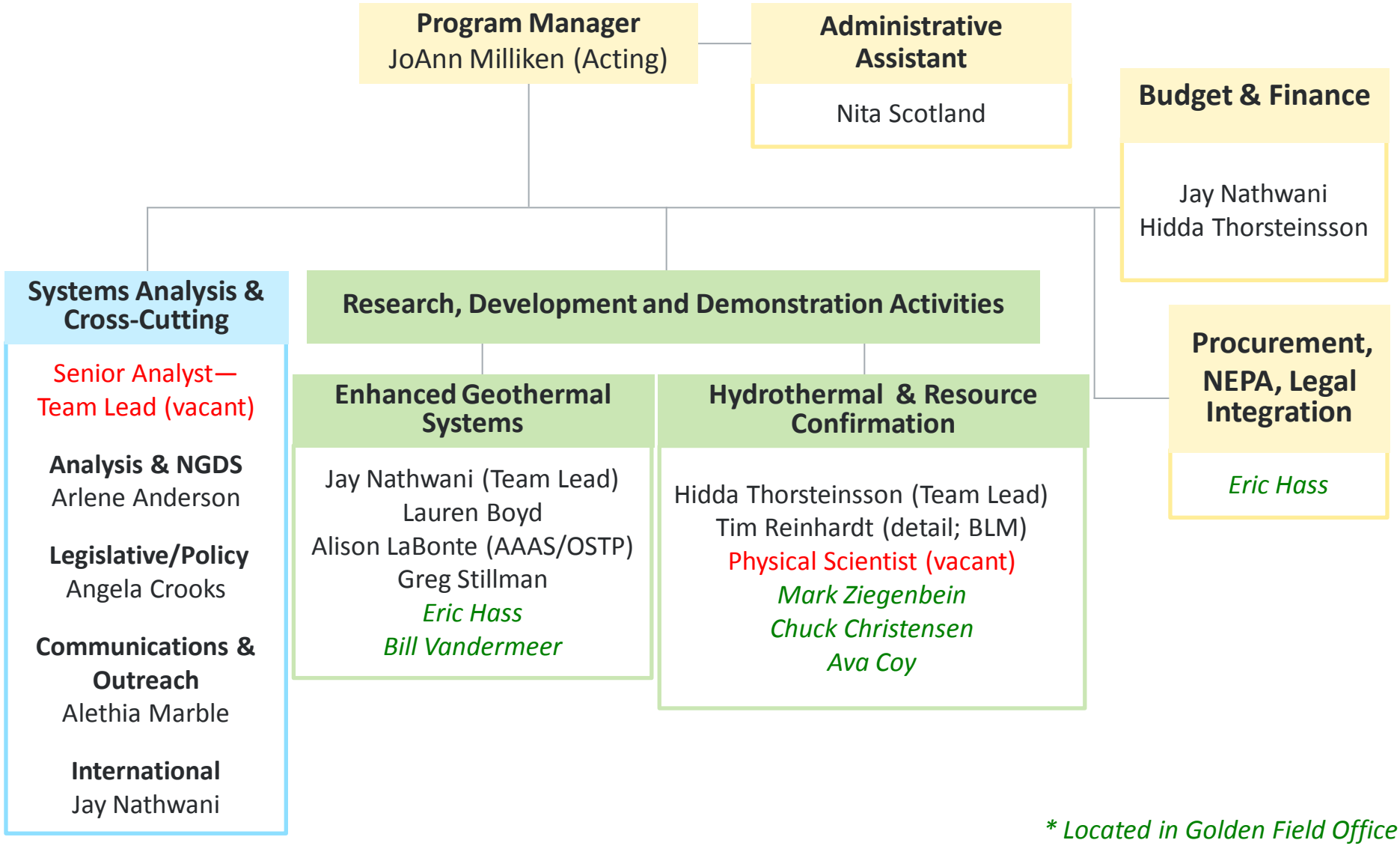
Current Program Goals

The Program's goal is reduce the cost of geothermal energy to be competitive with conventional sources of electricity, and accelerate the development of geothermal resources.

Current program pathways to increase geothermal power generation



DOE Program/Project Managers



** Located in Golden Field Office*

The Future

Geothermal Blue Ribbon Panel Asked to Help Shape the Future

Fifteen geothermal experts identified the obstacles to geothermal energy growth, discussed the appropriate role of DOE, and recommended priority R&D areas for the Program.

Recommendation—Narrow the focus of the Program and invest in critical need areas, targeting high-quality near-term resources to help the industry grow and long-term resources to tap the huge geothermal potential.

Accelerate Near-Term Market Growth—Hydrothermal

- Develop an inventory of high-quality prospects using existing technology
- Advance exploration technologies to reduce the cost and risk of drilling
- Develop technologies that reduce O&M cost

Secure the Future—Enhanced Geothermal Systems

- Define the optimal conditions for EGS and identify the best prospects
- Model the feasibility of reservoir creation using existing technology
- Develop tools to optimize power production and reduce costs
- Demonstrate the ability to create and maintain a reservoir in multiple geologic conditions

Financing and permitting were identified as major challenges for the industry. Panel members noted that policy in the form of a cost-shared drilling program and streamlined permitting would help overcome those challenges.

Cost Reduction Scenario Undiscovered Hydrothermal

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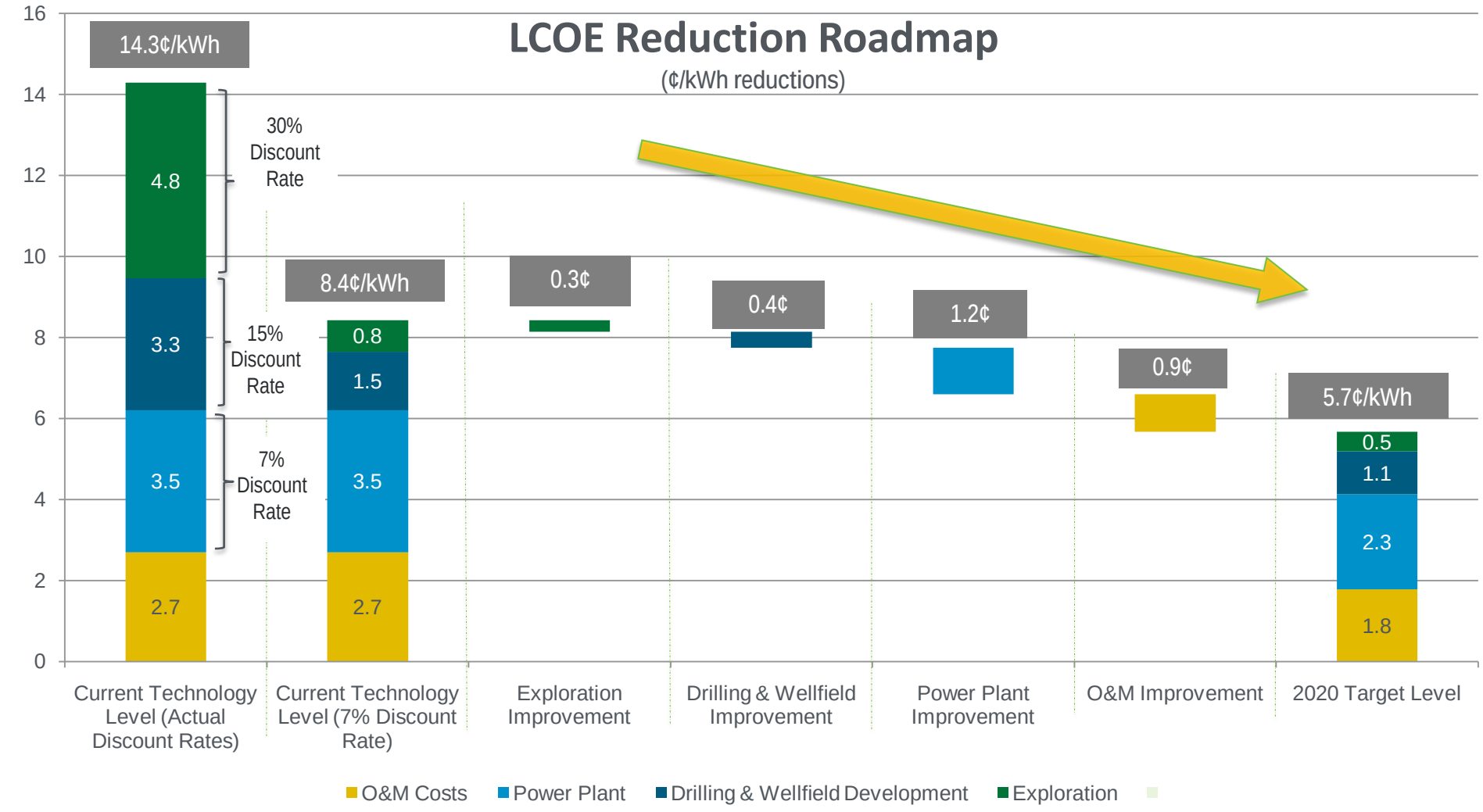
Primary cost drivers are power plant, O&M, exploration and drilling risk. Exploration cost and risk have led to high cost of capital. Therefore, the Program is focused on technologies and approaches to reduce upfront cost and risk.



