Hot Rocks and Hard Places

Geothermal Resources Council Annual Meeting – September 30, 2013

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

Doug Hollett, Director
Geothermal Technologies Office

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

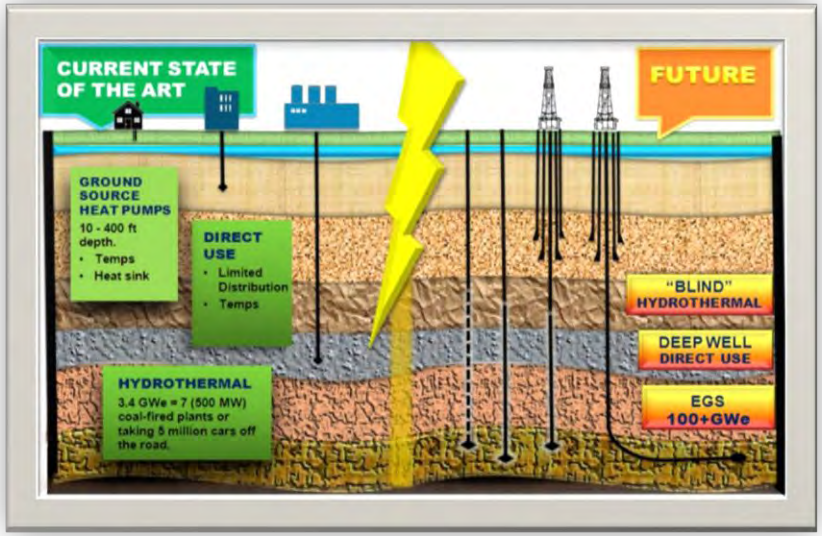
- Regulatory Roadmap: Streamlining
- National Geothermal Data System: Reducing upfront exploration cost

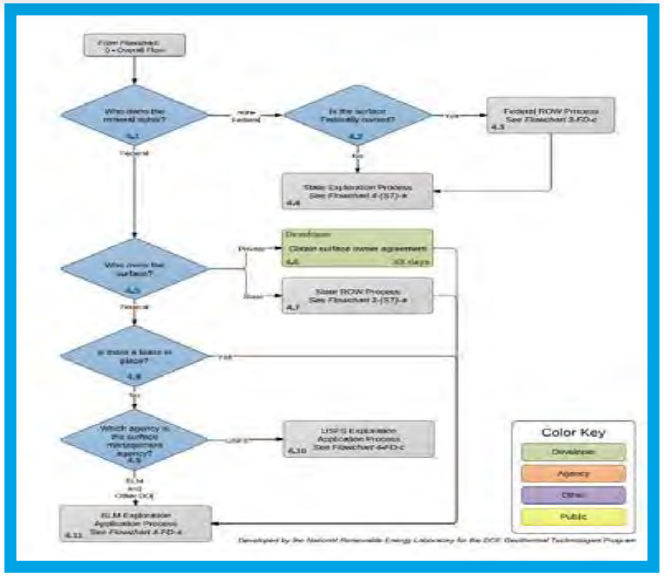
Additive Value

- 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





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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

