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Desert Peak (Source: Ormat Nevada, Inc)

Geothermal Technologies Office

Stanford Geothermal Workshop

February 11-13, 2013

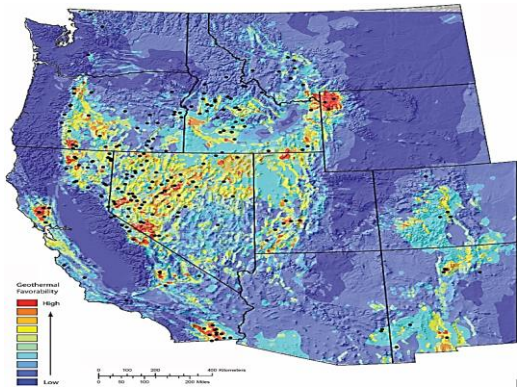
Doug Hollett, Director
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Geothermal Program: Key Goals and Objectives

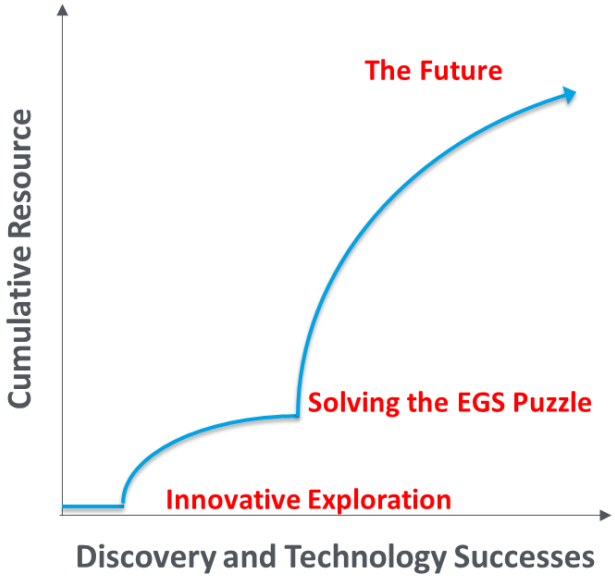
Creating Impact

Increased Focus

- ***Identify New Geothermal Opportunities***
  - **Lowered risk and cost**
  - **New prospecting workflow**
- ***EGS R&D and Underground Field Observatory***
  - **New techniques and technologies**
- ***Non-Technical Barriers***
  - **Regulatory Roadmaps and Optimization**
- ***Project Synergies***
  - **Co-Production and Distributed Power**
  - **Strategic Resources**



Geothermal Development Potential



- **EGS Demonstrations (3) and R&D successes**
  - **EGS underground field observatory in planning stages**

- **Projects:**
  - **~100+ MW of new hydrothermal capacity**
  - **NGDS, Regulatory Roadmap, Induced Seismicity Protocol**

- **Personnel:**
  - **New Staff: Josh Mengers (PMF); Dan King (AAAS); Chris Richards; Jodi Deprizio; Steve Hanson; Sharon Cosgrove**
  - **Leadership: Eric Hass (Hydrothermal), Lauren Boyd (EGS), Margaret Schaus (Operations), Jay Nathwani (Chief Engineer)**

- **Forums:**
  - **Workshop planned to better inform the Program – mid 2013**
  - **Student competition starting shortly**
- ***Increasingly looking at <u>impact</u> – areas or topics which are transformational and can make a significant difference will be funded***

3

Geothermal Program Balance

Transition from Near to Long Term

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	Low Temp	Co-Production	Hydrothermal	EGS
Timeline	**Current**	**Near Term**	**Near to Intermediate**	**Long Term**
Strategy	Distributed Energy	Leverages O&G investment	Sector Growth	Transformation
Scale	**100's KW to several MW scale**	**10's-100's MW scale, aggregate to several GW potential**	**10's GW additional potential**	**10's - 100's GW potential, but high risk**
Constituency	Local or Rural, Direct Use	Growing Interest, New Potential Sector	Majority of the Private Sector	Fewer Players