Competitive Funding Opportunities

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Upcoming Funding Opportunity Announcements (FOAs) will focus on exploration and EGS R&D and Systems Analysis.

Geothermal R&D FOA

Anticipated Release: this week

Anticipated Total Funding: $70 million over 3 years

Potential topics:

- Advanced Exploratory Drilling Technologies
- Advanced Well Completion Technologies
- Zonal Isolation
- Observation Tools and Data Collection System for Reservoir Stimulation
- Geophysical Exploration Technologies
- Geochemistry/Rock-Fluid Interactions

For a link to the Notice of Intent go to: geothermal.energy.gov

You can sign up to receive notifications when FOAs are released: www.geothermal.energy.gov

Systems Analysis FOA

Anticipated Release: July 2011

Anticipated Total Funding: $3M over 2 years

Potential topics:

- Techno-Economic Impact of Federally Funded Geothermal Technologies
- Identification of Regional Geothermal Data Needs for Mapping New Geothermal Prospects
- Establishing High Quality Geothermal Data Sets
- Technology Assessment of Logging Techniques

Innovative Heat Recovery FOA

- Released in FY 2010, the objective of this FOA is to demonstrate innovative approaches to recovering heat from geothermal reservoirs.
- Selected projects will be announced in June 2011

Upcoming Program Activities

Data Collection and Model Validation

- To ensure Program cost analyses are representative and relevant
- To determine baseline cost and performance and track progress toward goals

Input to Strategic Planning and Roadmapping Efforts

- Blue Ribbon Panel Recommendations
- Exploration Roadmap
- EGS Roadmap
- Induced Seismicity Protocol
- Induced Seismicity Roadmap

Merit and Peer Reviews

- Proposal Evaluations
- Stage-Gate and Go/No-Go Reviews
- In-Progress Reviews

This Annual Program Peer Review will also Shape the Future

Purpose—Peer review is critical to ensuring that DOE projects are advancing geothermal technology and are enabling the Program and industry to achieve their goals.

1. **Provides DOE with Project Evaluations**—external, objective and informed evaluations on the relevance of funded projects to the Program's goals and objectives, the effectiveness of project management, the progress made toward the project objectives, and the potential of the future plans to move the technology forward.
2. **Provides Feedback to Principal Investigators** — they benefit from the peer review through expert feedback on project execution and suggestions on how to resolve problems or enhance the value of their research.
3. **Provides Forum for Collaboration and Transfer of Technology**

Your evaluations and feedback will shape the direction of this Program.

Thank you for being here!

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Hydrothermal and Resource Confirmation Overview