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

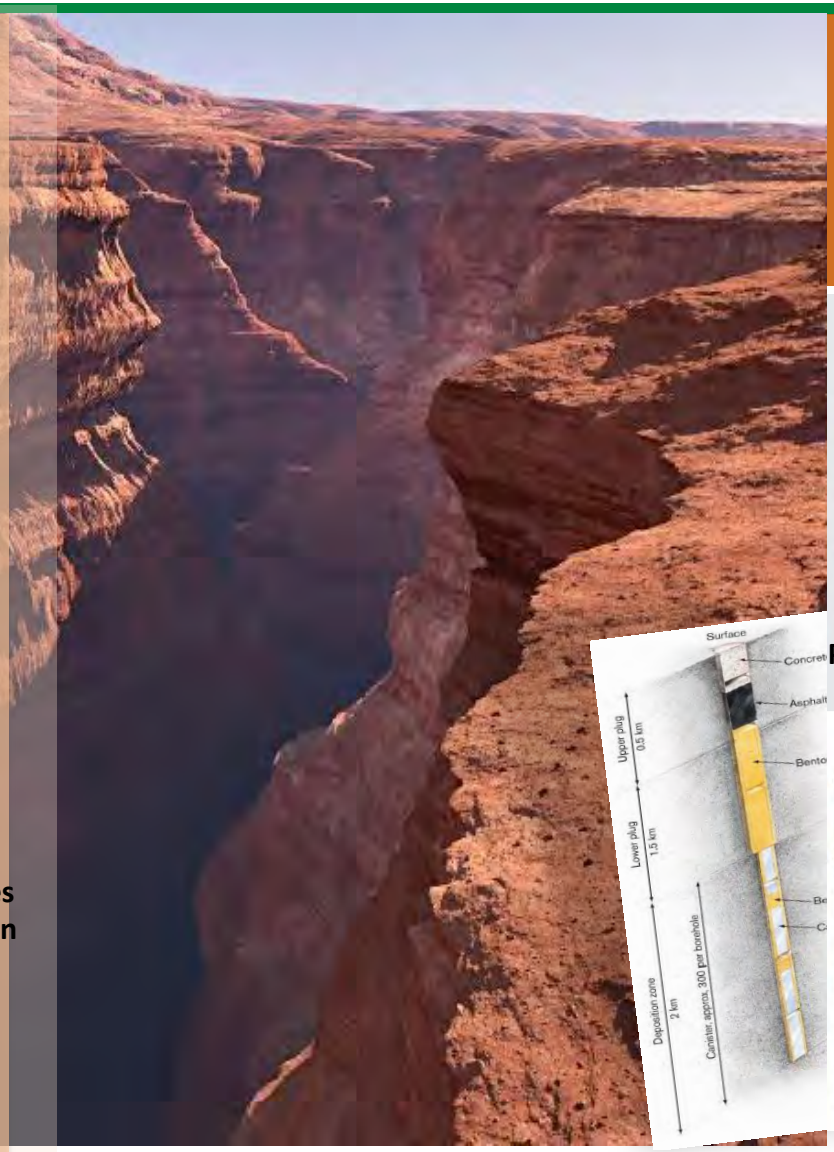
Create/construct desired subsurface conditions in challenging high-pressure/high-temperature environments

Sustaining

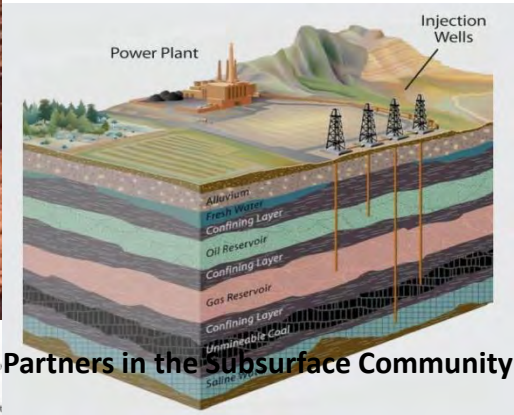
Maintain optimal subsurface conditions over multi-decadal or longer time frames through complex TMHC system evolution

Monitoring

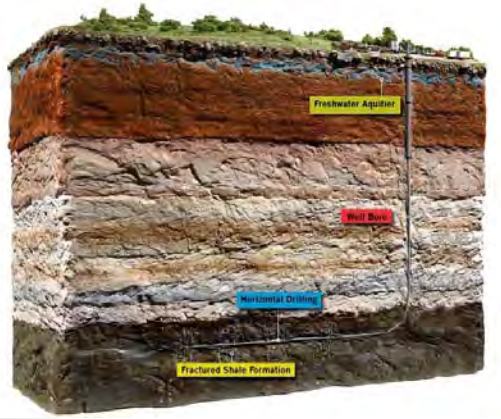
Improve observational methods and advance understanding of multi-scale complexities through system lifetimes



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



Partners in the Subsurface Community



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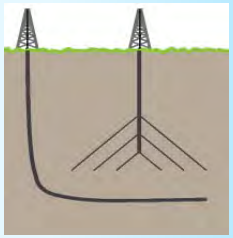
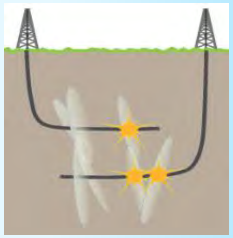
Key Barriers to EGS Development *Technology and Engineering Needs*