Geothermal Potential by 2030

Pathway to Growth

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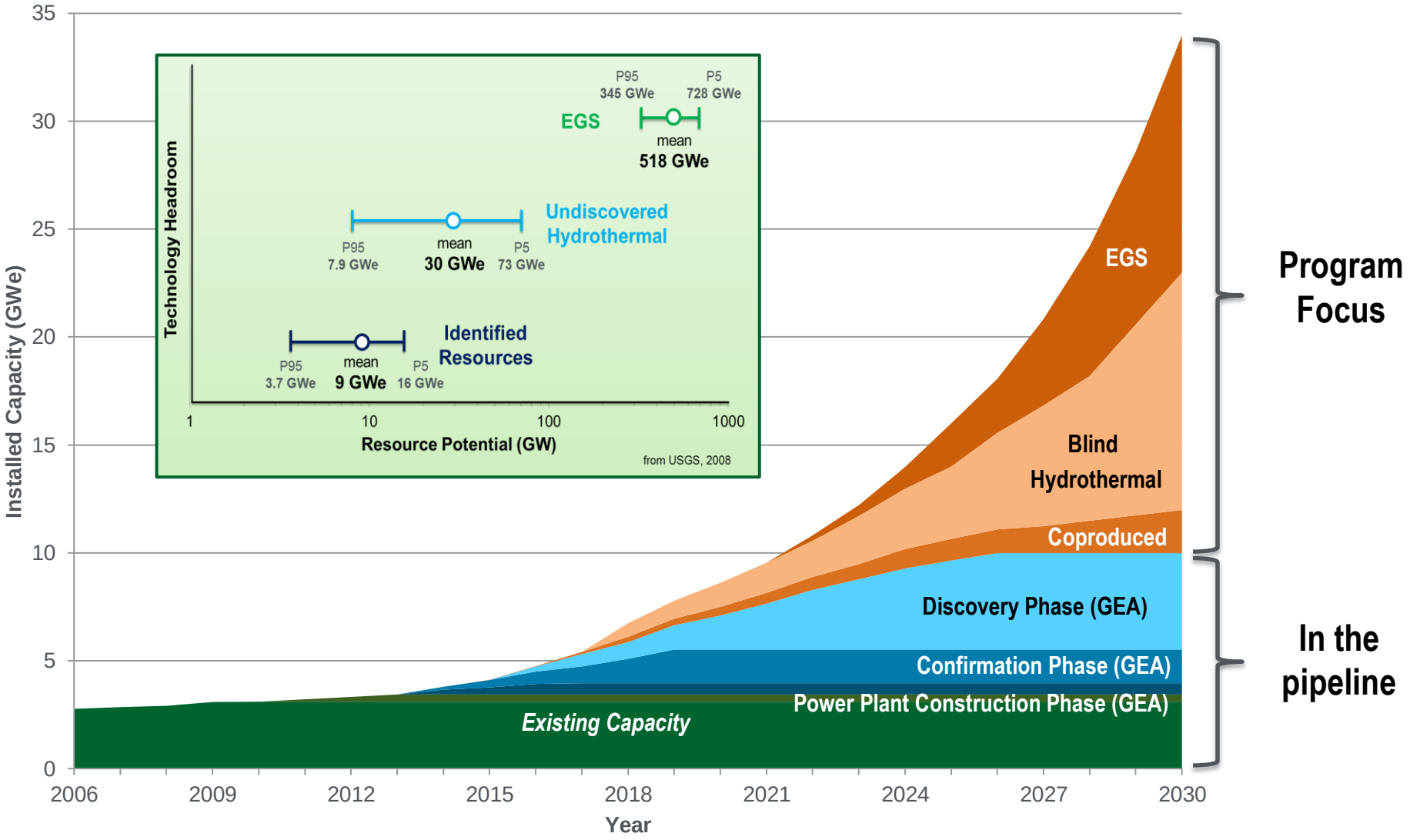

