Recent Advances in US Geothermal R&D: Implications for Global Development

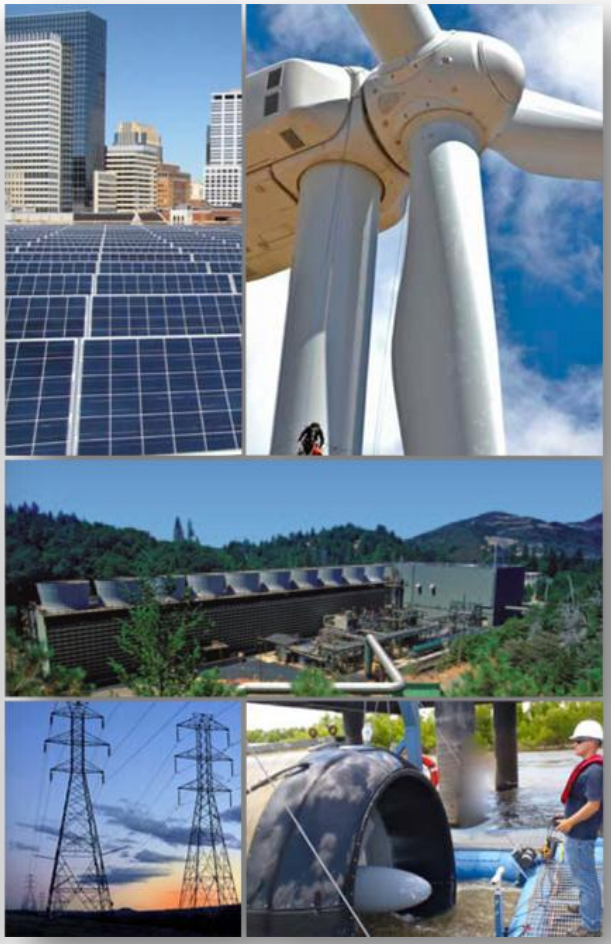
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

APEC Workshop on Geothermal Energy Development
Taipei, Chinese Taipei
June 25, 2013

Doug Hollett, Director, Geothermal Technologies Office
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Sustainable
TRANSPORTATION

Renewable
ELECTRICITY GENERATION



Energy Saving
HOMES, BUILDINGS, & MANUFACTURING

Geothermal Program: Key Goals and Objectives

Creating Impact

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Increased Focus

Identify New Geothermal Opportunities

- **Lowered risk and cost**
- **New prospecting workflow**

Enhanced Geothermal Systems (EGS) R&D, Demonstrations and Underground Field Observatory

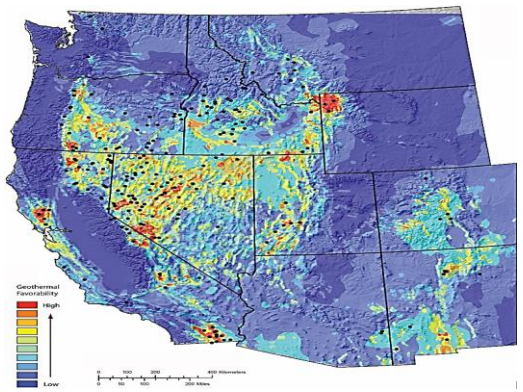
- **New techniques and technologies**

Non-Technical Barriers

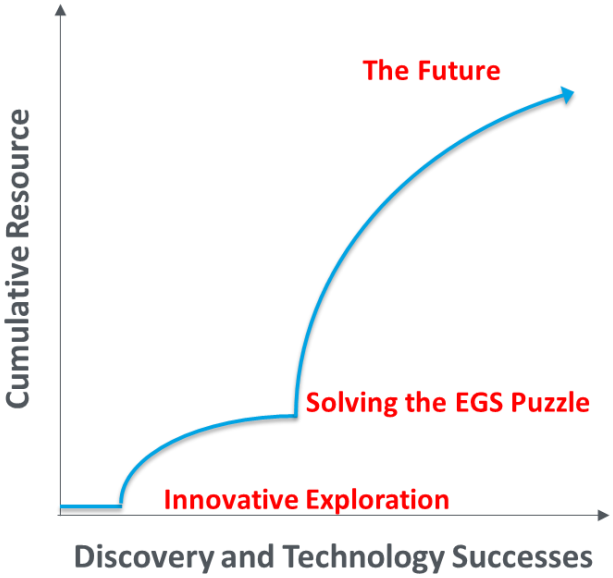
- **Regulatory**
- **Financial/Commercial**

Project Synergies

- **Co-Production and Distributed Power**
- **Strategic Materials**



Geothermal Development Potential



Geothermal Program Balance

Transition from Near to Long Term

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	Low Temp	Co-Production	Blind Hydrothermal	In-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 GW potential**	**10's GW additional potential**	**100's MW- GW's potential- low risk**	**10's - 100's GW potential -high risk**
Constituency	Local or Rural, 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 Lab

GTO Operational Space

Geothermal Power Plants

2011-2012

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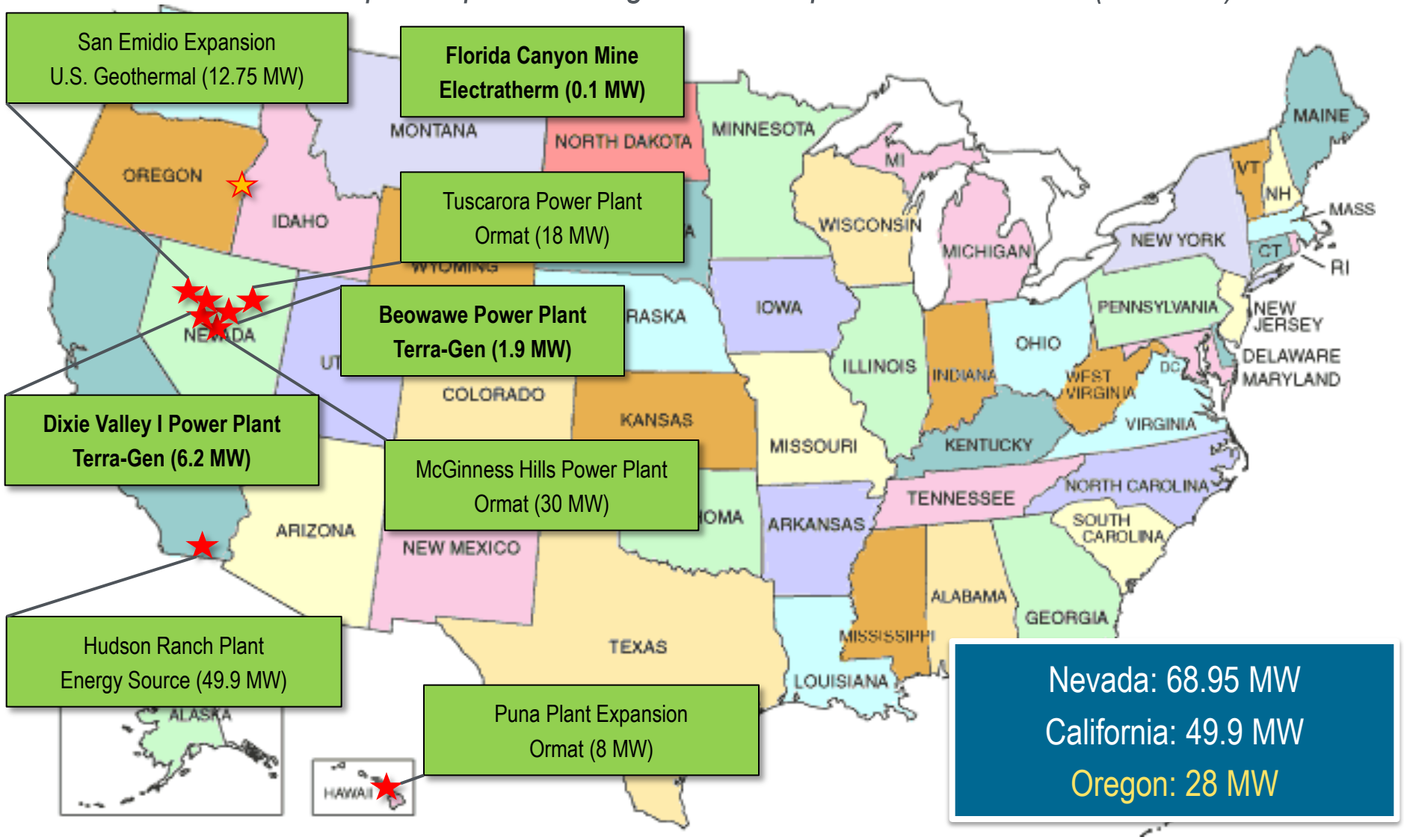
Geothermal power plants brought online/expanded in 2012-13 (154 MW)