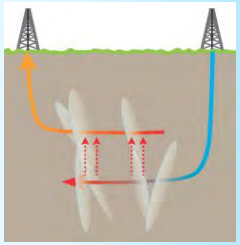
Technology Barriers	GTO-Funded Solution Set	GOAL



Reservoir Access
New well geometries and concepts, optimized drilling



Reservoir Engineering
Characterize local stress, zonal isolation, novel fracturing methods, increase fractured volume per well



Productivity
Increase flow rates without excessive pressure needs or flow localization

Sustainability
Maintain productivity with minimal thermal drawdown and water losses

Hard/Hot-rock drilling, completion technologies

Rotary steering

Stress-field diagnostics

Smart tracers

Zonal Isolation

High-T sensors

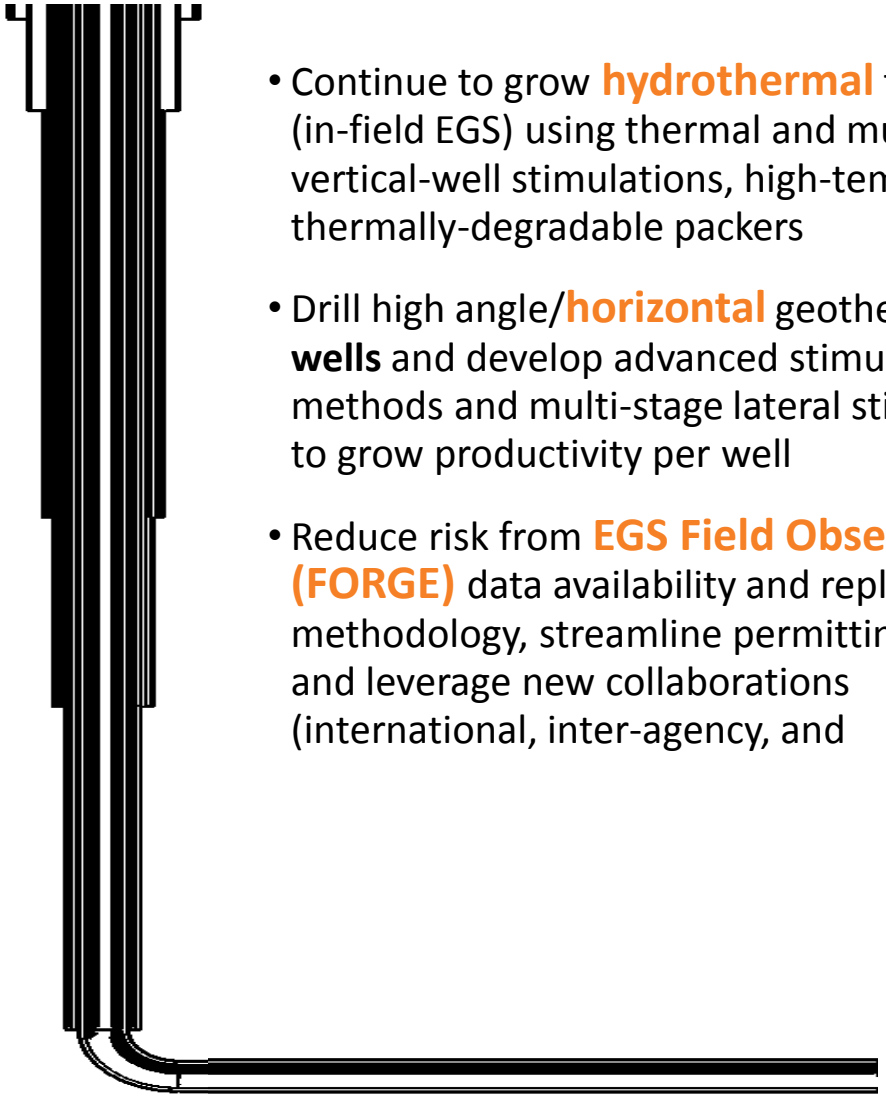
Cross-well monitoring

Diverter technologies

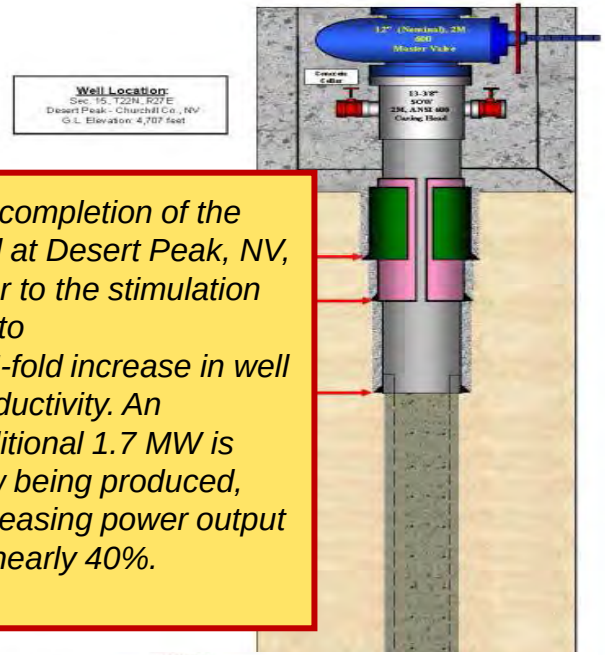
EGS Success

Game-changers

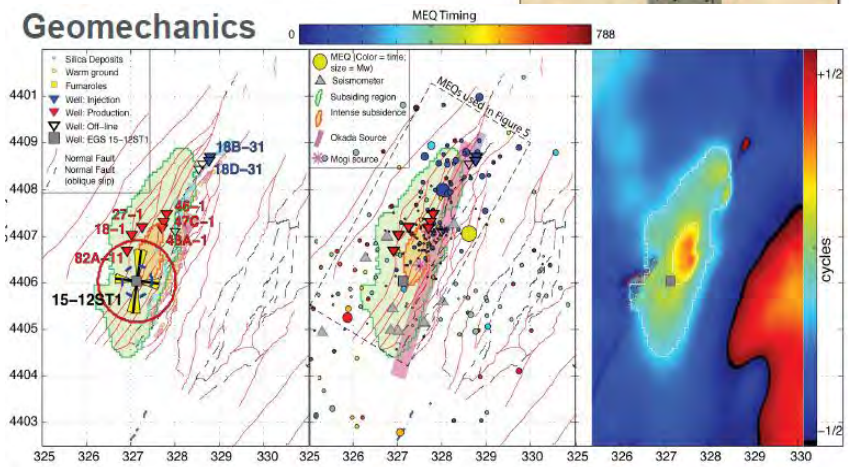
What's Next for EGS? *In-Field Stimulations, Horizontal Wells, Replicability*



- Continue to grow **hydrothermal** fields (in-field EGS) using thermal and multi-stage vertical-well stimulations, high-temperature thermally-degradable packers
- Drill high angle/**horizontal** geothermal **wells** and develop advanced stimulation methods and multi-stage lateral stimulations to grow productivity per well
- Reduce risk from **EGS Field Observatory (FORGE)** data availability and replicable methodology, streamline permitting and leverage new collaborations (international, inter-agency, and



Re-completion of the well at Desert Peak, NV, prior to the stimulation led to 175-fold increase in well productivity. An additional 1.7 MW is now being produced, increasing power output by nearly 40%.



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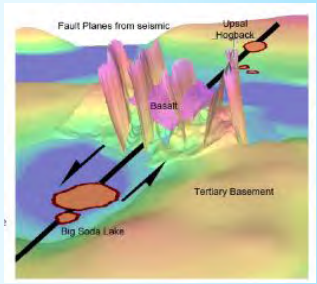
Key Barriers to Hydrothermal Expansion

Innovative Exploration Technology Needs

Technology Barriers	GTO-Funded Solution Set	GOAL



Resource Characterization

Non-unique signals, blind resources, cost, downhole tools limited by temperature

New occurrence models

Play Fairway analysis

Blind resource signatures

Reservoir Access

Comparative lack of high performance drilling tools for large diameter, high-temperature, rock drilling, cost

