Geothermal R&D: The DOE Perspective

International Forum on Geothermal Energy / October 28-29, 2013 / Mexico City

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

Doug Hollett, Director
Geothermal Technologies Office

Sustainable
TRANSPORTATION

Renewable
ELECTRICITY GENERATION

Energy Saving
HOMES, BUILDINGS, & MANUFACTURING

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Renewable Electricity Generation

EERE advances America's "all of the above" strategy and leads a large network of researchers and other partners to deliver innovative technologies that will make renewable electricity generation cost-competitive with traditional sources of energy.

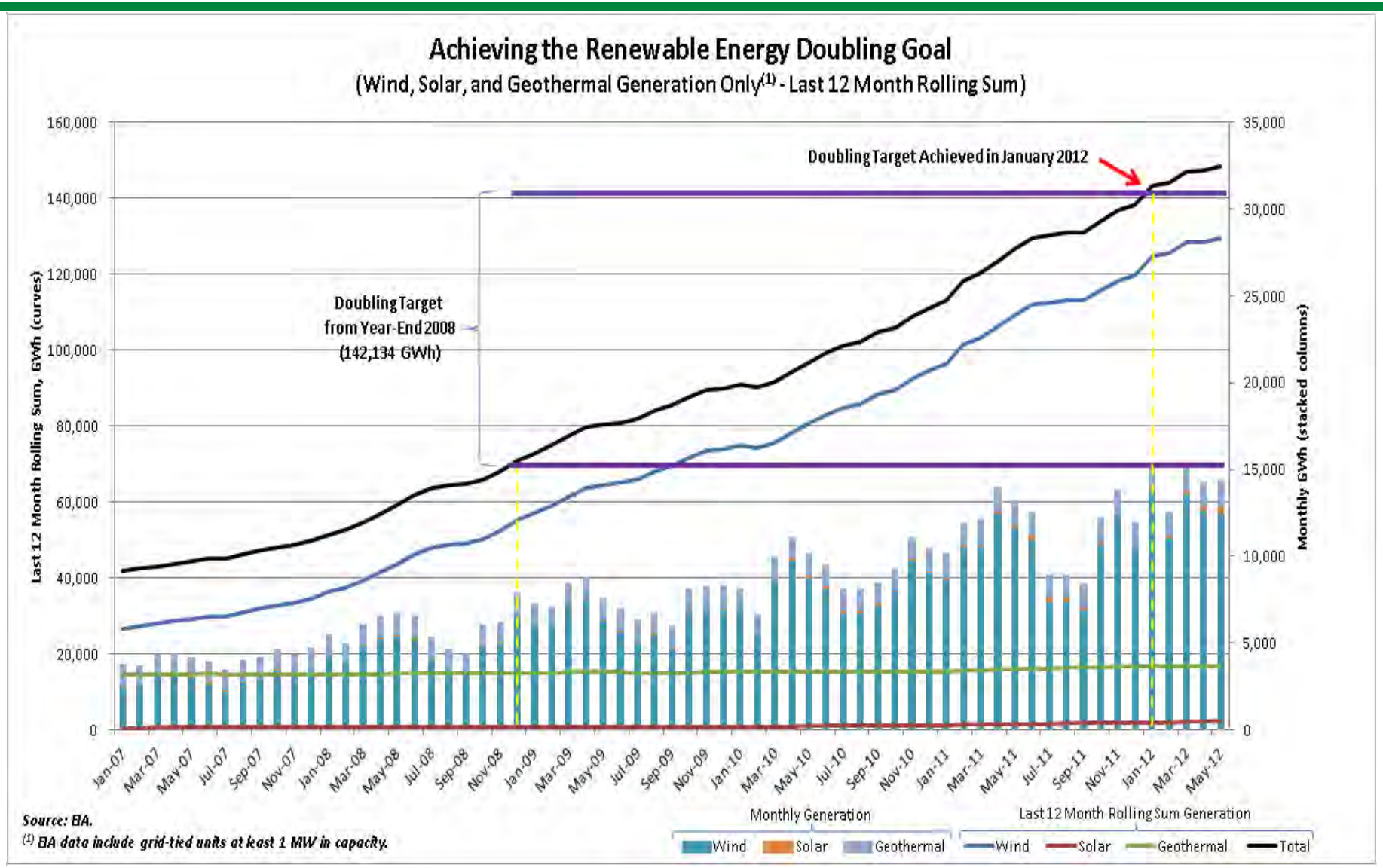
Solar Energy Technologies Office Making solar energy cost competitive with other forms of energy by the end of the decade. Reducing installed costs of solar energy systems by 75% will drive wide-spread, large-scale adoption.

Wind Power Technologies Office Manages the public's investment in wind technologies to improve performance and lower cost of wind power.

Water Power Technologies Office Researches, tests, evaluates, and develops renewable, environmentally responsible, and cost-effective electricity from water resources, including hydropower, marine and hydrokinetic technologies.

Geothermal Technologies Office Researches, develops, and validates innovative and cost-competitive technologies and tools to locate, access, and develop geothermal resources in the U.S.