Geothermal Projects

Phase III and IV Development

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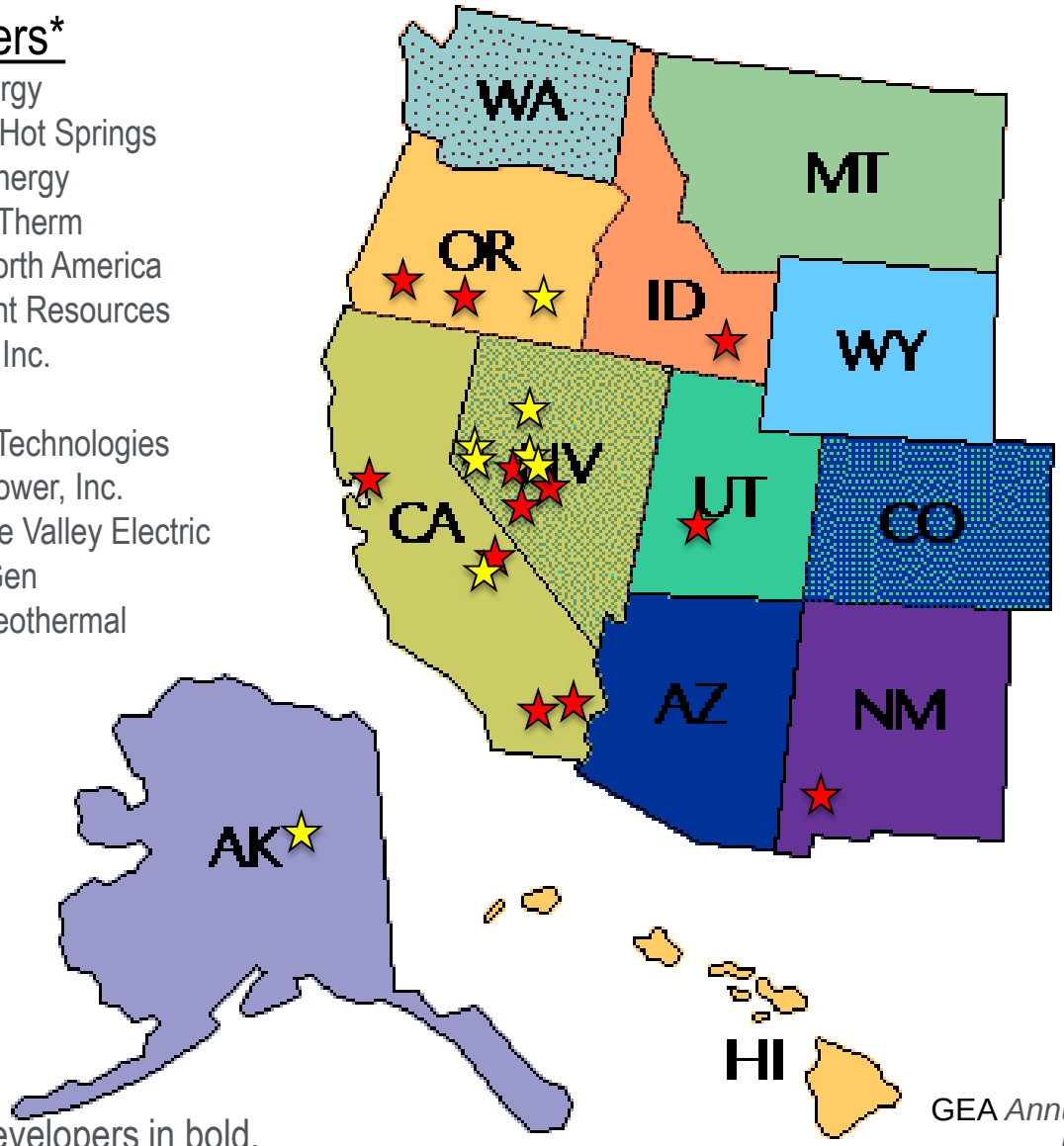
Developers*

- CalEnergy
- Chena Hot Springs
- Cyrq Energy
- ElectraTherm
- Enel North America
- Gradient Resources
- Kodali, Inc.
- OIT
- Ormat Technologies
- Ram Power, Inc.
- Surprise Valley Electric
- Terra-Gen
- U.S. Geothermal



★ Phase III

~750 MW

(Planned Capacity Addition)

★ Phase IV

~200 MW

(Planned Capacity Addition)

Phase III: Permitting and Initial Development

Phase IV: Resource Production and Power Plant Construction

*Nevada Developers in bold.

SOURCE:

GEA *Annual US Geothermal Power Production and Development Report* (April 2012)

US Geothermal Potential by 2030

Pathway to Growth

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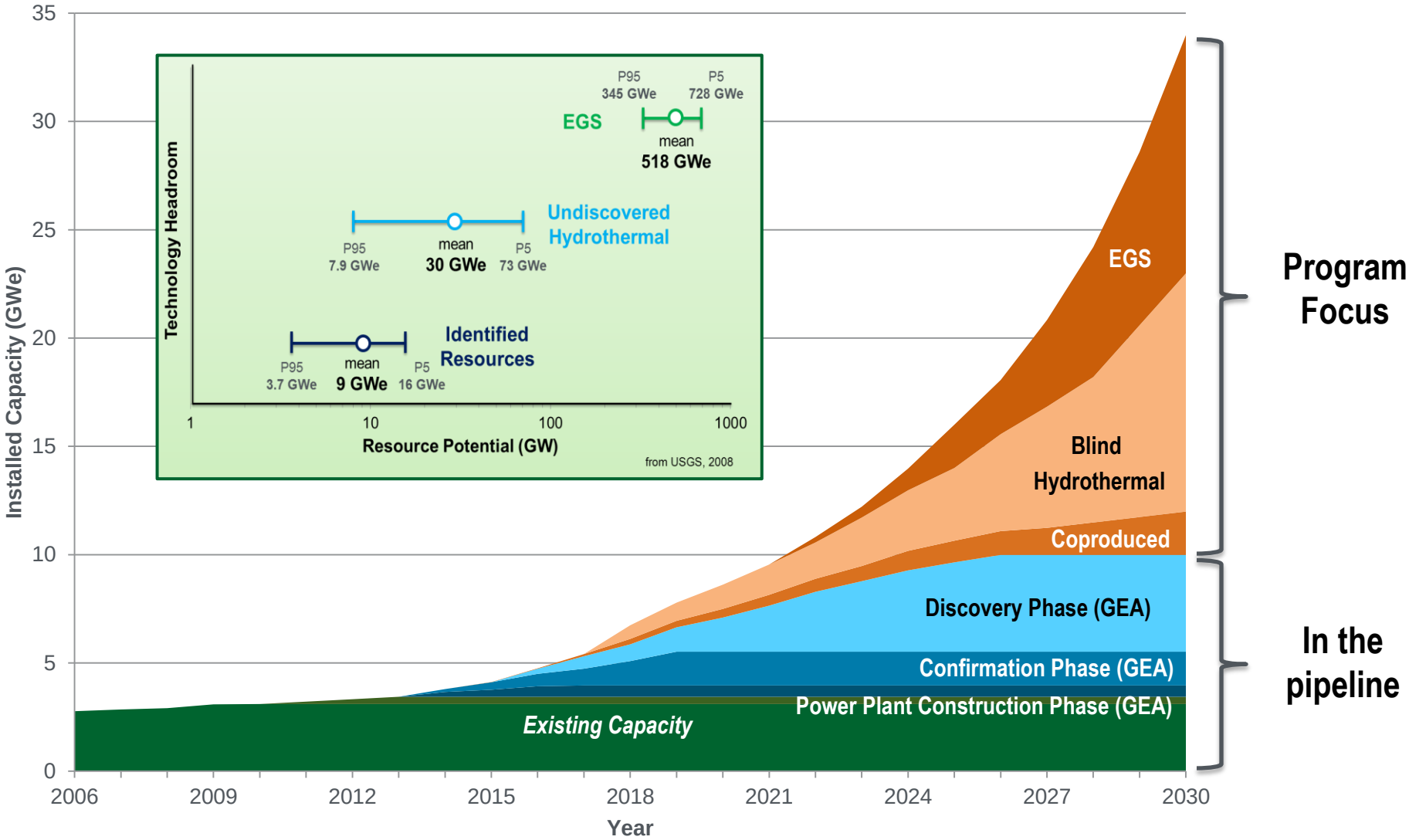

EERE's 5 Core Questions

Where and How Does The R&D Fit?

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1. **High Impact**
2. **Additionality**
3. **Openness**
4. **Enduring Economic Benefit**
5. **Proper Role of Government**

Geothermal Office Investment Synergies

R&D Successes in One Area Multiply to Other Programs

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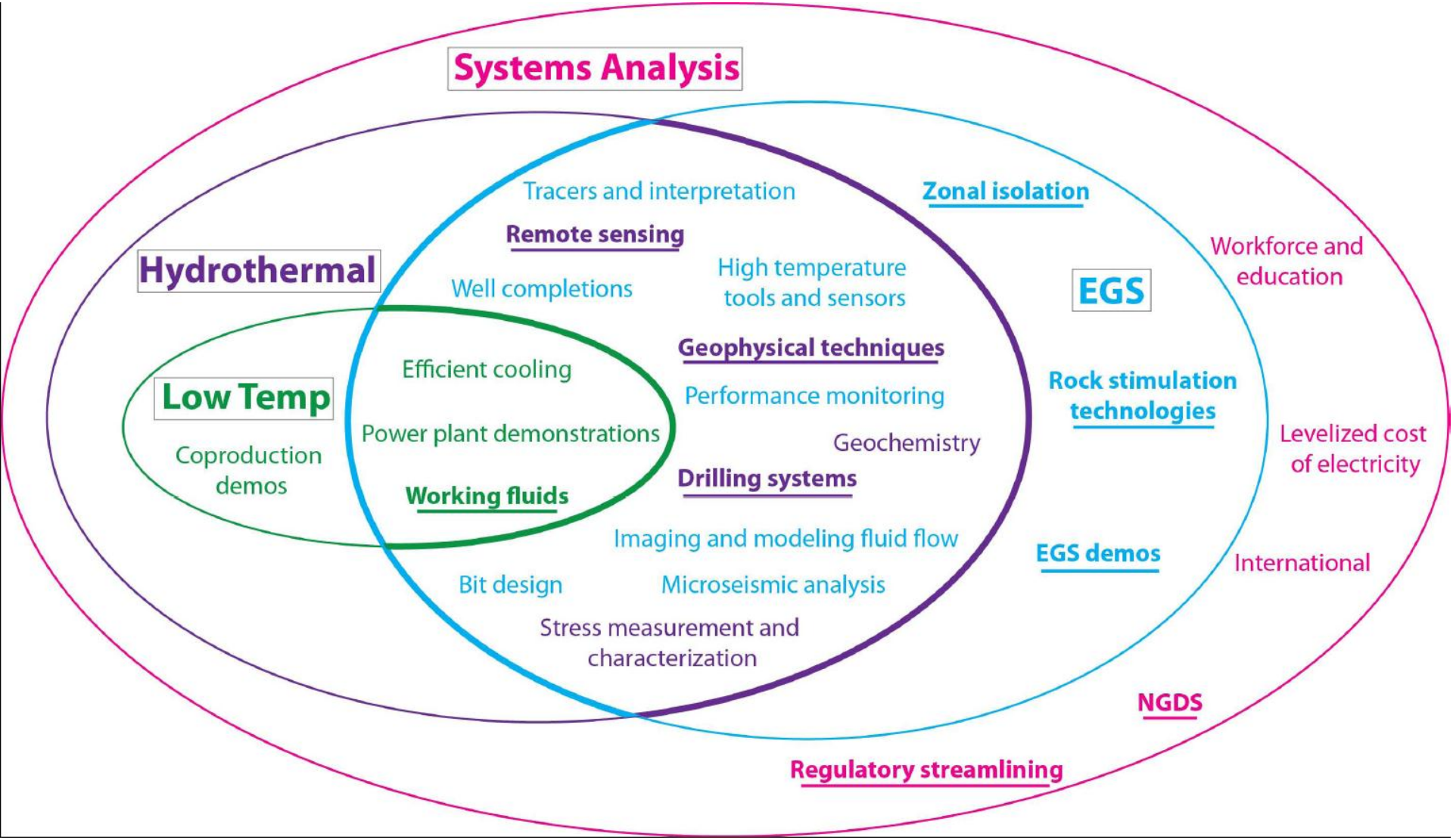