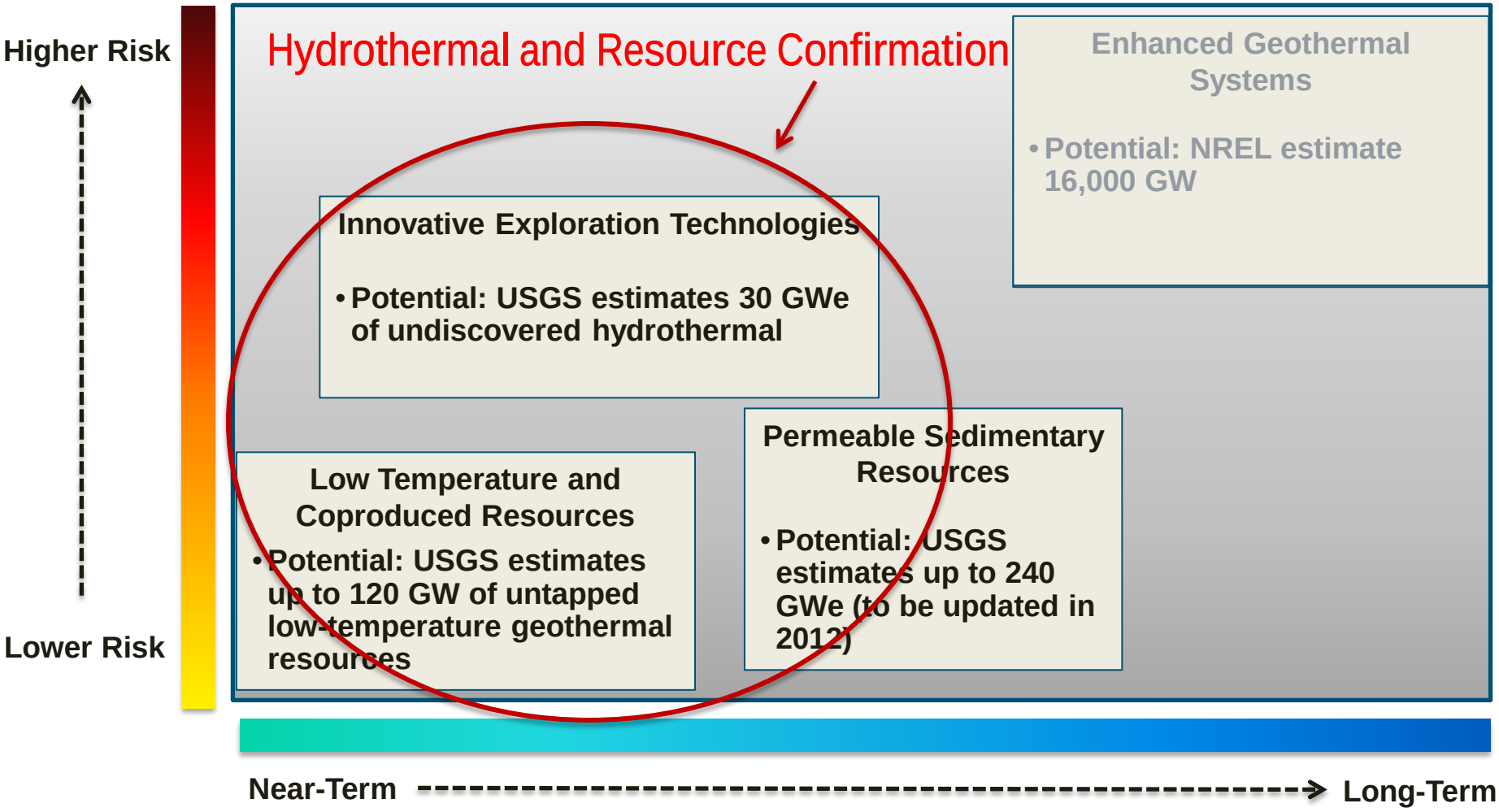
June 6, 2011

Geothermal Technologies Program Peer Review

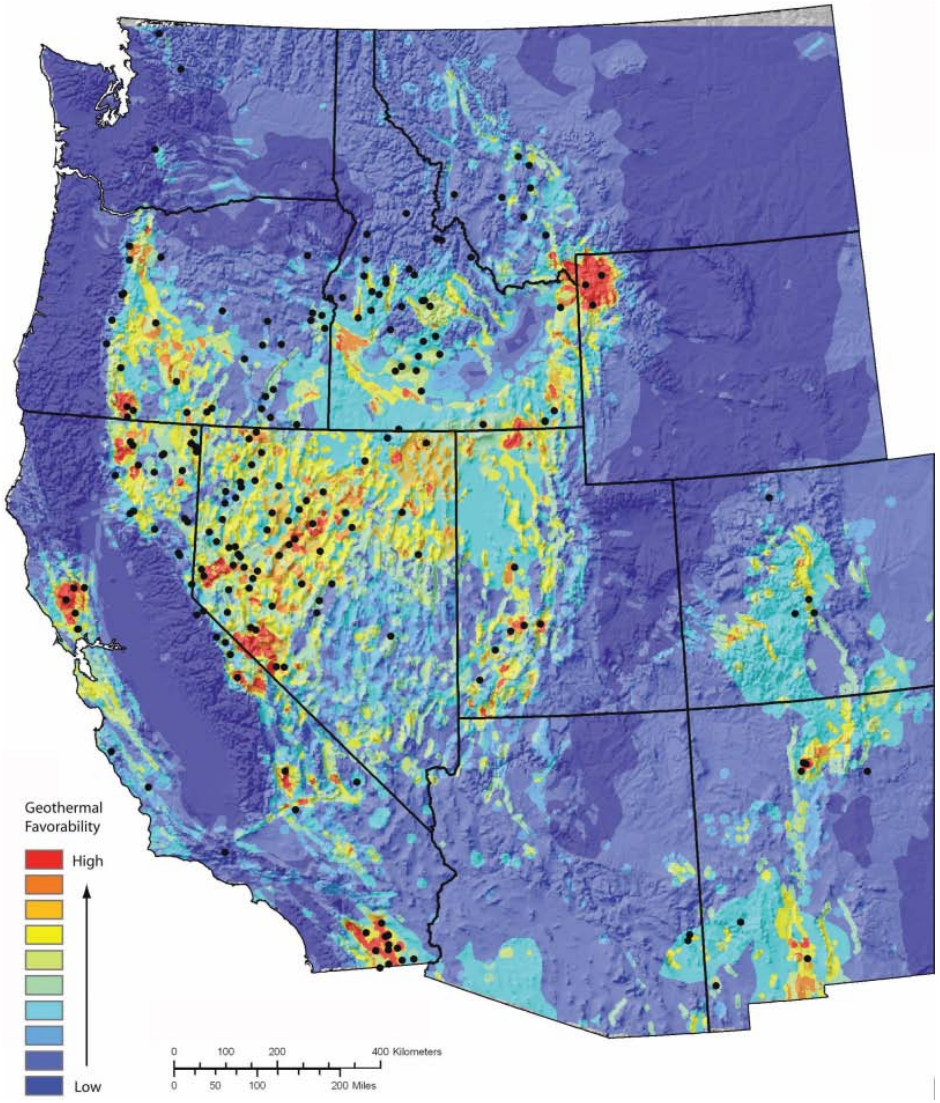
Bethesda, MD

Hidda Thorsteinsson
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Hydrothermal and Resource Confirmation – Where do we play?



Opportunity



30 GW of undiscovered resources

- 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

Ref. USGS 2008

Challenges & Approach

Challenges

- The exploration phase of geothermal development is a risky financial venture
- Some resources show no surface expression, making them difficult to confirm
- Making geothermal competitive with conventional sources

Approach

• Develop exploration tools for resource confirmation in undiscovered geothermal fields to reduce high upfront exploration risks and costs.

• Conduct regional data gathering

• Continue R&D to lower operation and maintenance costs

Goals

Research, develop and demonstrate new technology and approaches to identify X amount of prospects capable of producing at least 50 MW at competitive prices with conventional sources by 2020.

- Confirm 400 MW and validate 2 new innovative methods by 2014 (ARRA)
- Lower exploration costs per site
- Increase exploration success rates?
- In the process of roadmapping to establish exploration technical and cost targets

It's been an exciting year!

- Seven new exploration wells have been drilled
- Currently drilling 1 well in the Snake River Plain
- 17 projects in active exploration phases throughout the western U.S
- Installed a bottoming plant at Beowawe, NV

Project Highlights

Calpine at Caldwell Ranch, CA

Preliminary results from three wells drilled show a good resource and a combined capacity of about 12MW.

Ormat at Maui, HI

Demonstrating viability and cost-effectiveness of merged gravity-helimagnetics for geothermal exploration.

TerraGen at Beowawe, NV

Built and commissioned a 2 MW low temperature bottoming plant, achieving a nearly 20 percent increase in electrical capacity.

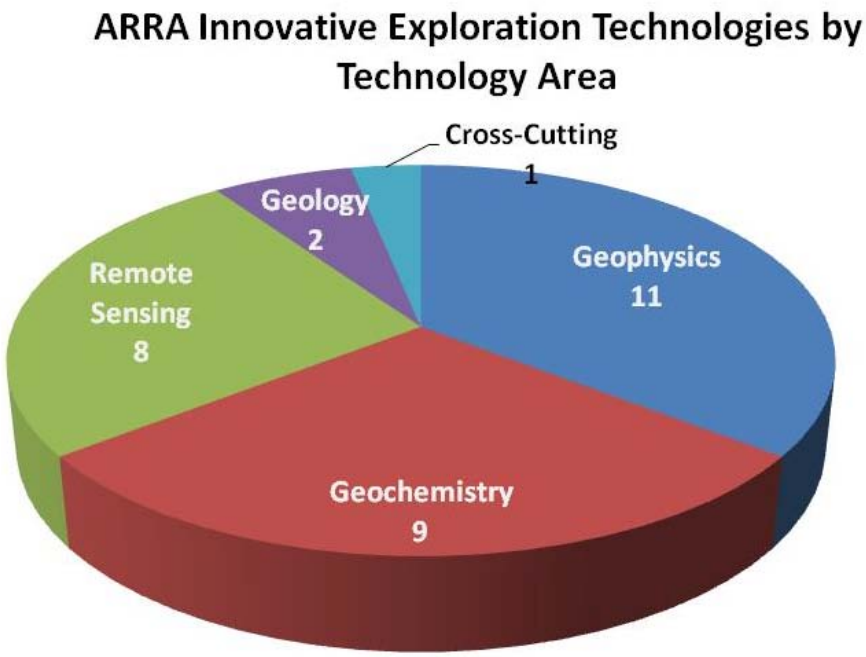
Investment in Hydrothermal & Resource Confirmation (HRC)

Recovery Act	
Exploration Technology Validation	$97.2M
HRC Research and Development	$17M
Low Temperature Demonstrations	$18.7M

FY 2010	
Low Temp and Coproduced Resources	$14.5M

FY 2011	
Hydrothermal and Resource Confirmation	$17M

FY 2012 Request	
Hydrothermal and Resource Confirmation	$29M



Number of ARRA IET Projects working in each technology area

Technologies

Regional Reconnaissance

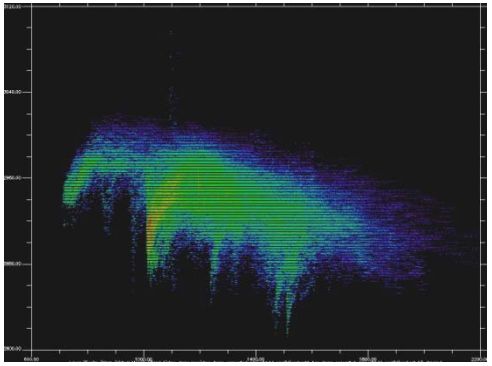
- Remote Sensing
- Data Gathering & Analysis