The United States Doubles Renewable Energy



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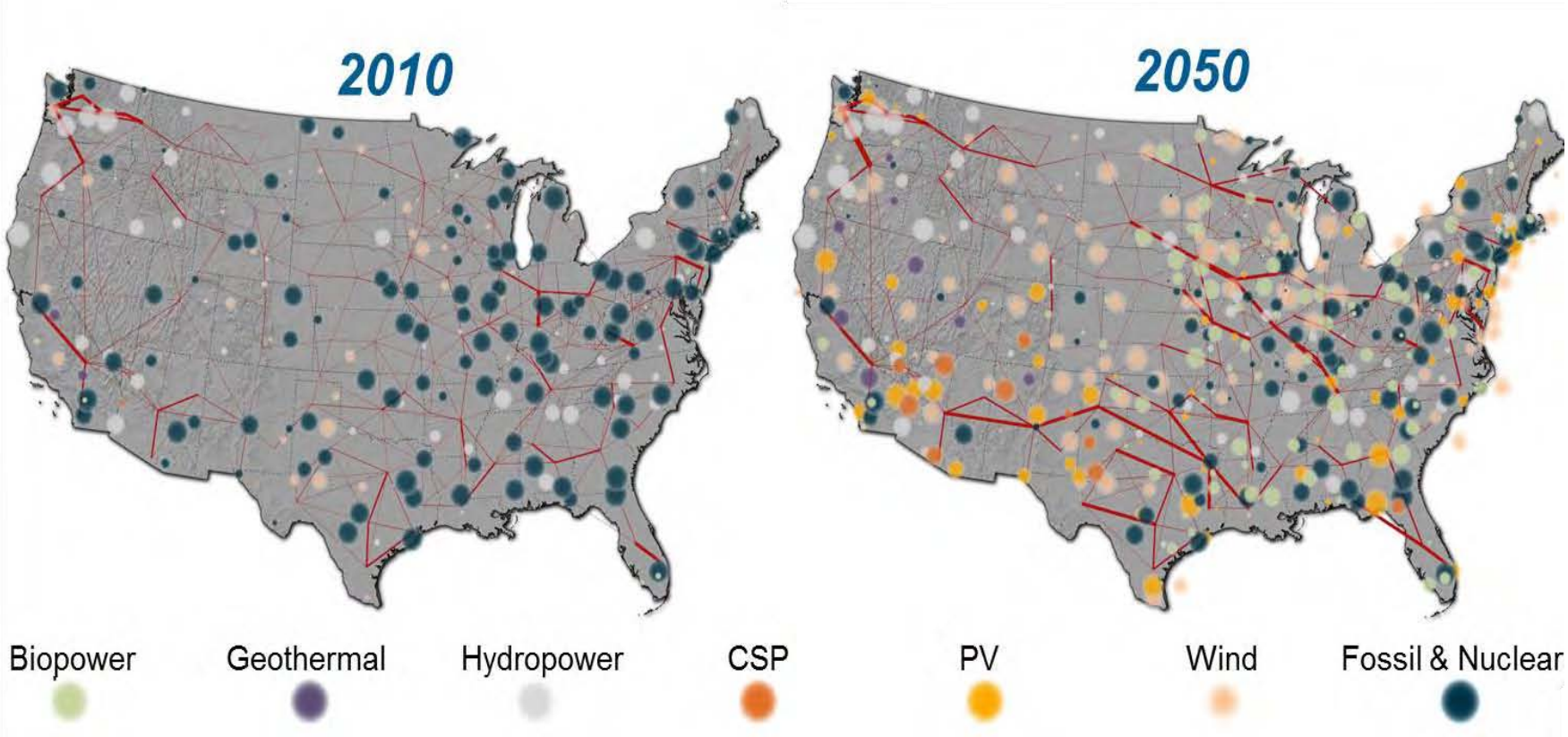
NREL Renewable Energy Futures



- RE generation from technologies commercially available today
- a more flexible and diverse electric system
- more than adequate to supply 80% of total U.S. electricity generation
- By 2050, meet electricity demand on an hourly basis in every region of the country

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Geothermal: Key Goals, Objectives & 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

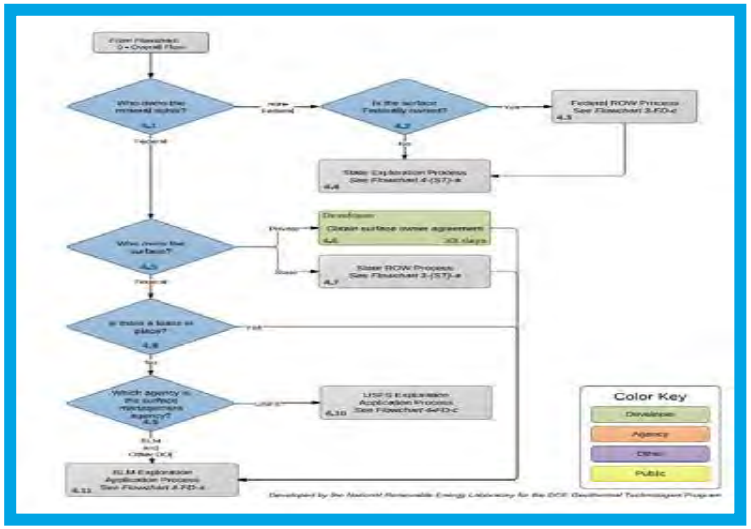
- Regulatory Roadmap: Streamlining
- National Geothermal Data System: Reducing upfront exploration cost

Additive Value

- Coproduction and Distributed Power
- Strategic Materials

Subsurface Engineering "Crosscut" Initiative

- Intra- and inter-agency efforts to address common subsurface challenges and better leverage DOE funding



NGDS

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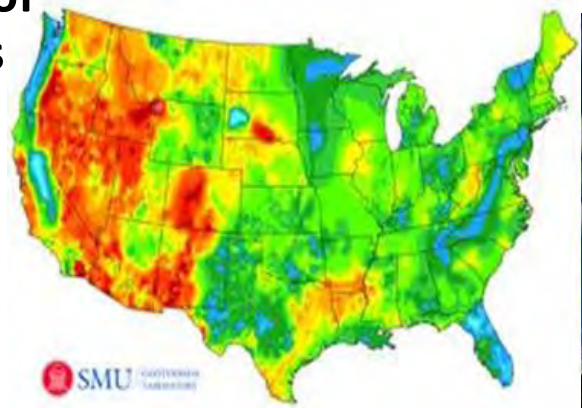
Geothermal Perspectives *Why is it important – and why should we care?*