Economic Analysis Drives R&D Priorities

Drilling, Project Size – Risk and Costs

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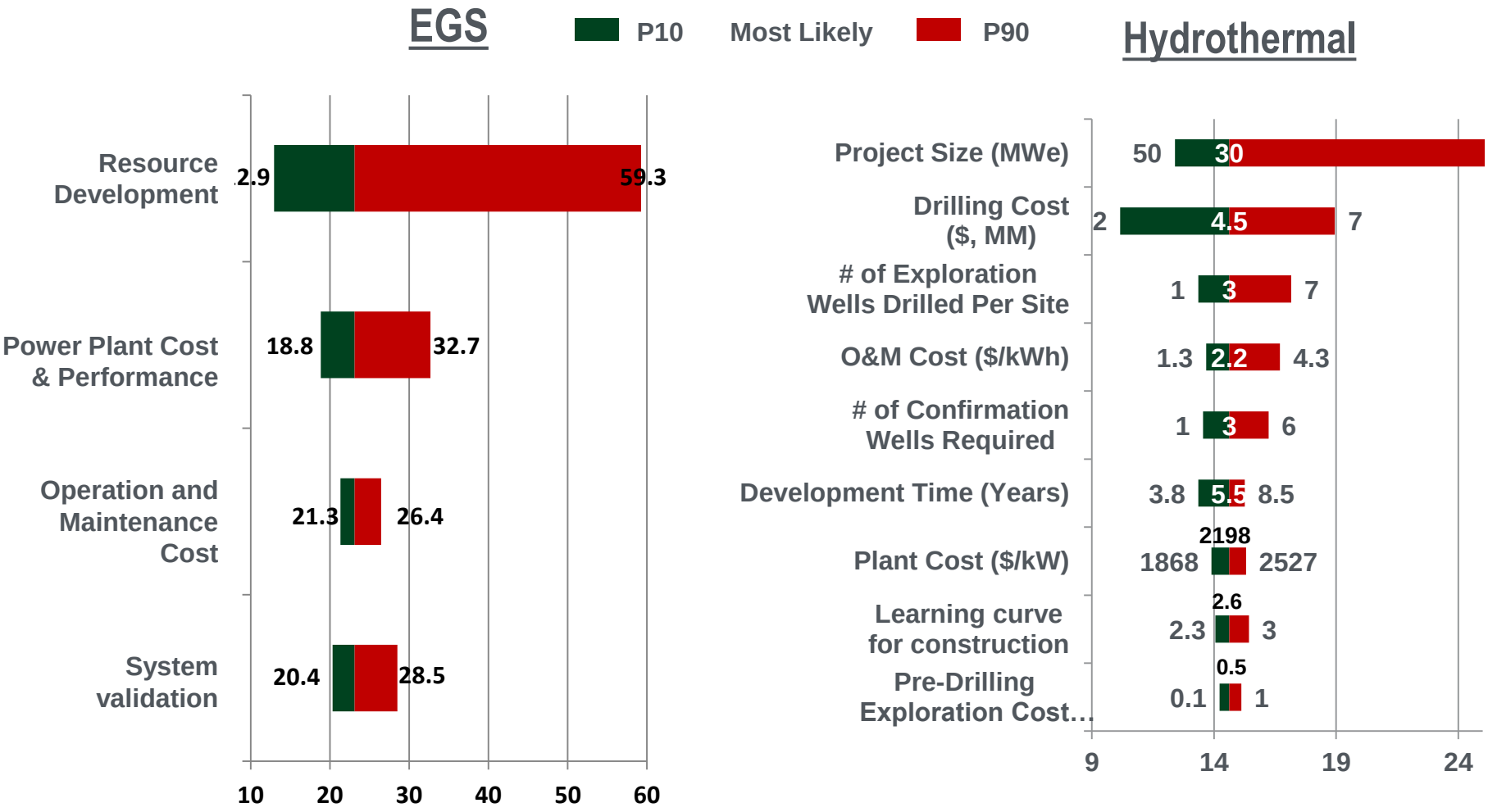

Need combined improvements and efficiencies

Technology Success: Pathway to Growth

Accomplishments in 2011-2012

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Low Temp | Co-Production | Blind Hydrothermal | In-Field EGS | Greenfield EGS

Low-temperature:

- **Beowawe Power**: Beowawe, NV – 2.5 MW added
- **TerraGen Sierra Holdings**: Dixie Valley, NV – 6 MW online

Co-Production:

- **Simbol Materials**: Lithium extraction plant groundbreaking expected 2013
- Deploying two binary systems in operating O&G fields.

Hydrothermal:

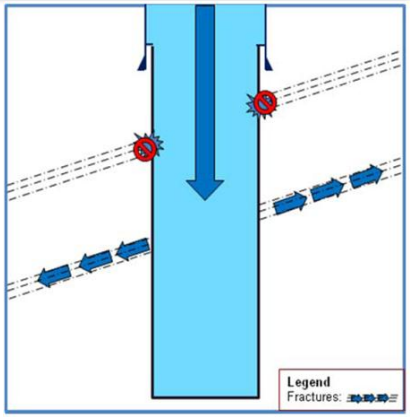
- ~150+ MW of new hydrothermal capacity
- 26 wells drilled to date

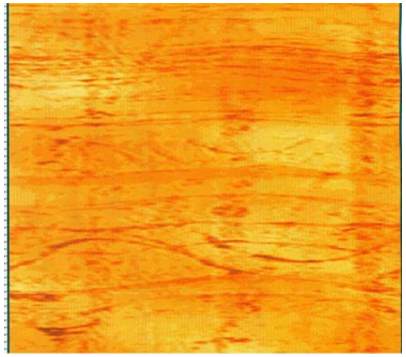
EGS Demonstrations:

- **IN-FIELD:** **Ormat**: Desert Peak, NV – 1.7 MW
- **NEAR-FIELD:** **Calpine**: The Geysers, CA - 5 MW
- **GREENFIELD:** **AltaRock**: Newberry, OR

Cross-Cutting Research & Development:

- **CSI Technologies /AltaRock**- Diverters
- **Baker Hughes** – Ultrasonic Fracture Imager
- **Sandia National Lab** – PDC Bits





Baker Hughes

Polycrystalline Diamond Compact Drill Bit

Recent Project Successes

Low Temperature Portfolio

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Beowawe Power, LLC

- Funding Source: ARRA
  - DOE Funds: $2M
  - Awardee Cost Share: $2.4M
- Completed construction in 2011 of a binary power plant
- Plant came online in the Spring of 2011 producing 2.5 MW gross

Completed Beowawe Power Plant
(Photo credit: TG)

Terra-Gen Sierra Holdings, LLC (Dixie Valley)

- Funding Source: ARRA
  - DOE Funds: $2M
  - Awardee Cost Share: $13.4M
- Binary Power Plant online and producing 6 MW gross since September 2012
- Unit has operated over 500 hours as of November 2012

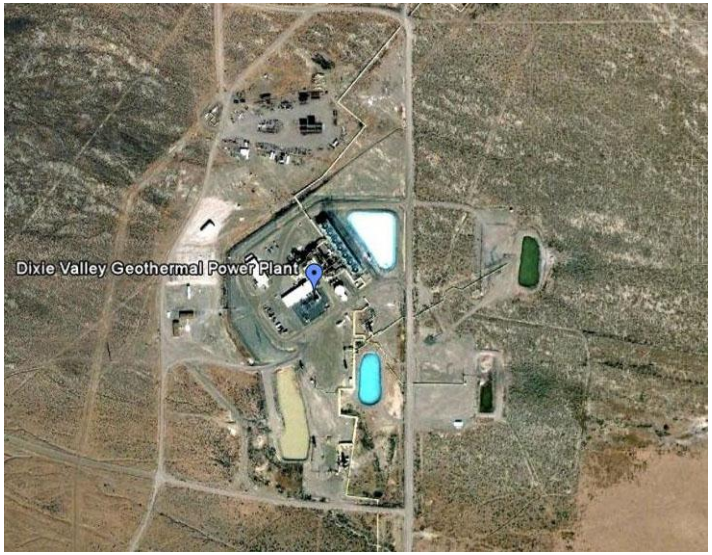

Image by Google Maps

What's next for Hydrothermal?