Geothermal Power Plants

2011-2012

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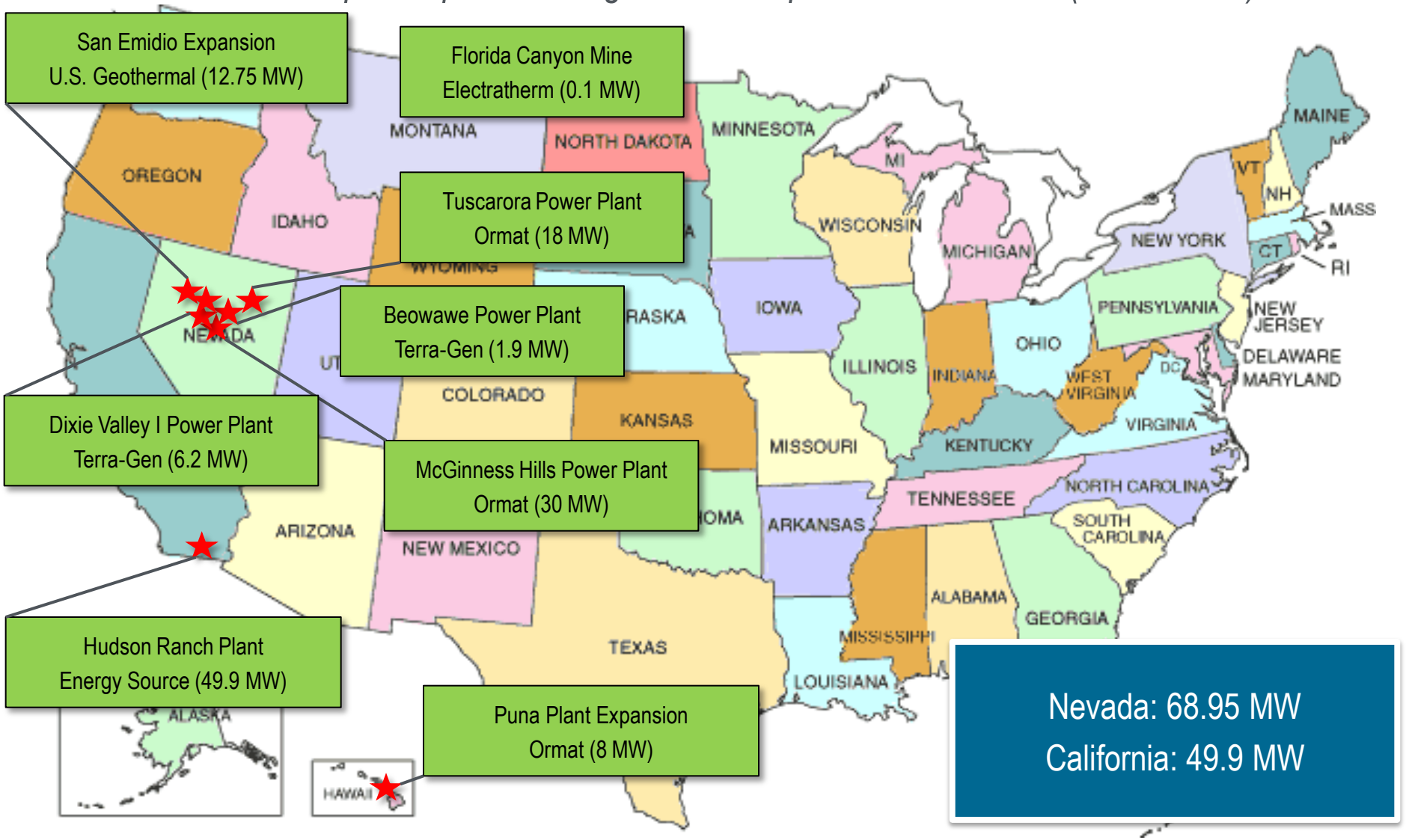
Geothermal power plants brought online/expanded in 2011-12 (126.85 MW)