High temperature tools

Feasibility study for Horizontal wells

Sustainability

Maintain productivity with minimal thermal drawdown and water losses

Rotary steering

Remote sensing

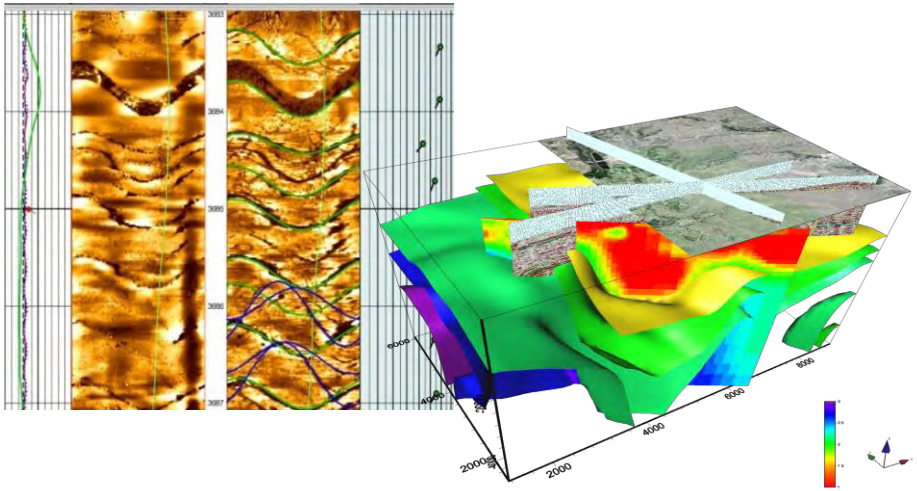
Leveraging O&G technologies

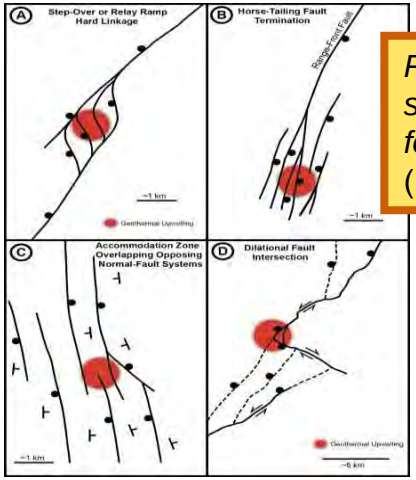
Hydro thermal Growth

Game-changers

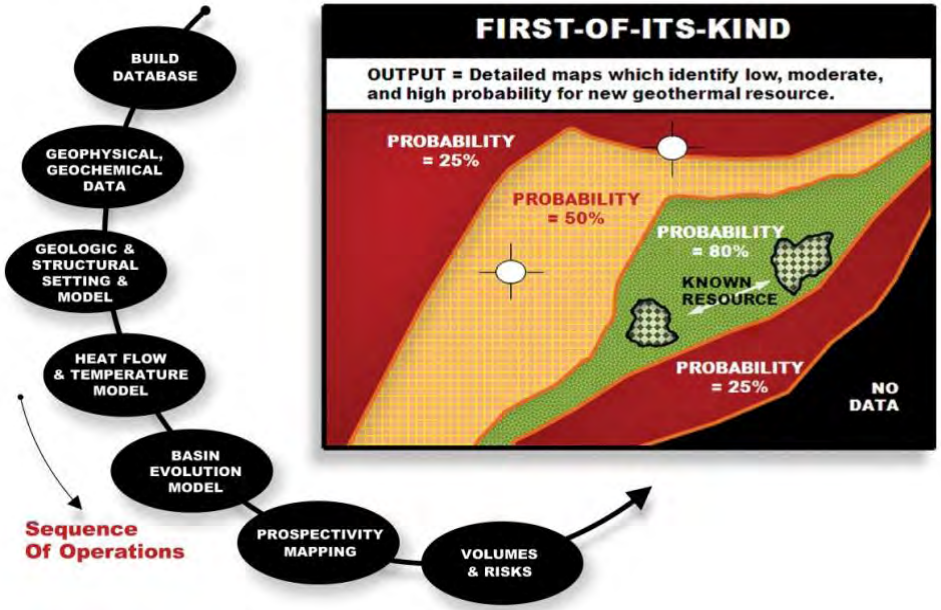
What's Next for Hydrothermal? *Tools, Maps, Analysis, "Plays"*

- **Advance Innovative Exploration Technologies** (IET) through targeted drilling and geophysical techniques
- **Accelerate adoption of modified Oil and Gas technologies** into the geothermal sector
- **Execute Play Fairway Analysis** (adapted from oil and gas) - observational, analytical integration, interpretation, basin and system evolution





Favorable structural settings and setting types for geothermal systems (Faulds et al., 2011)



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Key Barriers to Low Temp Expansion *Technology and Engineering Needs*

Technology Barriers	GTO-Funded Solution Set	GOAL

Cooling Technologies

Air-cooled systems are constrained in hotter areas of the arid, but geothermal-rich Western U.S.