- **Large, global resource**
  - 3.4 GWe US installed
  - 12 GWe worldwide
  - 12 GWe global under development
- **Baseload energy, renewable, low emissions**
- **Potential for expansion out of the traditional "hot" regions in the US**
  - +30 GWe hydrothermal "yet-to-find"
  - +100 GWe possibility for EGS
  - Significant "low temp" potential
- **Opportunity for significant growth –** but requires more knowledge of and R&D regarding subsurface



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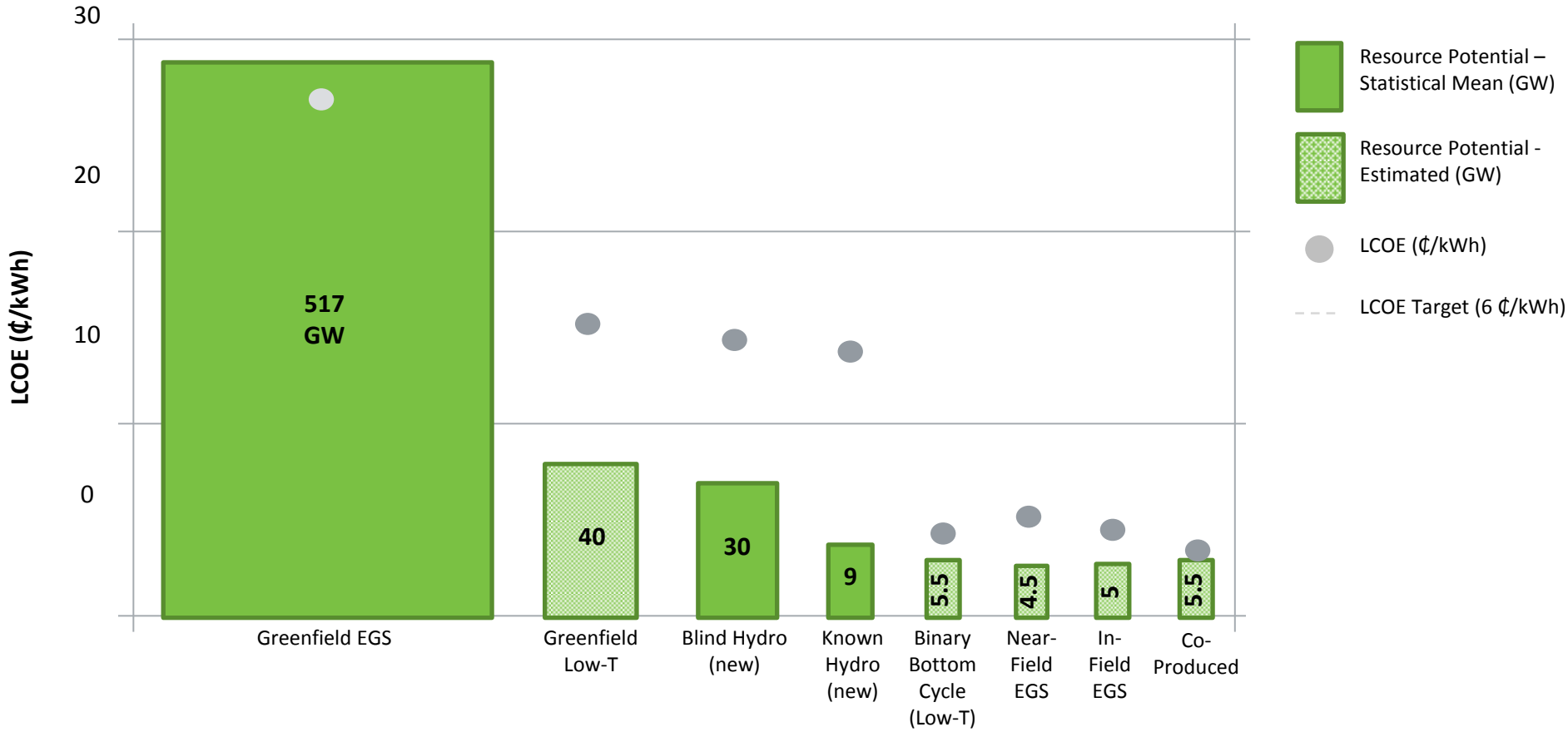
US Geothermal Potential (Gwe) and Electricity Costs (¢/kwh)

Current installed capacity: 3.4 Gwe (~ 3.5 million homes)