Tools, Maps, Analysis, "Plays"

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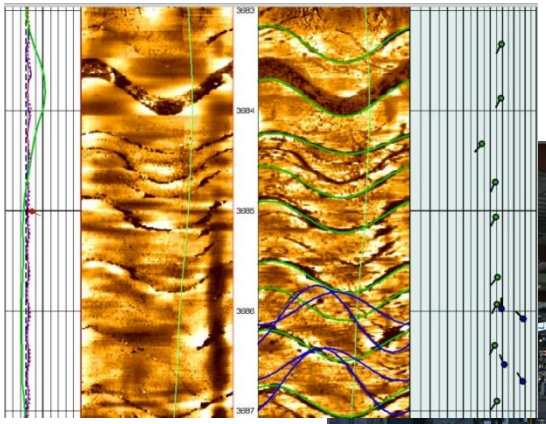
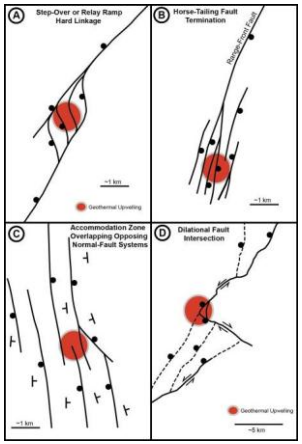
- Continue to advance Innovative Exploration Technologies (IET) and demonstrations

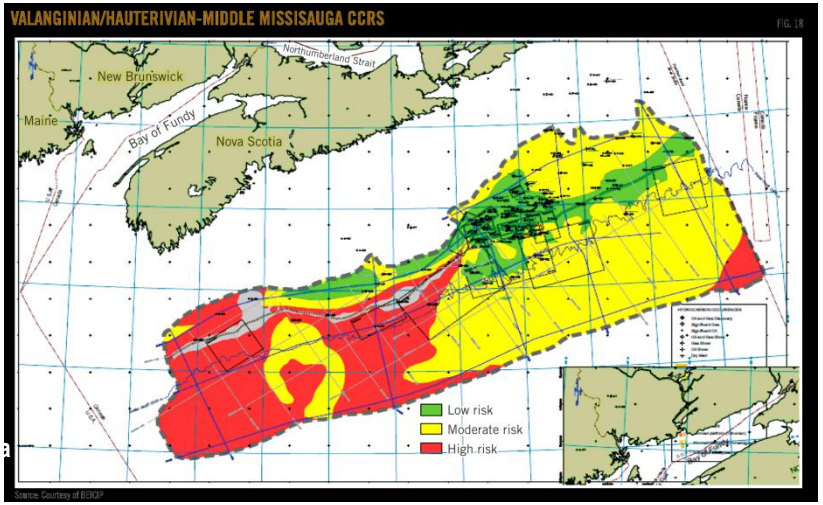


- New drilling and measurement technologies

- Play fairway analysis (borrowed 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)



Source: CNSOPB, Nova Scotia

EGS "Facies" Model

Physico-Thermo-Mechanical Characterization

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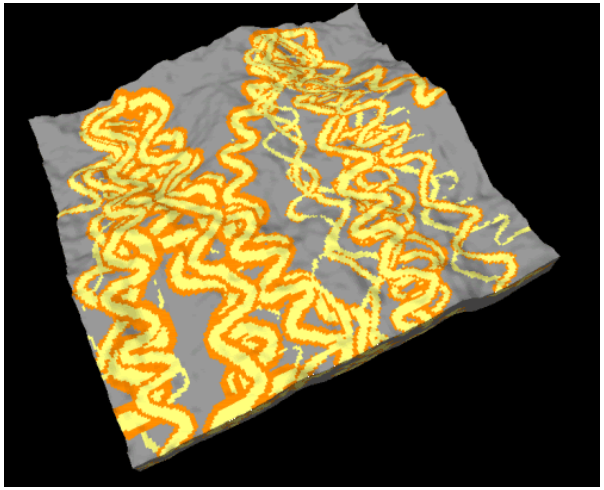
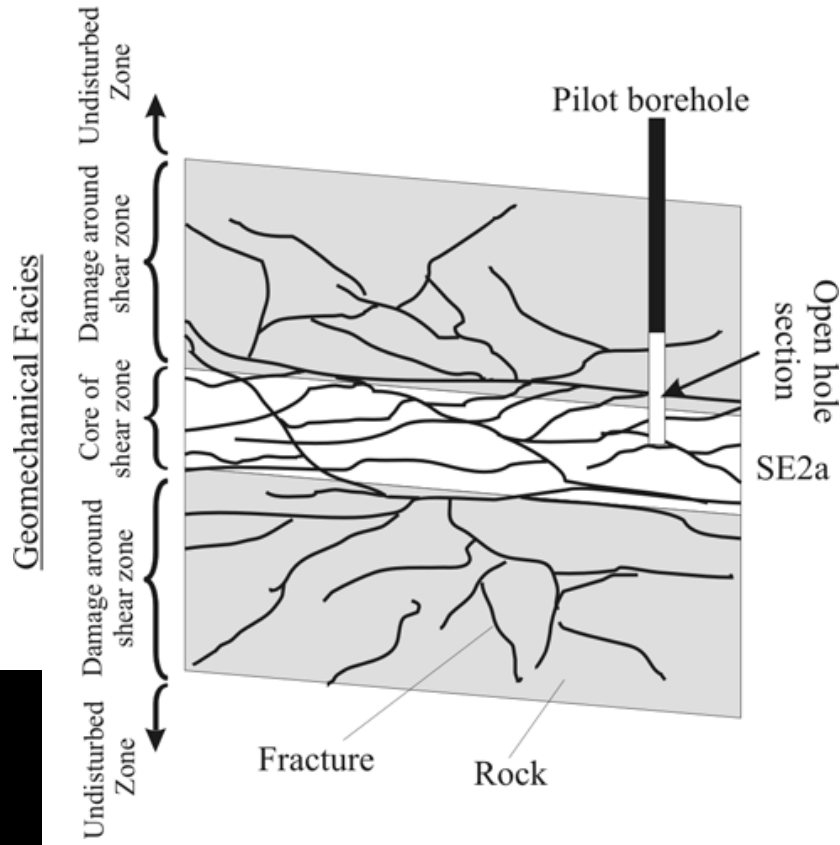
- Oil and gas uses "facies" routinely to describe geologic settings in the subsurface – *standard practice*
- Not yet done routinely in geothermal; critical path towards describing "flow units" and like-kind reservoir units.
- Will allow large scale reservoir and resource characterization and upside definition





Core Program Focus

EGS Demonstration Projects

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The Geysers, CA

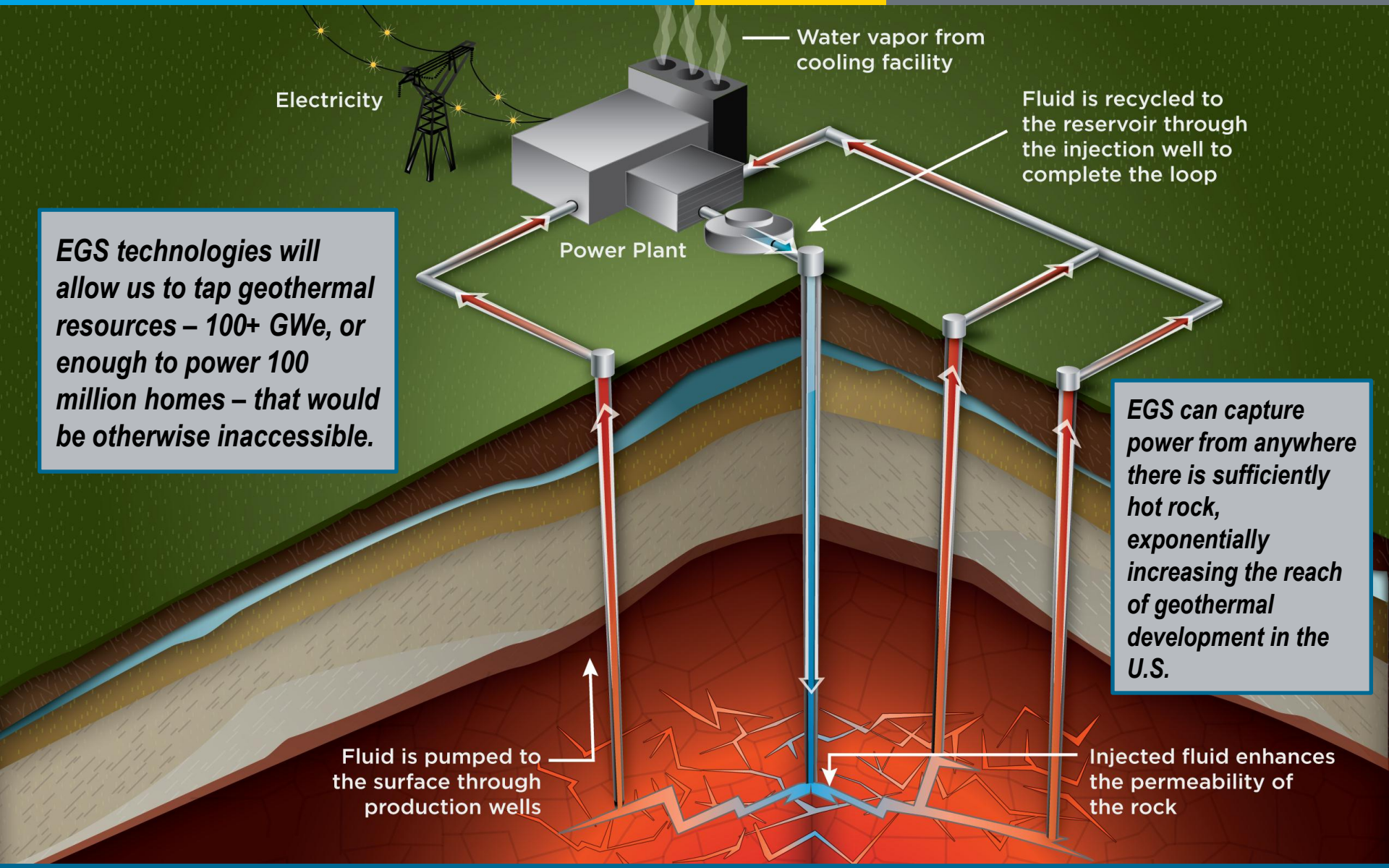

Desert Peak, NV


Well head
Newberry, OR


Newberry, OR

Performer	Project Site	Site Information	Stimulation Timeline	Funding
Ormat Technologies Inc.	Desert Peak, NV	Adjacent to existing hydrothermal sites	***Successful stimulation – commercial, grid-connected, 1.7 MWe***	**$ 4.3 M**
Geysers Power Company, LLC	The Geysers, CA	Reopen two existing wells to deepen for injection and stimulation	***Successful stimulation, 5 MWe scale***	**$ 6.2 M**
University of Utah	Raft River, ID	Improve the performance of the existing Raft River geothermal field	FY13 stimulation	**$ 8.9 M**
Ormat Technologies Inc.	Bradys Hot Springs, NV	Improve the performance of the existing Brady's geothermal field	FY13 stimulation	**$ 3.4 M**
AltaRock Energy Inc.	Newberry Volcano, OR	High potential in an area without existing geothermal development	***Successful stimulation***	**$ 21.4 M**
NakNek Electric Association	NakNek, AK	Located in remote location in Alaska without existing geothermal development	Project closeout	**$ 12.4 M**

What is EGS?