Geothermal Projects

Phase III and IV Development

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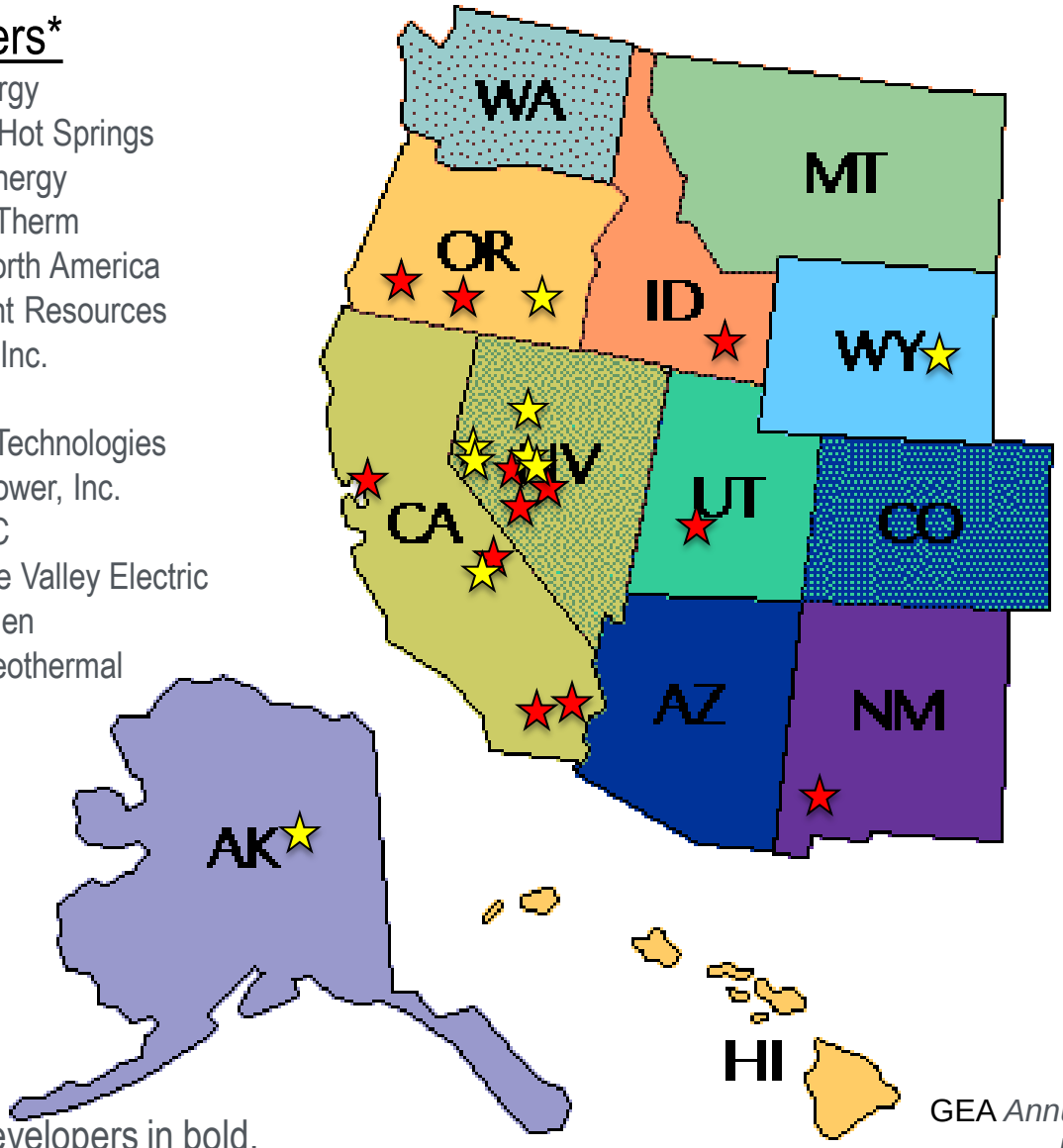
Developers*