Target: Getting to 30 Gwe by 2030



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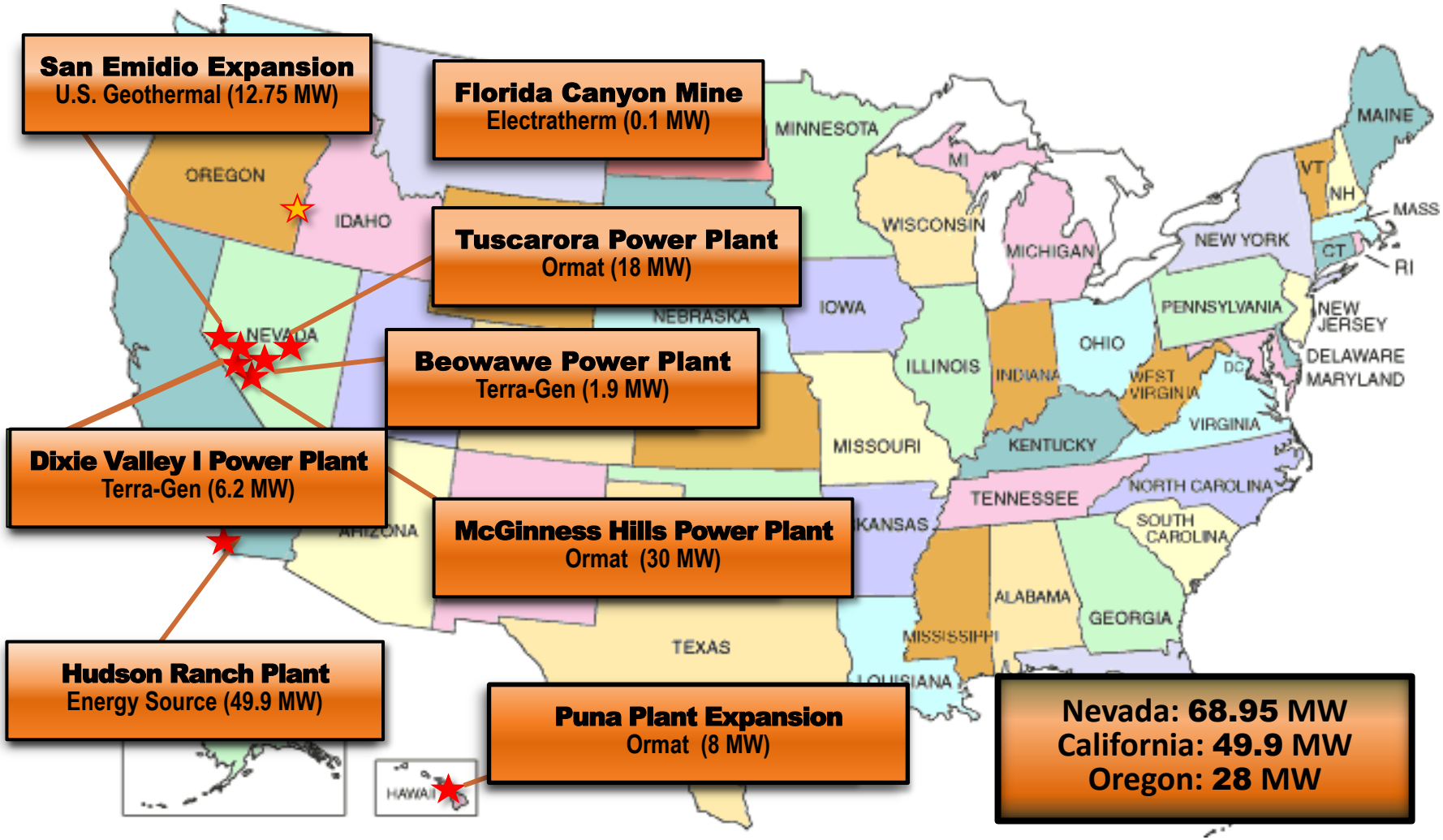
Geothermal Power Plants

Geothermal power plants brought online/expanded in 2012-13 (154 MW)



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Geothermal Program Balance

Transition from Near to Long Term

	Low Temp	Coproduction	Blind Hydrothermal	In-Field & 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

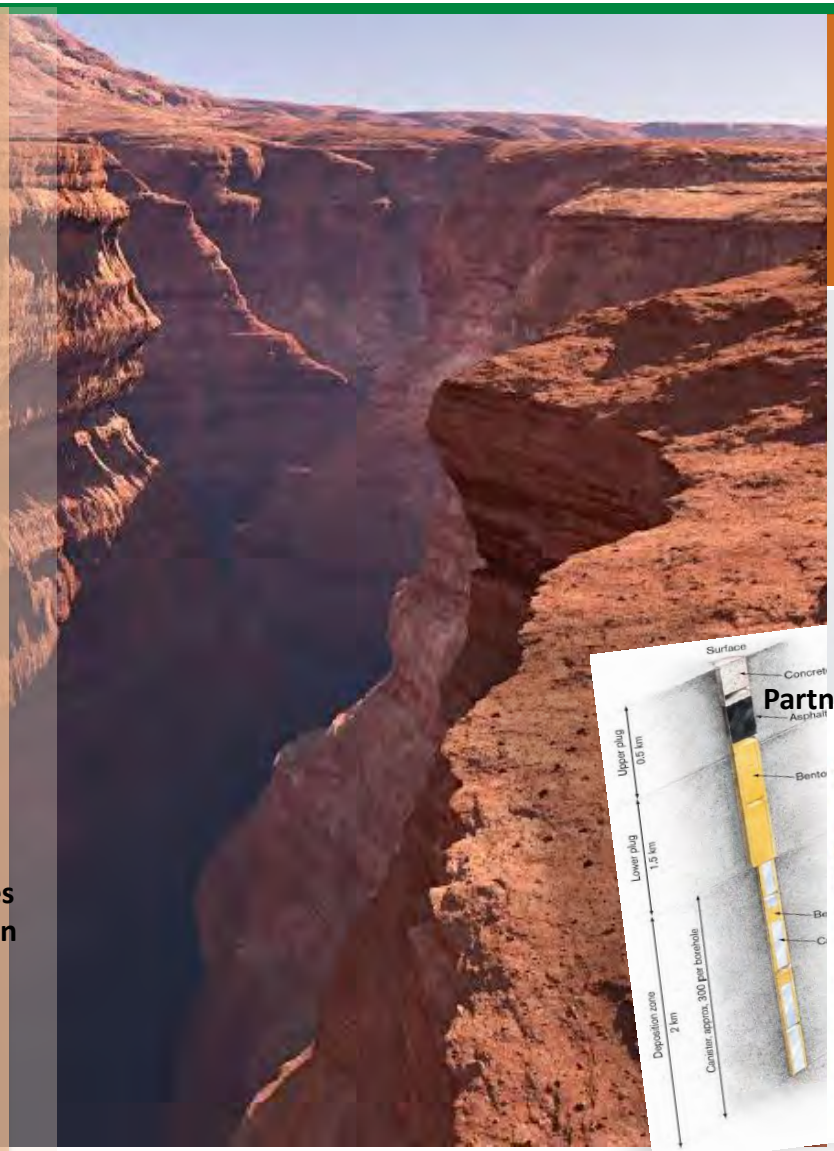
Create/construct desired subsurface conditions in challenging high-pressure/high-temperature environments