EGS technologies will allow us to tap geothermal resources – 100+ GWe, or enough to power 100 million homes – that would be otherwise inaccessible.

EGS can capture power from anywhere there is sufficiently hot rock, exponentially increasing the reach of geothermal development in the U.S.

Desert Peak EGS Demonstration

1st US Grid-Connected EGS Project

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"If we can go to all the hundred or thousands of wells that are unproductive and tinker with them to make them productive, this is a game changer."

Paul Thomsen, Director of Policy and Business Development at Ormat
– **MIT Technology Review, 4/2013**

- Ormat Technologies' Desert Peak-2 EGS project successfully supplied 1.7 MW electricity to the grid – a first-in-the-nation achievement
- DOE invested $5.4 million, with a private costshare of $2.6 million
- Desert Peak represents a near-term opportunity to develop EGS at lower cost and risk; potential for reserve additions at highly competitive costs

Pathway to larger, more complex and more challenging R&D efforts

"DOE's Geothermal Technologies Office is changing geothermal development in the U.S."

Lucien Bronicki, Ormat Founder and Chief Technology Officer (4/2013)
– **Yahoo: Stockwatch**

Enhanced Geothermal Systems (EGS)

Facies Concept – A Continuum

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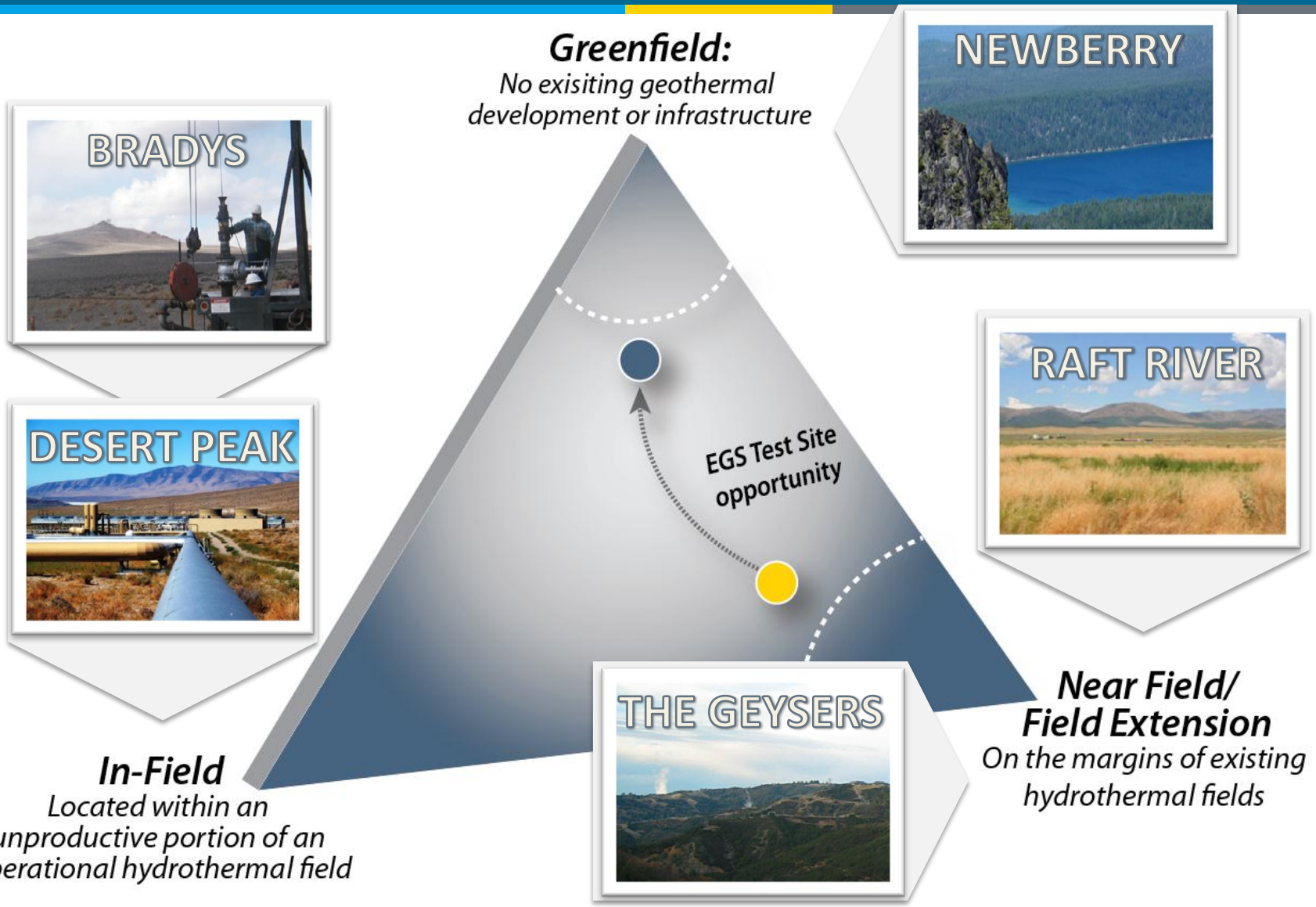

Near and Intermediate-Term EGS Growth

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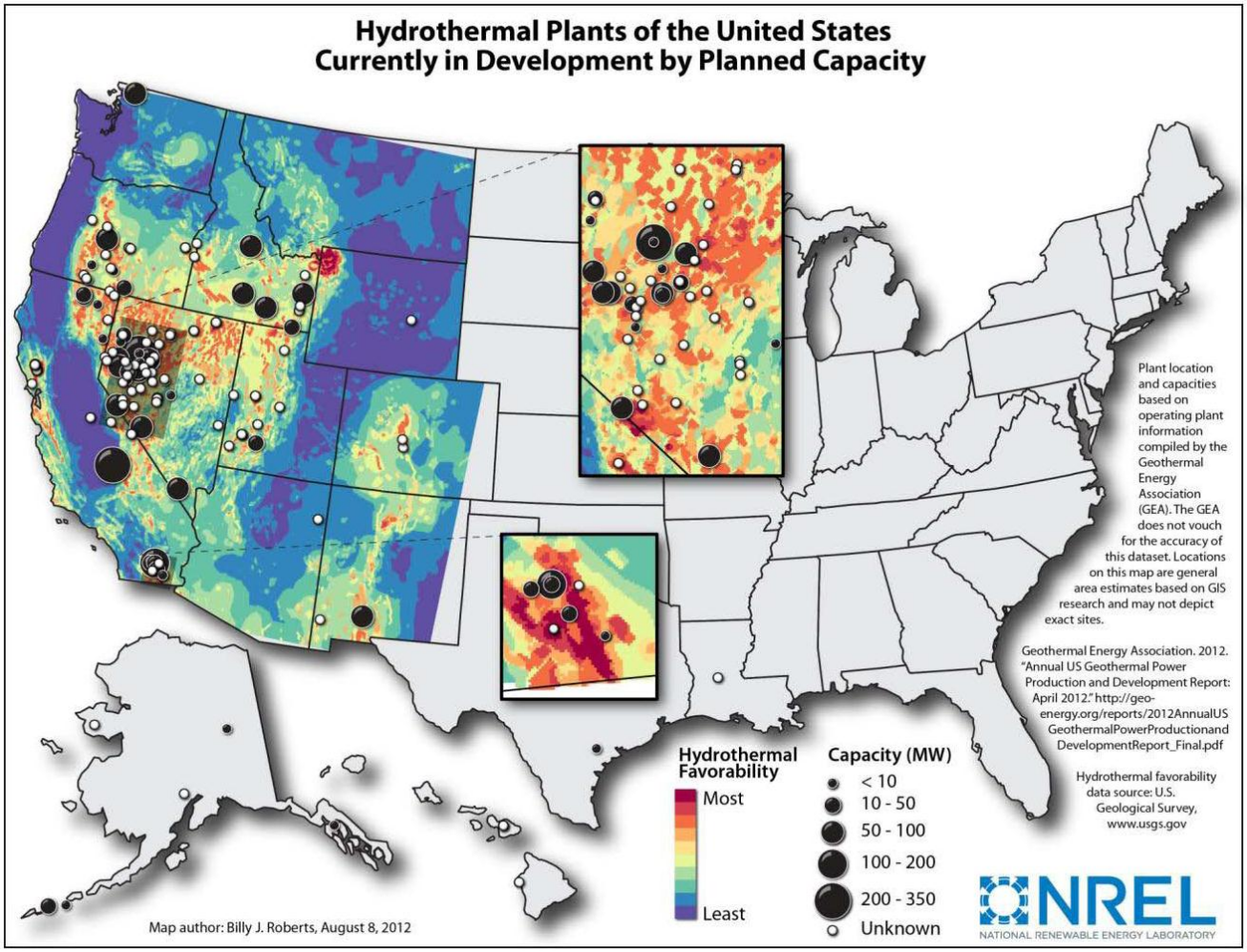
OUR VISION:

Increased success at Demo projects

Near-term use at existing fields as reservoir enhancement tool

1. Widespread deployment to ensure resource and reserve growth

2. Recognition by investment community of low risk and large opportunity



Preparedness- strategy, funding, oversight

Snapshot of Legacy International EGS

Important first steps

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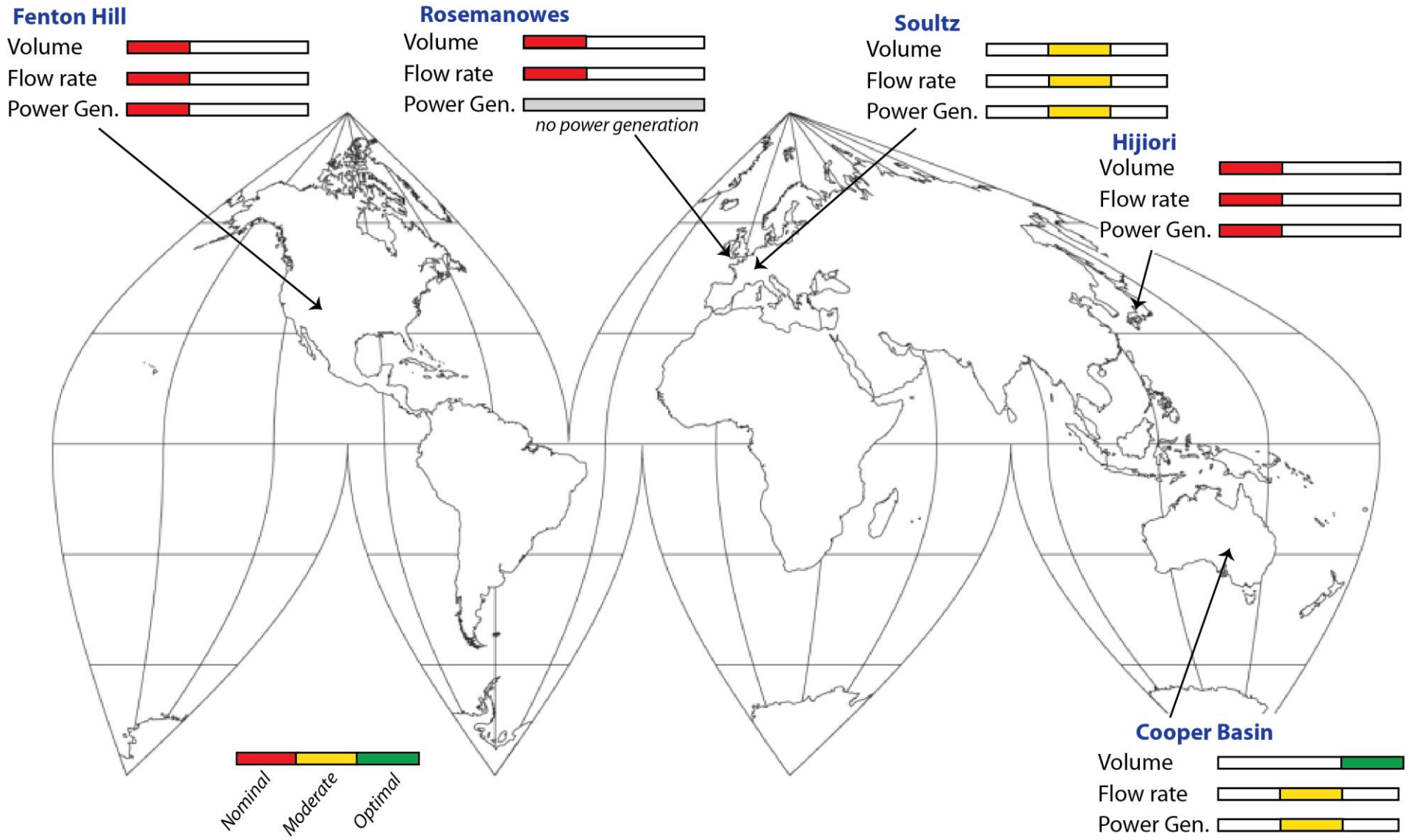

Snapshot of U.S. Efforts in EGS

EERE-funded demonstration projects showing excellent results

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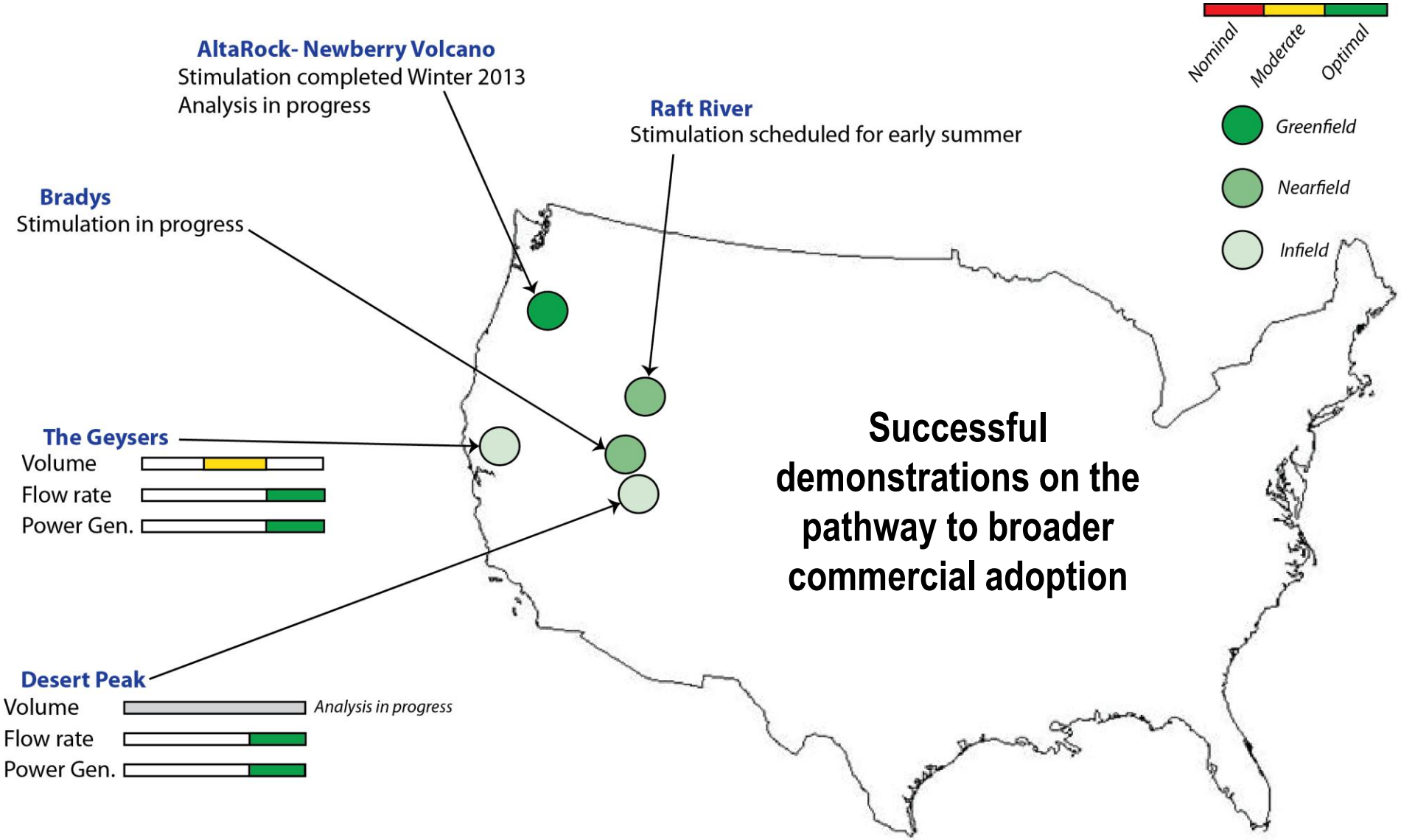

Current Global EGS Landscape

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Key Barriers to EGS Development

Technology and Engineering Needs

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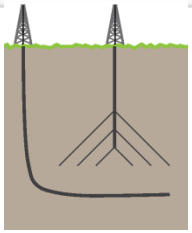
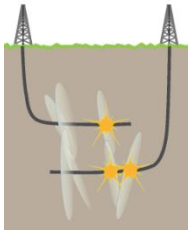
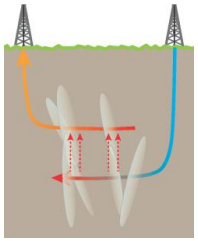
Technology Barriers	*Potential Solution Set*	*Goal*



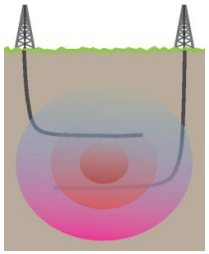
Reservoir Access
New well geometries and concepts, optimized drilling



Reservoir Creation
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

Horizontal wells – a first for geothermal

Rotary steering

Stress-field diagnostics

Smart tracers

Zonal Isolation

High-T sensors

Cross-well monitoring

Diverter technologies

EGS Success

Game-changers

EGS R&D Pathway

Needs and Opportunities

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R&D Pathway →

	In- to Near-Field EGS	EGS Field Lab	Industry Uptake
Timeline	**Near to Intermediate**	**Near to Intermediate**	**Intermediate to Long Term**
R&D Needs and Opportunities	Thermal Stimulations High-Temperature Thermally-Degradable Packers Multi-Stage Vertical-Well Stimulations	**First Horizontal Geothermal Wells** **Advanced Stimulation Methods** **Multi-Stage Lateral Stimulations** **New Subsurface Imaging Tech** **New International, Inter-Agency, and O&G Collaborations**	Reduced Risk from EGS Field Lab Methodology New Partnerships Streamline Permitting and Fundability Optimize Productivity and Operational Controls