Prospect Identification & Characterization

- Geophysics - advanced seismic, remote sensing, heat flow
- Geochemistry – geothermometers, soil gas surveys
- Geology – structural models
- Crosscutting – 3D modeling, multi-disciplinary conceptual models

Advanced Exploratory Drilling Technologies

- Tools/Components
- Systems
- Methods



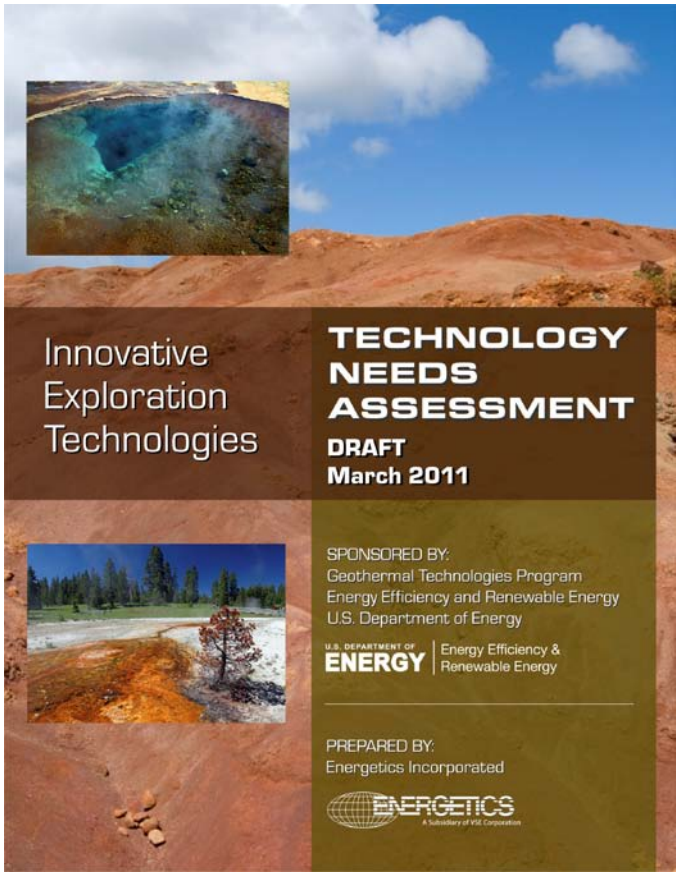
Operation and Maintenance

- Power Conversion
- Processes and Procedures

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

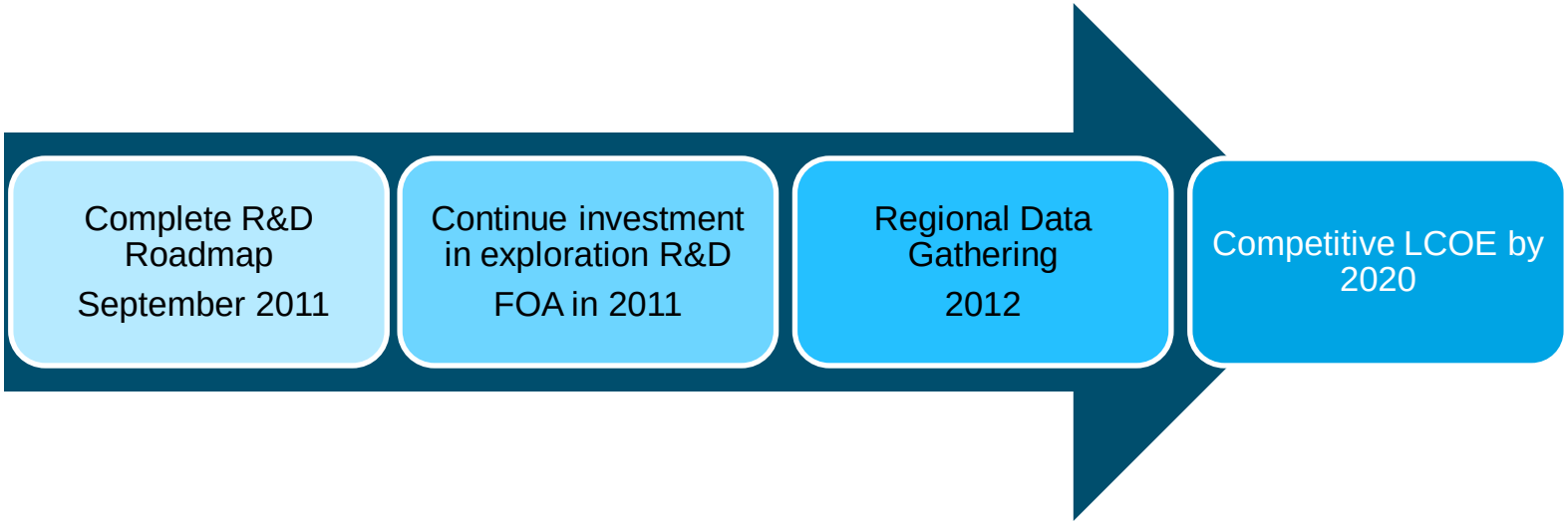


Ten advancement needs

Technology Areas
Non-invasive geophysical techniques and improved data collection and interpretation for existing techniques
Improved invasive measurements tools and techniques
Improved next-generation geophysical airborne data
Improved geochemical techniques to estimate reservoir temperature and processes
High resolution remote sensing data and reliable automated processing methods
Stress/strain data mapping
Multi-disciplinary conceptual models
3-D modeling software
Identification of potential surface signals that identify deeper, hidden systems
Create case study examples of geothermal systems in different settings

What's Next

- Establish technical and cost targets through roadmapping
- R&D in advanced exploratory drilling, and geophysical and geochemical techniques
- Gather data on exploration success rates, cost, technology baselines, etc.
- Continued progress on ARRA and FY10 projects
- Regional data gathering



Thank you!