Sustaining

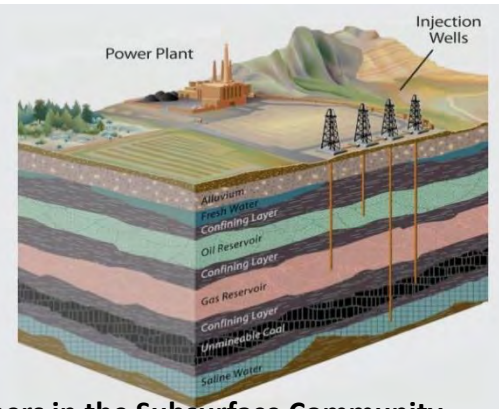
Maintain optimal subsurface conditions over multi-decadal or longer time frames through complex TMHC system evolution

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, CO2 sequestration, nuclear waste, storage etc.



Partners in the Subsurface Community

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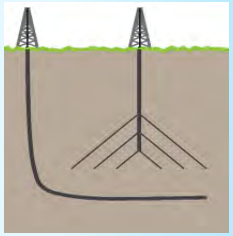
Key Barriers to EGS Development

Technology and Engineering Needs

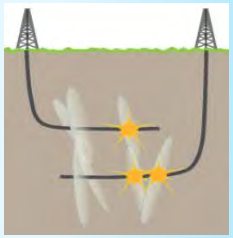
Technology Barriers	GTO-Funded Solution Set	GOAL



Reservoir Access
New well geometries and concepts, optimized drilling

Hard/Hot-rock drilling, completion technologies

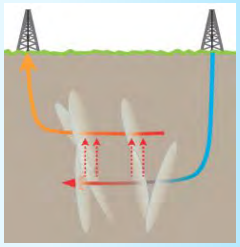
Rotary steering



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

Stress-field diagnostics

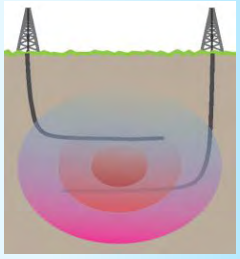
Smart tracers



Productivity
Increase flow rates without excessive pressure needs or flow localization

Zonal Isolation

High-T sensors



Sustainability
Maintain productivity with minimal thermal drawdown and water losses