- CalEnergy
- Chena Hot Springs
- Cyrq Energy
- ElectraTherm
- Enel North America
- Gradient Resources
- Kodali, Inc.
- OIT
- Ormat Technologies
- Ram Power, Inc.
- RMOTC
- 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)

Budget Overview

Challenging but a good path forward

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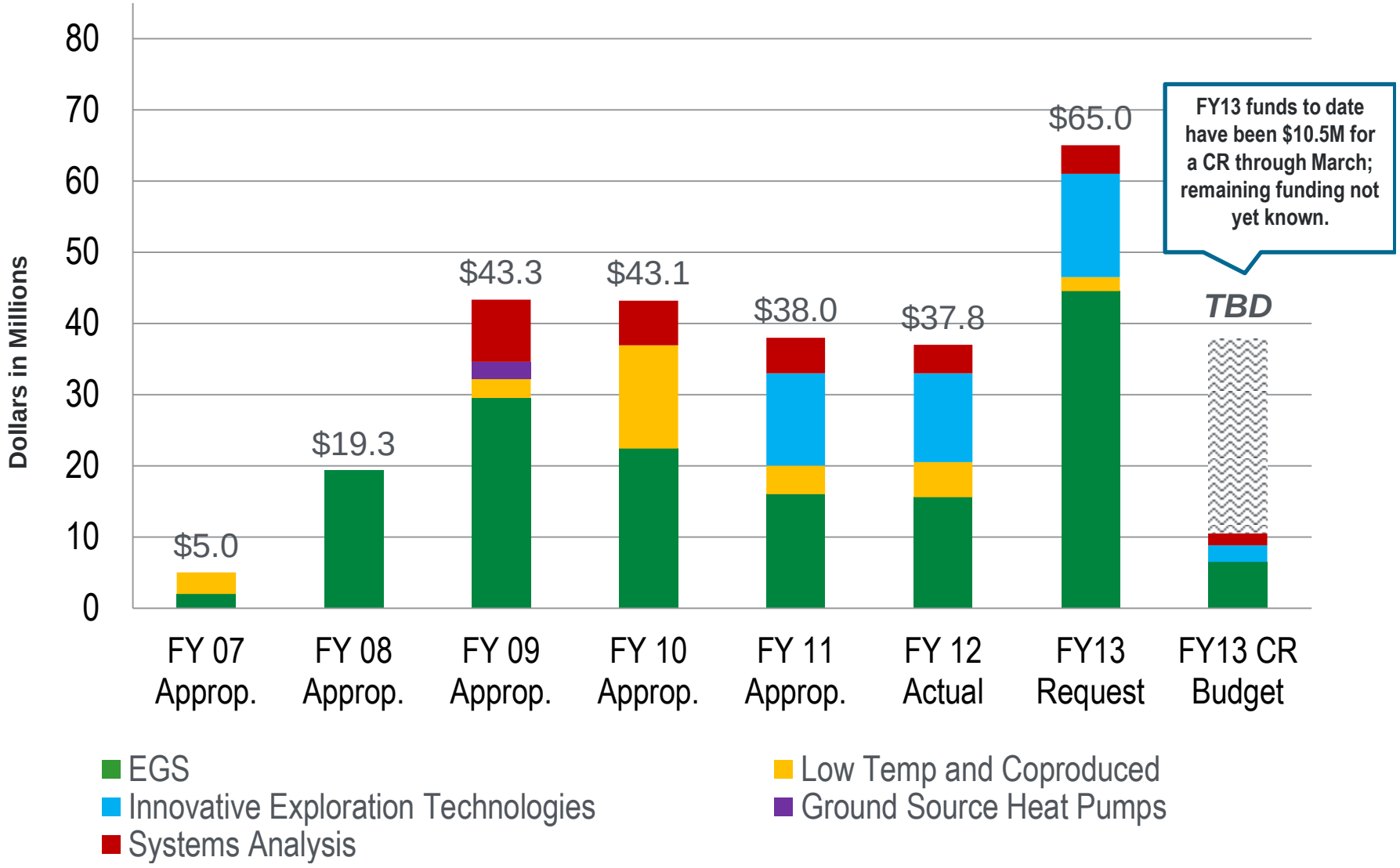