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EGS Subprogram Overview

June 6, 2011

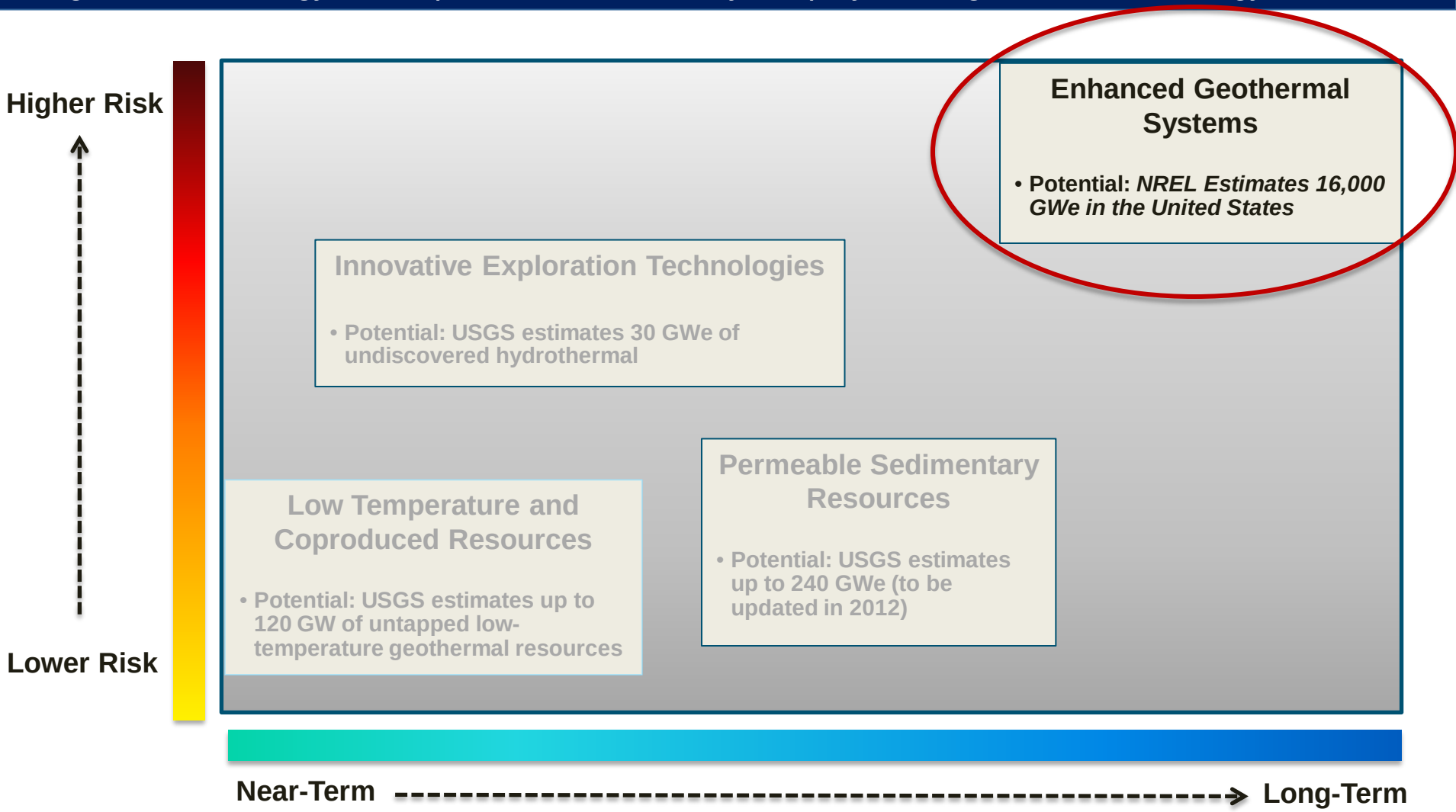
Geothermal Technologies Program Peer Review

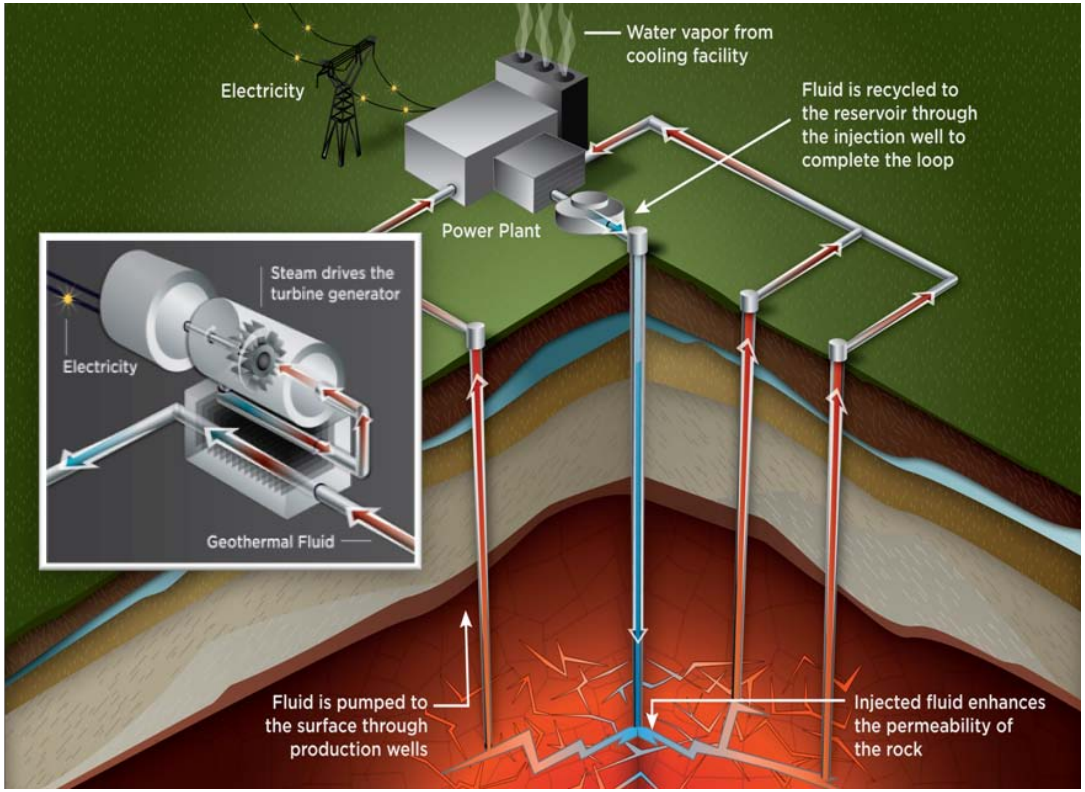
Bethesda, MD

Jay Nathwani
Geothermal Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Program Strategy

The Program currently supports a diverse portfolio that spans near- to long-term resources and low to high risk technology development. The Recovery Act played a big role in this strategy.





Opportunity

- Heat is present almost everywhere at depth.
- EGS can provide emission-free baseload power across the U.S.

Key Elements

- Stimulation opens up fractures in crystalline rock, creating a reservoir km below the surface.
- Water is injected through the reservoir and back to the surface to produce electricity.

Challenges

- Geothermal reservoirs must be engineered so that flow rates remain high while thermal drawdown is limited.
- Establishing inter-well connectivity 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.

Establish technical feasibility of 5 MWe by 2020 and sustain for 5 years

- **Reduce high level of risk during early stages of EGS development**
- **Resolve key component R&D challenges**
- **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**

Flow Rate:	***60 kg/s***
Drilling Systems:	***10,000 m, 374° C***
Downhole Sensors:	***>1000 hours***
Water Losses:	***<10%***
Reservoir Life:	***~30 years***

- Roadmapping workshop will refine performance and cost metrics.

Conduct RD&D to demonstrate technical feasibility of power production from an EGS reservoir and over the long-term, reduce the costs of energy production

Approach

Technology Advancement through R&D

- Develop tools and models that better characterize fractures and fracture networks.
- Advance high-temperature and high-pressure tools, sensors and equipment.
- Gain public support through experience and better scientific understanding of induced seismicity.

Demonstrations

- Seven demonstration projects in Nevada, California, Oregon, Alaska, and Idaho
  - Controlled hydrofrac stimulation is underway at Desert Peak, NV

Award Year	Estimated Total Funding (millions)	# Projects
Pre- FY 2008	$4.3 (Demos)	1 (Demos)
FY 2008	$19.0 (R&D) $18.6 (Demos)	17 (R&D) 3 (Demos)
ARRA	$111.9 (R&D)* $ 44.2 (Demos)	76 (R&D) 3 (Demos)
FY2009	$29	
FY2010	$16	
FY2011	$16	
FY2012	$61.5 (Request)	

* includes cross-cutting R&D

Enhanced Geothermal Systems (EGS)

The Program collaborates with industry, universities and national laboratories on R&D, which drives cost reductions for all geothermal systems. EGS Demonstration projects includes near field and green field sites.