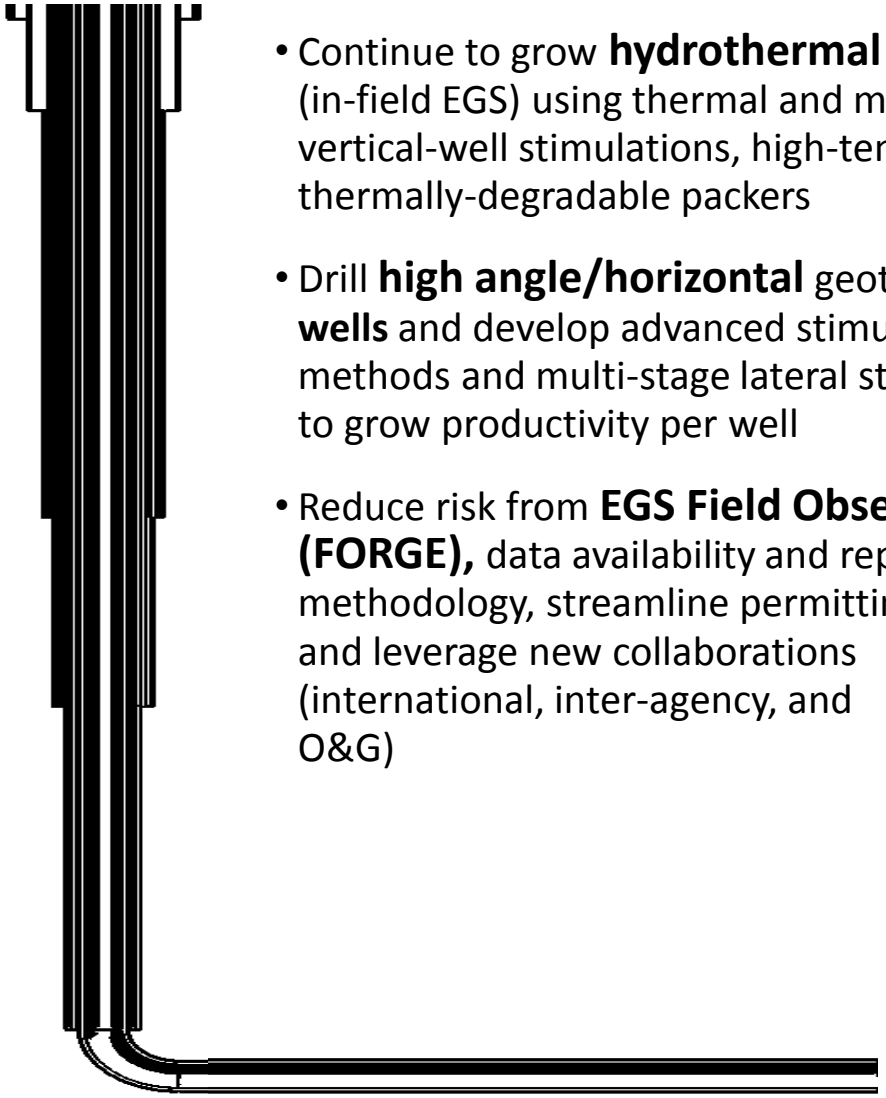
Cross-well monitoring

Diverter technologies

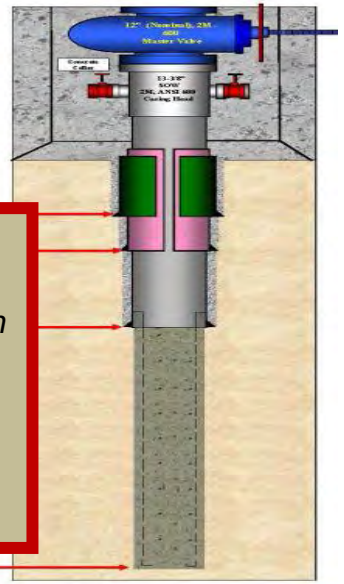
EGS Success

Game-changers

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

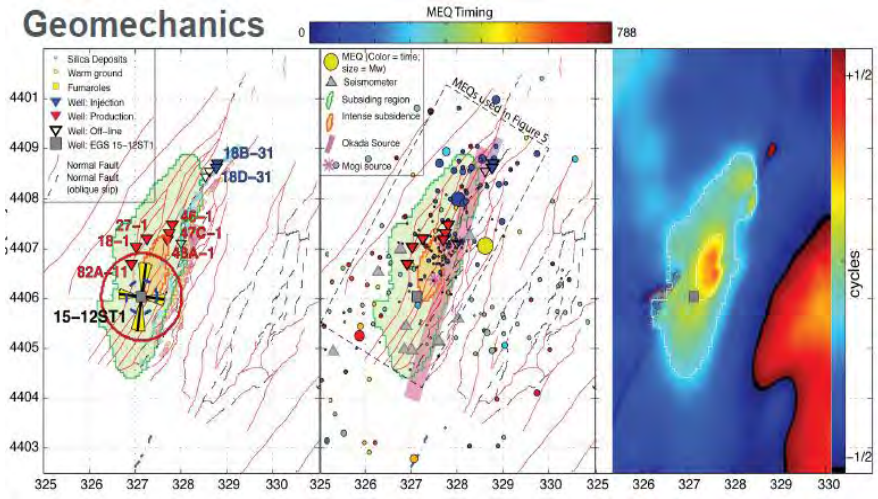


- Continue to grow **hydrothermal** fields (in-field EGS) using thermal and multi-stage vertical-well stimulations, high-temperature thermally-degradable packers
- Drill **high angle/horizontal** geothermal **wells** and develop advanced stimulation methods and multi-stage lateral stimulations to grow 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 O&G)



Re-completion of the well at Desert Peak

- *175-fold increase in well productivity*
- *additional 1.7 MW*
- *increased power output by nearly 40%.*



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Current Global EGS Landscape