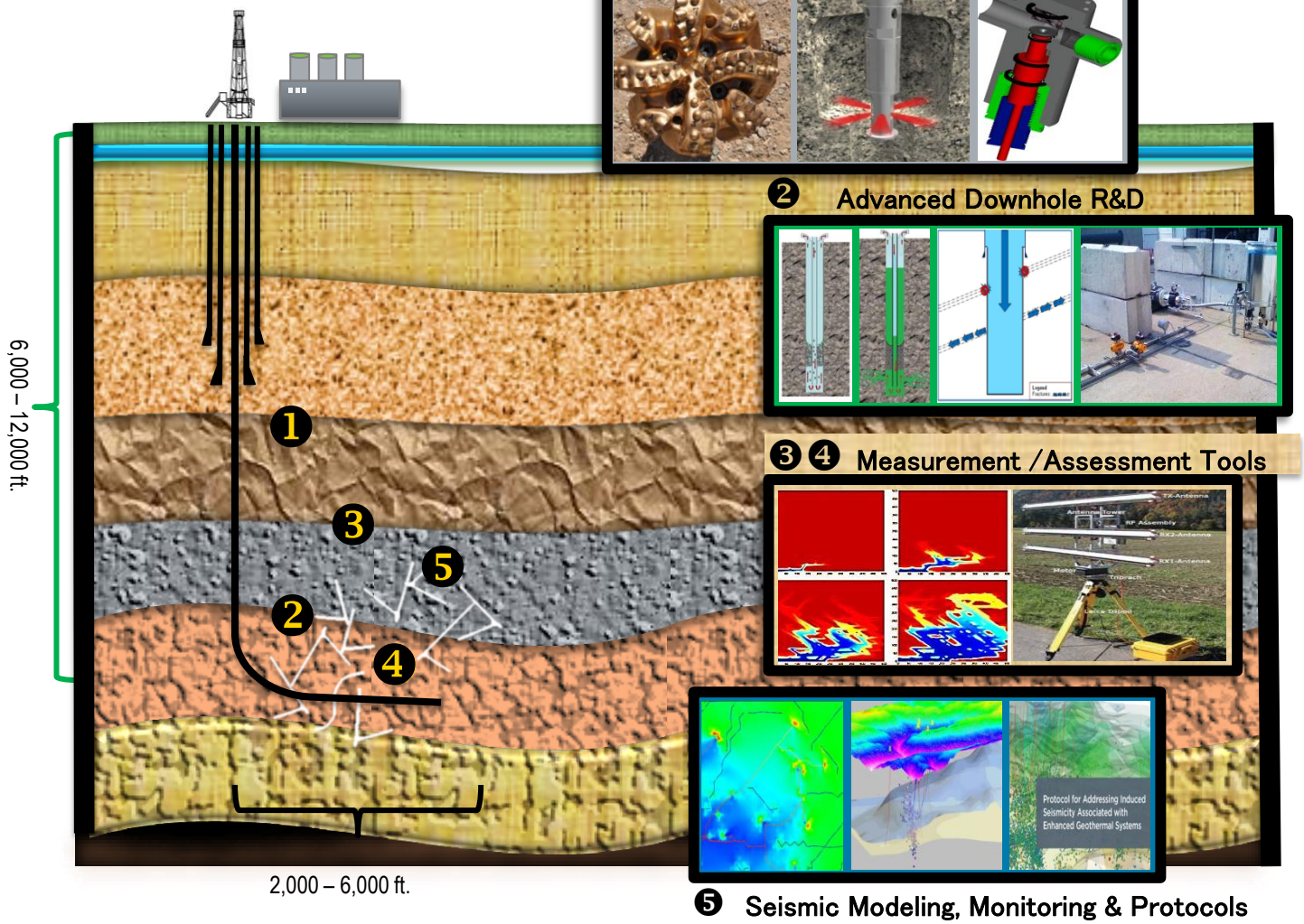
Challenges → Innovative Solutions

Low Risk: Testing of downhole tools, monitoring systems, etc.

Medium Risk: Testing of new drilling systems, chemical diverters, etc.

High Risk: Testing of potentially "destructive" well stimulation techniques

Examples: energetic well stimulation, testing which could lose part of the wellbore, stimulation which could alter a significant volume of the subsurface reservoir



FORGE

Frontier Observatory for Research in Geothermal Energy

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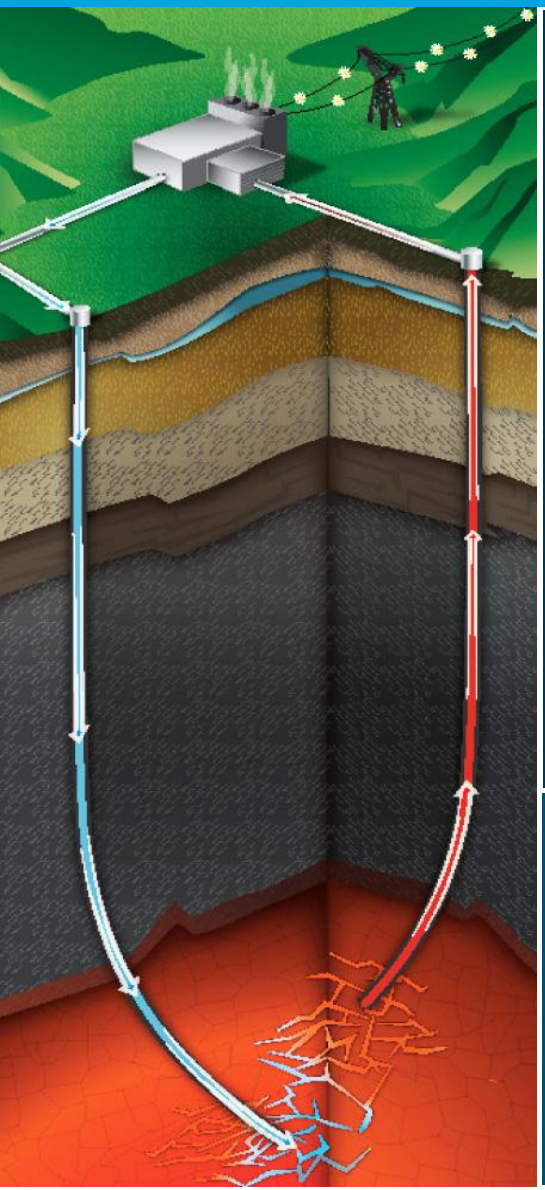


WHY?

Promote transformative science and engineering to:

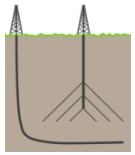
- Address key barriers
- Validate and optimize EGS technology
- Ensure deep understanding and reproducibility for commercial scale-up

Federal Role:

- Test technologies/take technical risks not possible in private sector
- Aggressive timeframe
- Gather and disseminate comprehensive data sets

Direct benefits to all areas of research in the geothermal space

TECHNICAL CHALLENGES



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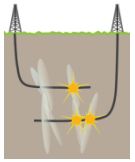

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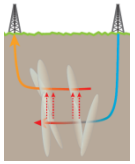

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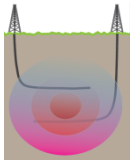

Sustainability

Maintain productivity with minimal thermal drawdown and water losses

FY13	FY14	FY15-19

Pre-conceptual Planning → Conceptual Design → Preliminary Design → Final Design → Site Characterization → RD&D/ Operations → Closeout

EGS Field Lab
What does success look like?

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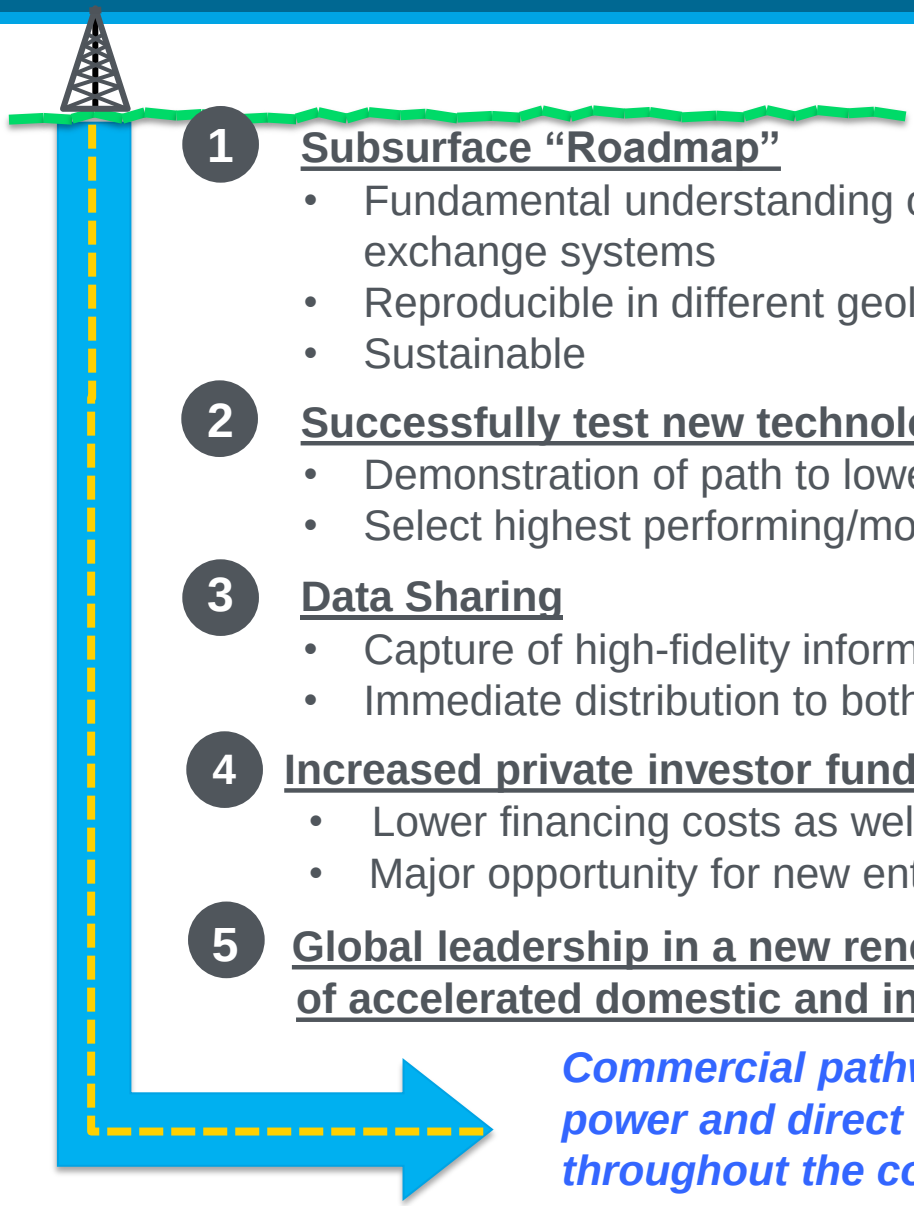