EGS Demonstration Projects

Recipient	Project Site	Site Information	Status
AltaRock Energy Inc ($21.5 M)	Newberry Volcano, OR	High potential in an area without existing geothermal development	Completing EA and ISMP
Naknek Electric Association ($12.4 M)	Naknek, AK	Located in remote location in Alaska without existing geothermal development	Logging will be initiated next month
TGP Development Co. ($10.4 M)	New York Canyon, NV	Site adjacent to existing hydrothermal sites and shows high temperatures at shallow depths	Revising scope change
Ormat Technologies, Inc. ($4.3 M)	Desert Peak, NV	Adjacent to existing hydrothermal sites	Completed controlled hydrofrac
University of Utah ($8.9 M)	Raft River, ID	Improve performance of the existing Raft River geothermal field	Induced Seismicity draft report under review
Ormat Technologies Inc ($3.4 M)	Bradys Hot Springs, NV	Improve performance of the existing geothermal field	Building geologic and structural 3D model
Geysers Power Company, LLC ($6.2 M)	The Geysers, CA	Two existing wells will be reopened and deepened for injection and stimulation	Stimulation is planned

Polycrystalline diamond compact drill bit which has worn down in hard rock (below) and must be replaced – adding time and cost to drilling.

The Program is investing in innovative drilling technologies – including **hydrothermal spallation**, (right) which use superheated water to cut through rock.

EGS Demonstration Induced Seismicity Stage Gate

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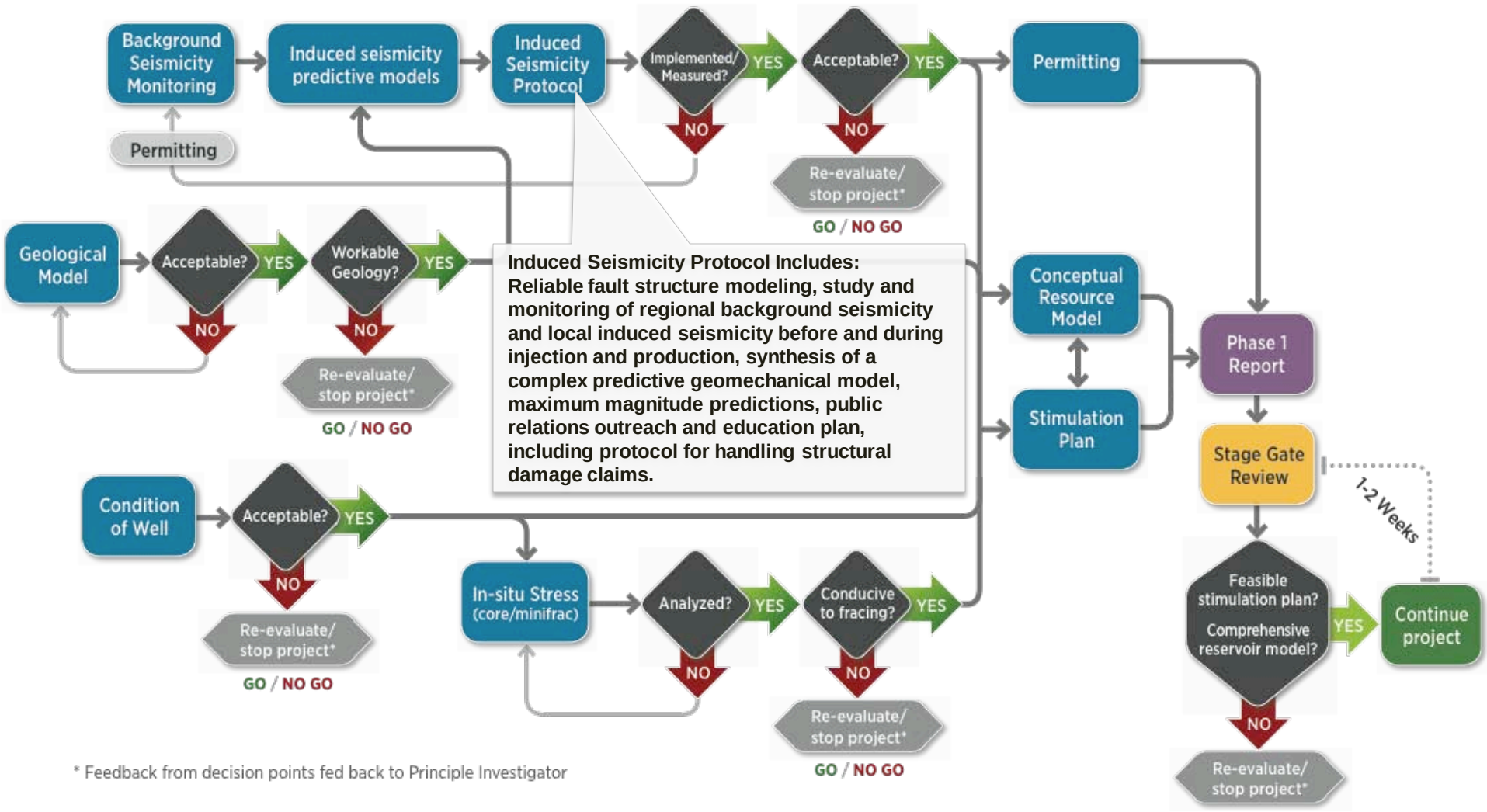
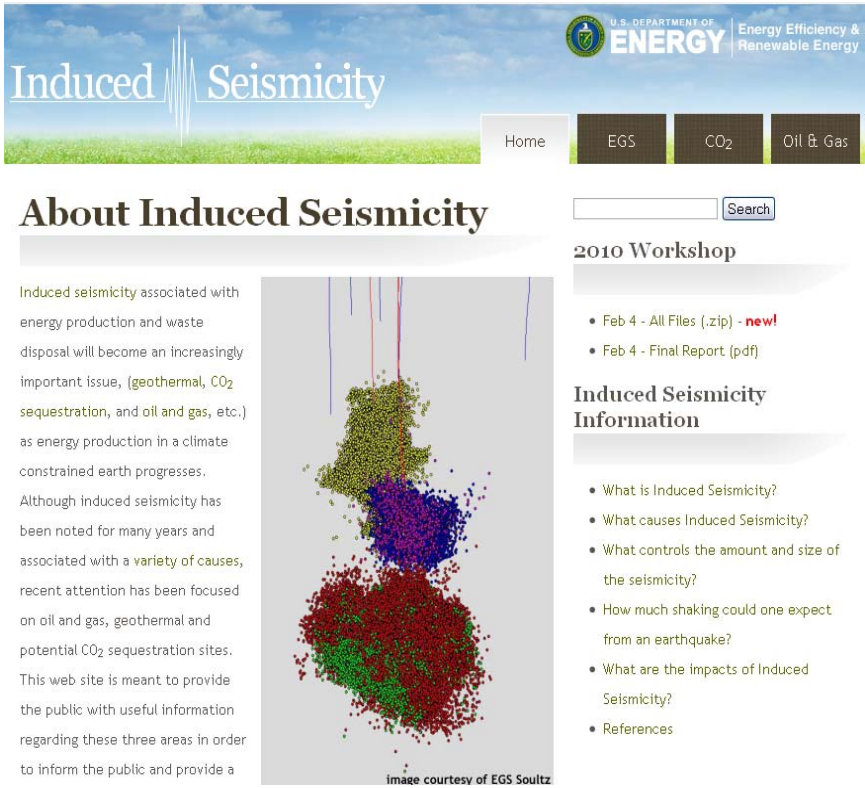
DOE-funded EGS demonstration projects must comply with a series of technical stages gates, including compliance with the induced seismicity protocol.



New Induced Seismicity Protocol

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.

- ***Living document*** for the public and regulators, and geothermal operators- should change as methods, experience and regulations change.
- ***Local conditions*** at project sites, including population density around sites, past seismicity, etc will dictate the action that takes place at each project.
- Procedures are suggested as an approach in order to ***engage the public, industry and regulators***.
- Provides a ***more accurate approach*** to address and estimate seismic risk associated with EGS.
- Identifies "***ground motion***" as the more relevant impact of induced seismicity as opposed to event magnitudes.
- Recommendations are based on pre-existing, well ***established engineering standards*** used in mining, constructions etc. related to shaking and noise.
- Discusses ***legal implications*** of recommended actions.