Newberry Volcano
Bend, Oregon
AltaRock Energy/DOE

4 MW Insheim
Insheim, Germany

24 MWt ECOGI
Buntsandstein
Germany

BRADY'S HOT SPRINGS
Churchill County, NV
Ormat/DOE

1.5 MW KiGam
Pohang Field
South Korea

United States

Germany
France

S Korea

RAFT RIVER
Raft River, Idaho
University of
Utah/DOE

2.9 MWe/3 MWt Landau
Landau in der Pfalz
Germany

1.7 MW Desert Peak
Churchill County, Nevada
Ormat/DOE

1.5 MW Soultz
Kutzenhausen, France

5 MW The Geysers
Middletown, California
Calpine Corporation/DOE

1 MW Habanero
Cooper Basin
Australia

Australia

Commercial

Demonstration

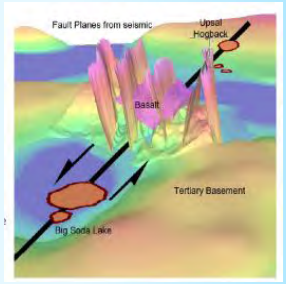
Under Development

Announced

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

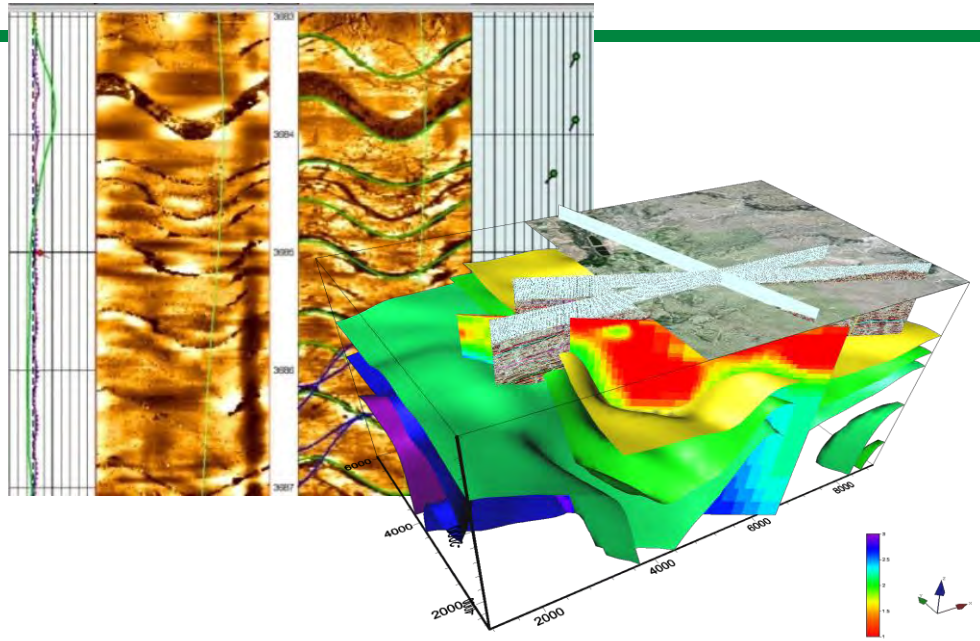
Hydro thermal Growth

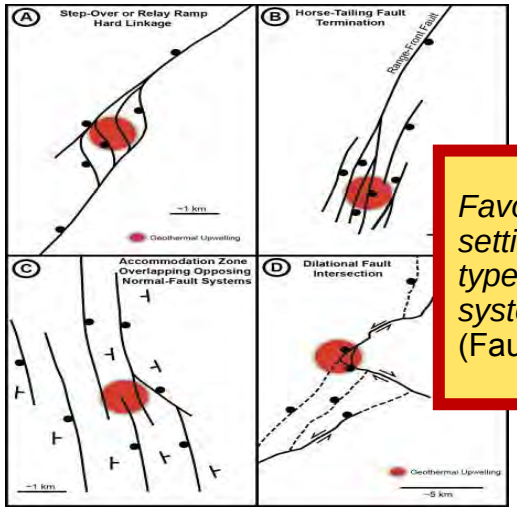
Game-changers

What's Next for Hydrothermal?

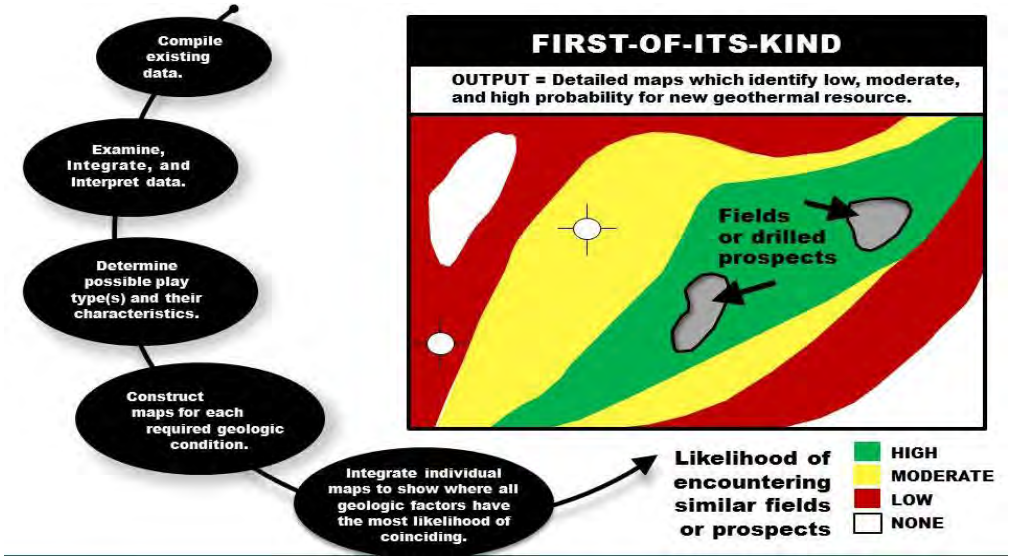
Tools, Maps, Analysis, "Plays"

- **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 systems evolution





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



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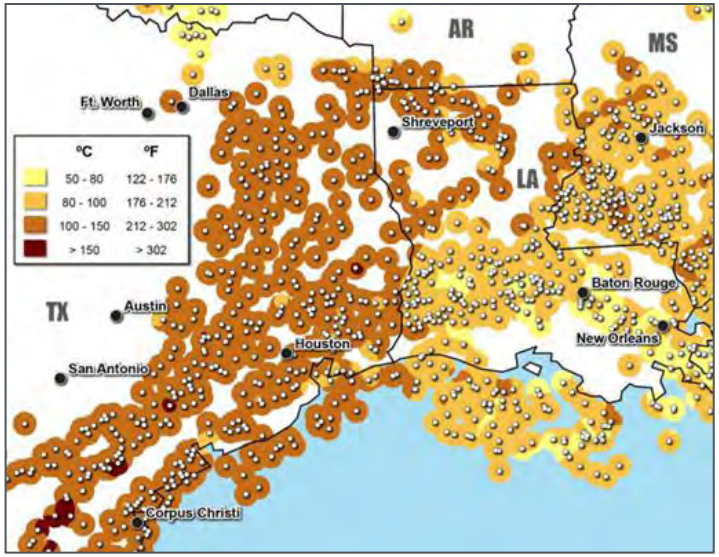
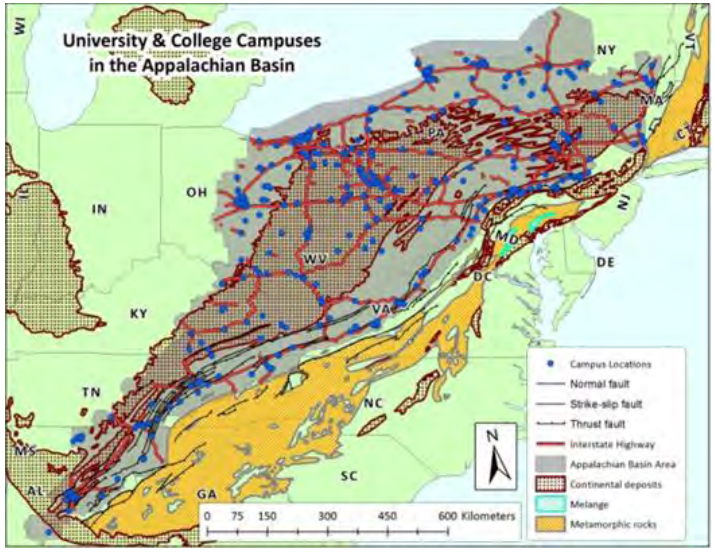
What's Next for Low Temp?