Fluid Value

Need additional uses/value streams to accommodate lower electricity value from low temp fluids

Energy Conversion

Improve efficiencies for lower temperatures, operation & maintenance, cost

Leveraging O&G infrastructure

Innovative conversion cycles

Hybrid cooling cycles

Materials Extraction

Advanced working fluids

Improved binary system components

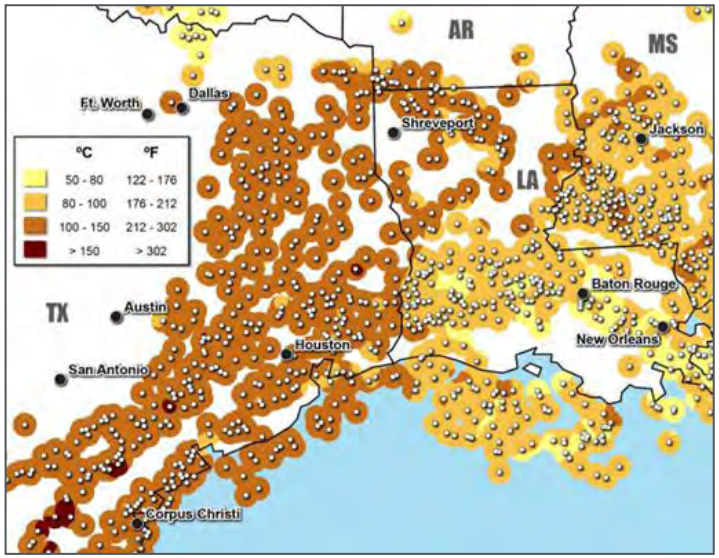
Hybrid Technologies

Co-production

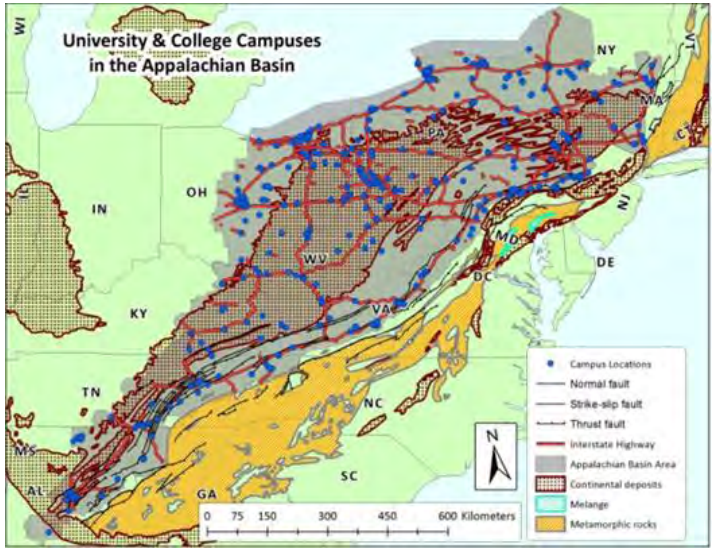
Lo-Temp Copro Growth

Game-changers

What's Next for Low Temp? *Materials Extraction, Direct-Use, Hybrid Systems*



- Execute on Coproduction initiative
- Strategic Materials - Resource assessment and feasibility
- Large-scale Direct Use: where does it make technical and commercial sense?
- R&D on innovative



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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**.