EGS Roadmap Workshop

DOE's continued EGS technology RD&D will have critical impact on the U.S. energy supply, but not without gaining public support through experience and better scientific understanding.

GTP will be holding a two-part EGS Roadmap Workshop

- Purpose: Exchange facts and information with subject matter experts to define performance and cost metrics and milestones needed to achieve EGS goals.

- Interested parties to e-mail to EGS@ee.doe.gov:
  - Name and contact information
  - Reason for participation and expected contributions to the workshop
  - An attached biography and CV

Photo credit: Ram Power Corp.

Timeline

- Workshop I – June 2011
- Draft Debut – Sept 2011
- Final Debut – Oct 2011

Thank you!

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Systems Analysis

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Arlene Anderson, Lead Systems Analysis
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Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

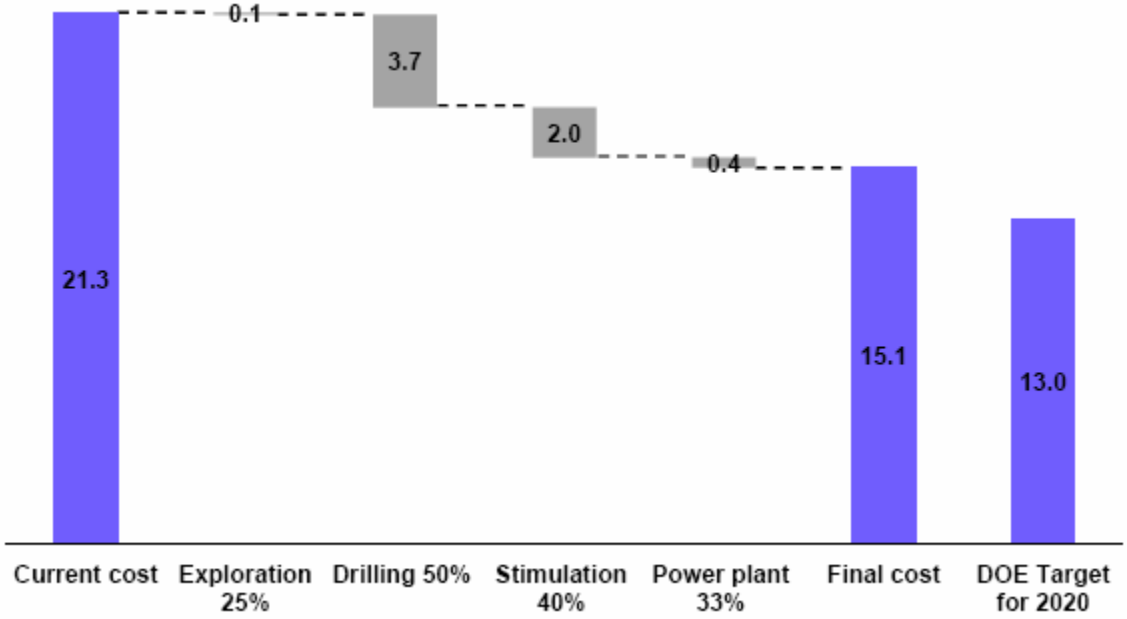
Systems Analysis Strategy

The Systems Analysis effort provides data and information tools to support geothermal RD&D and informs decision-makers.

Key Activity Areas

Techno-economic Analysis	• What are geothermal system costs and RD&D impacts on LCOE?
Market, Policy & Regulatory Analysis	• What is the geothermal market share? What are the regulatory barriers to adding more power to the grid?
Resource Assessment and Classification	• How do we estimate and describe the resource? • What is the supply potential?
Environmental Analysis	• What are the environmental impacts & benefits?
Data Provision	• How do we reduce development risks & enable RD&D through data sharing?

RD&D Lowers Geothermal LCOE



Impact of New Technologies on Near-Field EGS LCOE

(2010 cents per kilowatt hour)

Source: Turaga (ADI Analytics); June 6, 2011 Annual Peer Review

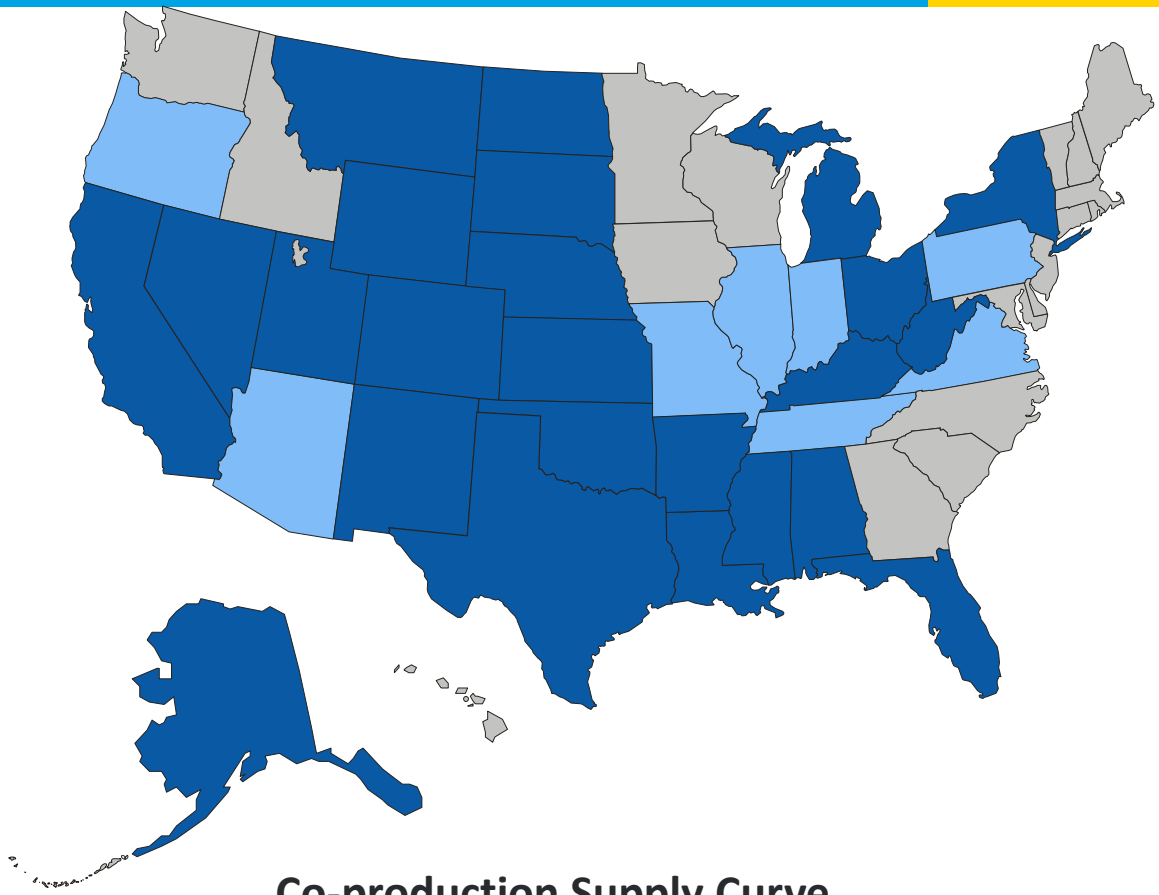
Resource Temperature (C)	117	378	189	458
Depth (m)	3,000	10,000	5,000	12,500
Exploration wells	1	2	1	2
Confirmation wells	0	2	0	3
Production wells	1	204	8	19
Injection Wells	1	143	3	13
Production Flow Rate (kg/sec)	12	150	12	85
Power Generation (MWe)	2	80	2	44
Exploration & Confirmation costs/MW ($K)	140	9,087	97	13,963
Well Field Dev. Costs/MW ($K)	3,888	66,421	7,852	51,714
O&M costs/MW ($K)	147	1,034	175	619
Capital Costs/MW ($K)	6,529	78,531	9,817	56,111
LCOE (c/kW-hr)	0.14	1.40	0.19	0.95