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 energy conversion

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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.

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

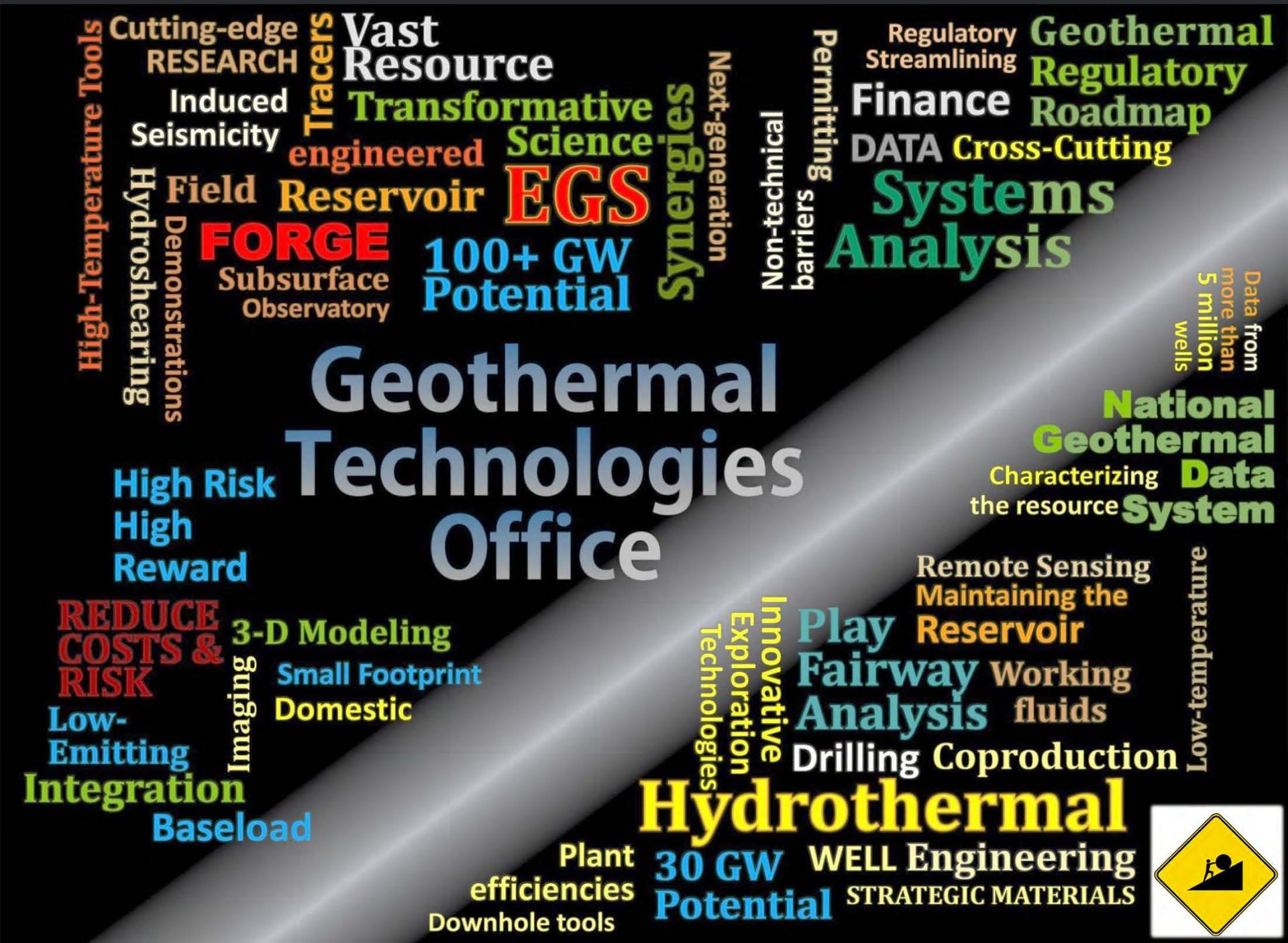
Confirmed an initial 11.4 MW of equivalent steam—50% more than early estimates—from three previously abandoned wells. **First geothermal project where an abandoned steam field has been successfully re-opened for production**.

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.**

Possible Areas for R&D Collaboration

- **Hydrothermal**
  - Coproduction with oil and gas operations
  - New Play and Prospect Mapping
- **EGS**
  - R&D on fractured rock systems
  - EGS Field Observatory – opportunity to participate
- **Direct Use**
  - Leverage our understanding of subsurface systems, including hot sedimentary basins
- **Hybrid System Concepts**
  - Geothermal with solar, or with minerals extraction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Cutting-edge RESEARCH
Vast Resource
Tracers
Induced Seismicity
Transformative Science
engineered
Field
Reservoir
EGS
Hydroshearing
Demonstrations
FORGE
Subsurface Observatory
100+ GW Potential
Synergies
Next-generation
Non-technical barriers
Permitting
Regulatory Streamlining
Geothermal Regulatory Roadmap
Finance
DATA
Cross-Cutting
Systems Analysis
High-Temperature Tools
Data from more than 5 million wells
National Geothermal Data System
Characterizing the resource
High Risk High Reward
REDUCE COSTS & RISK
3-D Modeling
Small Footprint
Domestic
Imaging
Low-Emitting
Integration
Baseload
Remote Sensing
Maintaining the Reservoir
Innovative Exploration Technologies
Play Fairway Analysis
Working fluids
Drilling
Coproduction
Low-temperature
Hydrothermal
Plant efficiencies
Downhole tools
30 GW Potential
WELL Engineering
STRATEGIC MATERIALS