1. **Subsurface "Roadmap"**
   - Fundamental understanding of how to create large-scale subsurface heat exchange systems
   - Reproducible in different geologic settings
   - Sustainable
2. **Successfully test new technologies in controlled environment**
   - Demonstration of path to lower costs
   - Select highest performing/most reliable methods and tools
3. **Data Sharing**
   - Capture of high-fidelity information and measurements
   - Immediate distribution to both public and private sector stakeholders
4. **Increased private investor funding due to lower risk and costs**
   - Lower financing costs as well
   - Major opportunity for new entrants into the industry
5. **Global leadership in a new renewable energy sector – with expectation of accelerated domestic and international adoption of EGS**

Commercial pathway to EGS well productivity and large-scale power and direct use – becoming more broadly distributed throughout the country, beyond the western US

Future GTO Initiatives/Focus Areas

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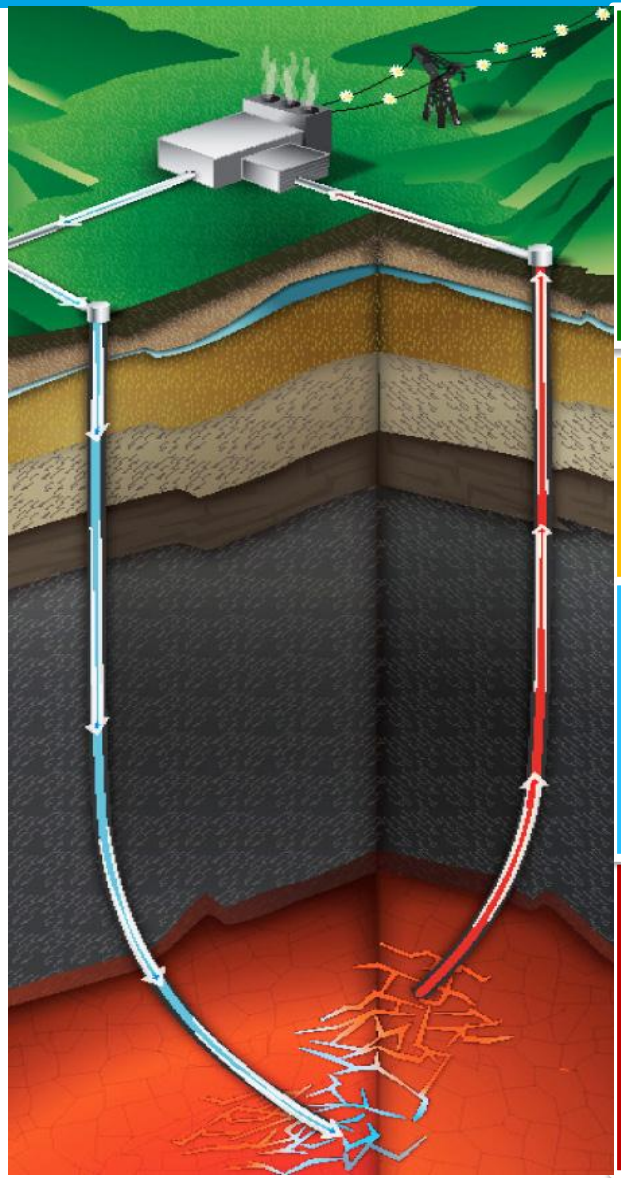
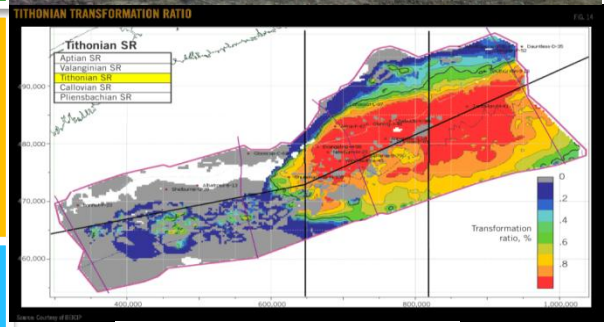


Enhanced Geothermal Systems

- EGS Field Observatory
- Advance down-hole R&D
- Characterization/Assessment tools

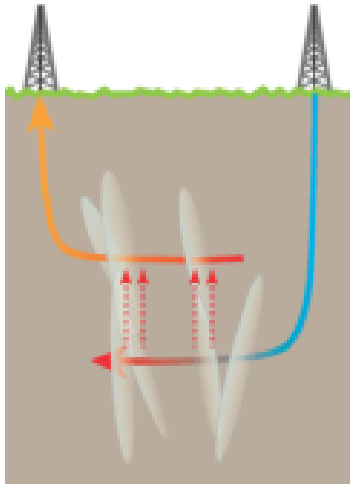
Hydrothermal

- Play Fairway Analysis/Mapping
- Advancing horizontal drilling technologies, high temperature tools
- Leverage oil and gas technologies



Low Temp/Coproduced

- Strategic materials
- Co-production and binary unit growth
- Direct Use and Distributed Energy
- Sedimentary systems



Systems Analysis

- Completion of Regulatory Roadmap, streamlining
- National Geothermal Data System (NGDS) deployment

Implications of Key R&D Advances

The Global Context

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- **EGS Demonstration Successes:**
  - Will accelerate industry adoption - will be seen as predictable, low risk and highly fundable
  - EGS Field Lab (FORGE) a major opportunity for multi-partner participation, R&D advances and sector transformation

- **Hydrothermal:**
  - New drilling technologies, new geophysical and exploration techniques and play fairway maps will lower risk and cost

- **Low Temperature:**
  - Co-Production success will drive adoption by oil and gas, and contribute to broader use of direct use and distributed energy

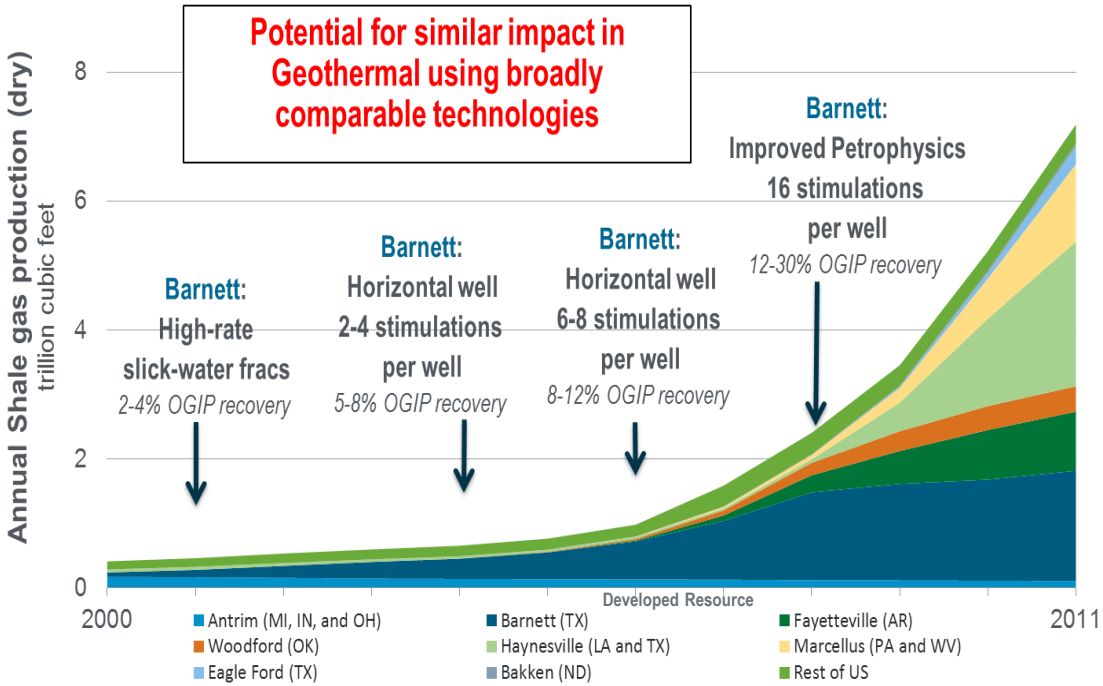
All highly transferable to international sites and opportunities

Global partnerships, collaboration, data sharing

Pathway to Transformative Change

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

US Shale Gas: Technology Innovations Spawned Sector Transformation



Sources: Lippman Consulting, Inc. 2011. Technology advances from King, 2012 (SPE 152596)

Geothermal Development Potential