EGS Cost Data

74 scenarios of EGS development

Source: Gowda (EGI); Economic Impact Analysis for EGS Presentation

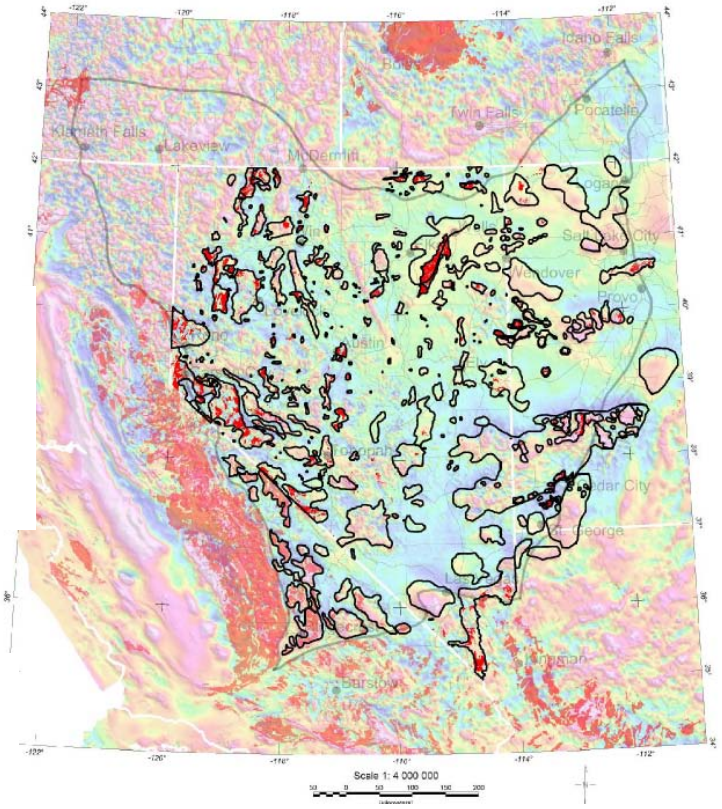
How Much Power Can Geothermal Provide – Estimating Resource Potential



Co-production Supply Curve

Developed database of 2.5 million wells from 32 state oil and gas well databases

Source: Augustine (NREL); June 6, 2011 Annual Peer Review



USGS Resource Assessment

Identifying issues for assessing geothermal resources

Source: Williams (USGS); June 6, 2011 Annual Peer Review

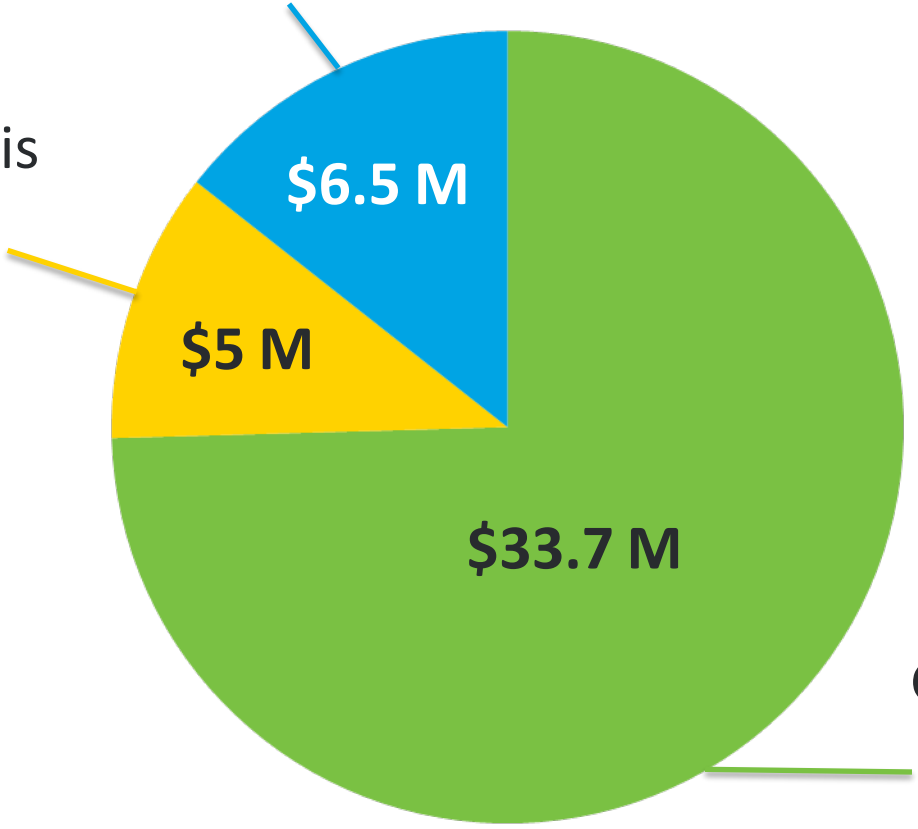
Funding & Budget—Systems Analysis

Systems Analysis

(ARRA Funding)

FY11 Funding

- Systems Analysis
- Education & Workforce Development
- International



National Geothermal Data System

(ARRA Funding)

Systems Analysis Portfolio

Techno-economic Analysis

Projects Undergoing Peer Review

- Geothermal Supply Curves—Geopressured and Co-produced
  - *Current Focus*—updating undiscovered hydrothermal and enhanced geothermal systems
- Life Cycle Costs of Baseline EGS
- Co-production Risk Assessment
- Decision Analysis for EGS
- Energy ROI of EGS
- GETEM Model Development
- Costs/Benefits of Geothermal Heat Pumps

Market, Policy & Regulatory Analysis

Projects Undergoing Peer Review

- Guidebook to Geothermal Power Finance
- RE Project Financing Website
  - *Current Focus*—WebView
- RE Finance Tracking Initiative (REFTI)

Current Focus

- Feed-in Tariffs; Incentivizing Geothermal Tool; Geo Business Models

Environmental Analysis

Projects Undergoing Peer Review

- Life Cycle Assessments on Emissions, Water and Energy Use
- Water Resource Requirements for Geothermal Energy Production

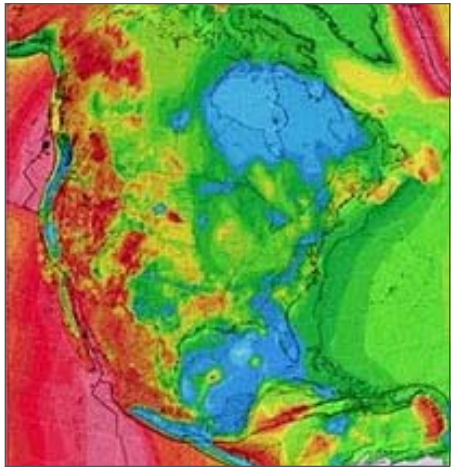
Systems Analysis Portfolio cont'd

National Geothermal Data System (Data Provision) + **Resource Assessment and Classification**

Three-part strategy to reduce the risk of geothermal development.

1. **System Design, Development and Testing**—system will encompass the full range of geoscience and engineering data:
   - data on geothermal site attributes, power plants, environmental factors, policy and procedure data, and institutional barriers;
   - resource classification and financial risk assessment tools.
2. **Data Development, Collection & Maintenance**—system will be populated by linking to high quality data sets in partnership with all state geological surveys, Southern Methodist University and all awardees.
3. **Resource Assessment and Classification**—in collaboration with the U.S. Geological Survey, revise and update the assessment of geothermal resources in all 50 states, including all types of geothermal resources (geopressured, EGS, hydrothermal, permeable sedimentary, etc).

NGDS National Geothermal Data System



Thank you!

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