Core Program Focus

EGS Demonstration Projects

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Performer	Project Site	Site Information	Stimulation Timeline	Funding
Ormat Technologies Inc.	Desert Peak, NV	Adjacent to existing hydrothermal sites	***Successful stimulation completed- additional work underway***	**$ 4.3 M**
Geysers Power Company, LLC	The Geysers, CA	Reopen two existing wells to deepen for injection and stimulation	***Successful stimulation***	**$ 6.2 M**
University of Utah	Raft River, ID	Improve the performance of the existing Raft River geothermal field	Initiating in early FY13	**$ 8.9 M**
Ormat Technologies Inc.	Bradys Hot Springs, NV	Improve the performance of the existing Brady's geothermal field	Initiating in early FY13	**$ 3.4 M**
AltaRock Energy Inc.	Newberry Volcano, OR	High potential in an area without existing geothermal development	***Initial data indicates successful stimulation***	**$ 21.4 M**
NakNek Electric Association	NakNek, AK	Located in remote location in Alaska without existing geothermal development	Project on Hold	**$ 12.4 M**

Current EGS Demo Schedule

Spring 2013

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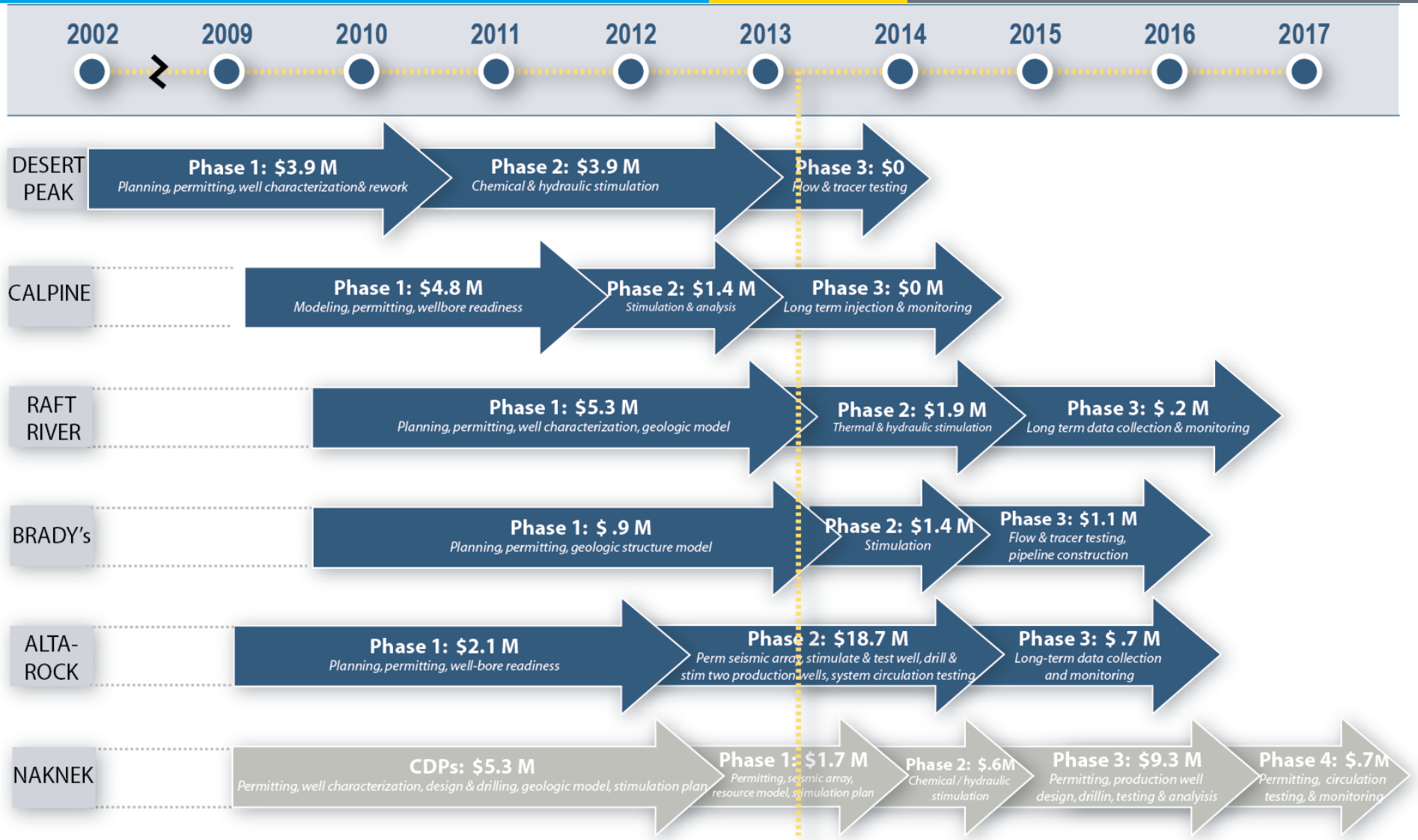