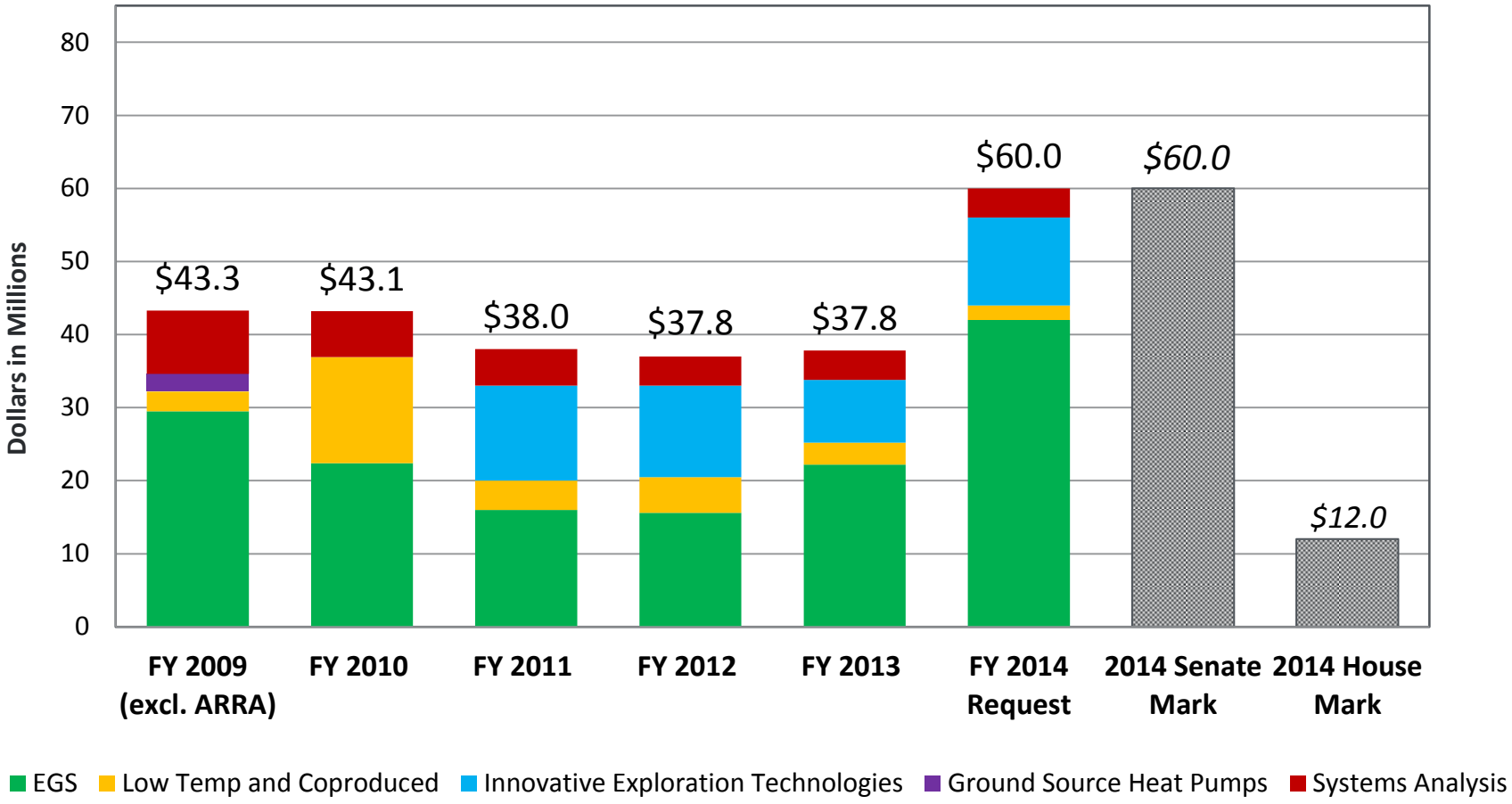
Geothermal Regulatory Roadmap (GRR)

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.

Budget Overview



Planned GTO 2014 FOAs *Subject to Availability of Appropriations*

Program	Topic	Summary	Funding Range
EGS	Integrated EGS R&D	Solicitation will focus on R&D related to zonal isolation, novel stimulation methodologies, joint geophysical techniques for fracture and reservoir imaging, unique well designs and configurations, and advanced tracer technologies	$5M - $6M
Innovative Exploration Technologies	Innovative Exploration Technologies Towards Geothermal Play Fairway Analysis	Solicitation will focus on regional-scale assessments of risk/probability for finding new resources, highlighting the most prospective parts of a region and creating geothermal "play fairway" maps	$2M - $3M
Low Temperature and Coproduced Resources	Geothermal Energy Production Coupled with Strategic Materials Recovery	Solicitation will focus on strategic mineral identification and extraction technologies from geothermal brines	$1M - $2M

Federal Loan Guarantees for *Advanced Fossil Energy Projects*

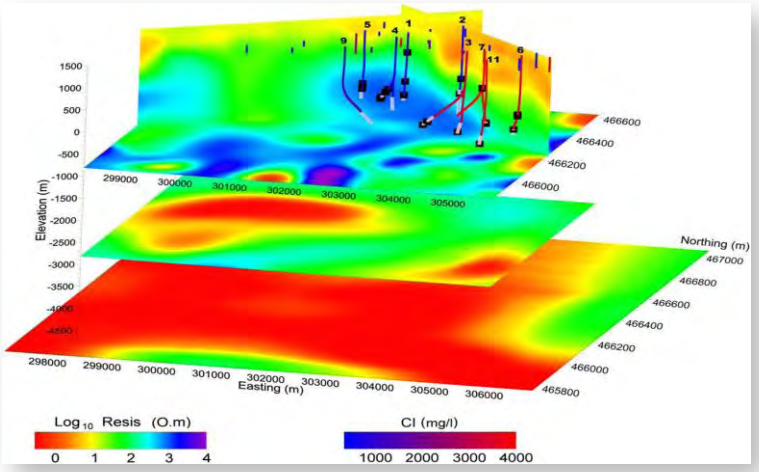
DRAFT July 2, 2013

Up to $8B potentially available

- **Advanced Resource Development**
  - *"Novel oil and gas drilling, stimulation, and completion technologies, including dry fracking that avoid, reduce, or sequester air pollutants or anthropogenic emission of greenhouse gases"*
  - *"Use of associated gas to reduce flaring"*
  - *"Methane emissions capture from energy production, transmission of distribution"*
- **Carbon Capture (CO2 capture)**
- **Low Carbon Power Systems**
- **Efficiency Improvements**
  - *"Combined heat and power"*
  - *"Waste heat recovery"*
  - *"High efficiency distributed fossil power systems"*

Reference:
http://lpo.energy.gov/resource-library/solicitations/advanced-fossil-energy-projects-solicitation/

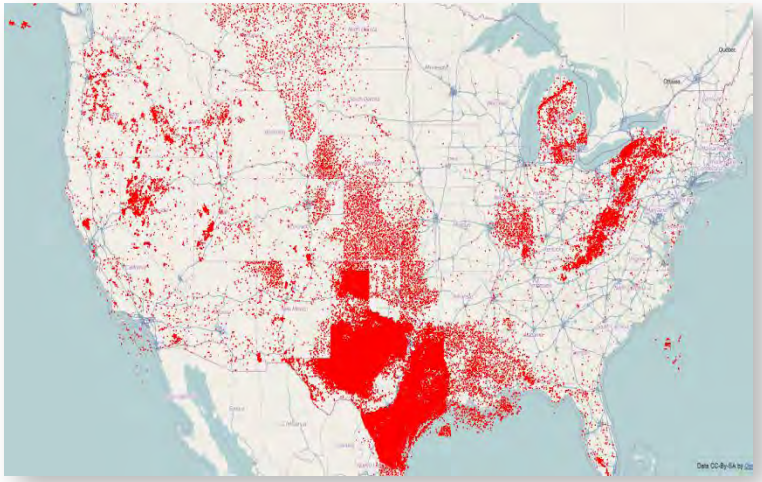
2013 GTO Peer Review Top Projects: *"A Tie!"*



Phillip Wannamaker, University of Utah

" Fracture Network and Fluid Flow Imaging for Enhanced Geothermal Systems: Applications from Multi-Dimensional Electrical Resistivity Structure"

- Improve **electrical resistivity imaging** through accurate surface representation **to overcome high exploration risks**



David Blackwell, Southern Methodist University

"*Heat Flow Database Expansion for NGDS Data Development, Collection and Maintenance*"

- Improve **access** to information and allow for **new interpretation** of data, thereby increasing its **usefulness** for commercial geothermal energy development
- Significant data aggregation nearly complete