Enhanced Geothermal Systems (EGS)

Facies Concept – A Continuum

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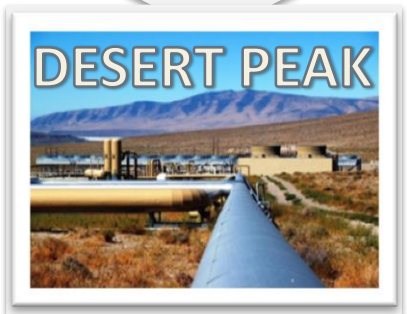
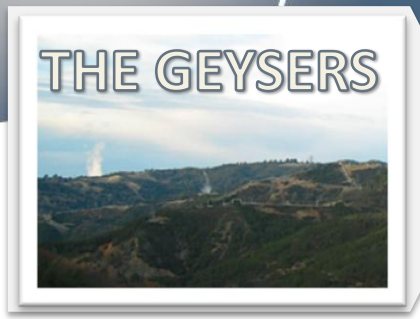
Greenfield:
No exisiting geothermal development or infrastructure



EGS Test Site opportunity



In-Field
Located within an unproductive portion of an operational hydrothermal field

Near Field/ Field Extension
On the margins of existing hydrothermal fields

Near and Intermediate-Term EGS Growth

OUR VISION:

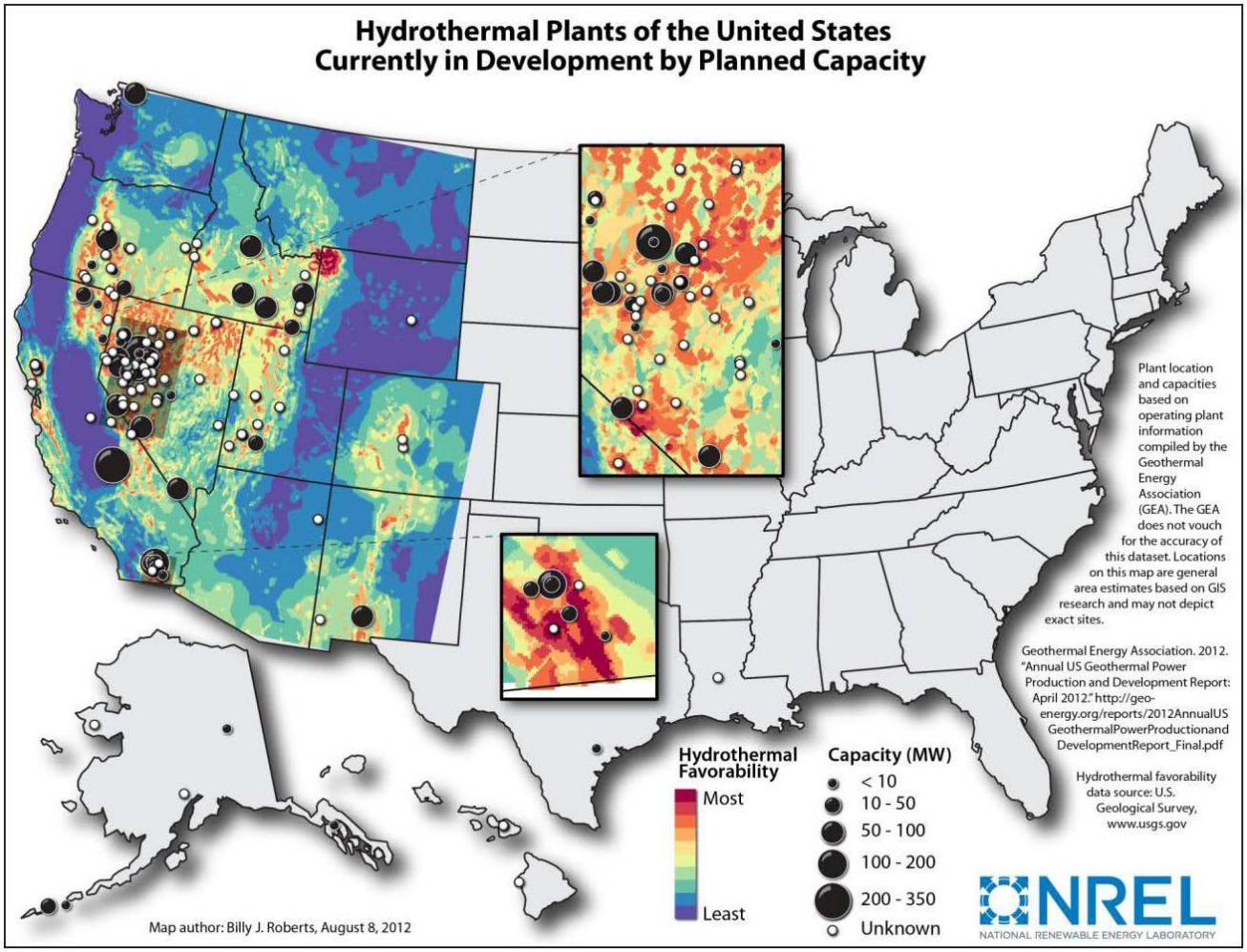
Increased success at Demo projects

↓

Near term use on margins of existing fields as reservoir enhancement tool (many in NV!)

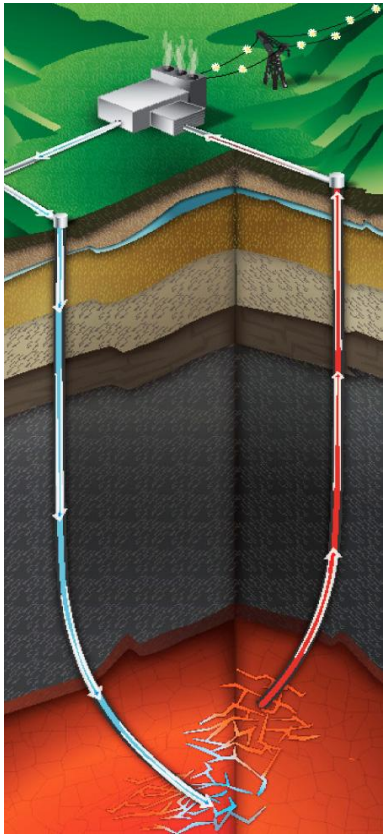
↓

Widespread deployment as routine reservoir enhancement tool at existing and fields in development



Preparedness- strategy, funding, oversight

EGS Technology → **Vast Resource** → **Field Lab Vision** → **Tested in an Ideal Setting**



Fully horizontal drilling has never been attempted in geothermal development.

How It Works

Man-made reservoir is created in hot rock that has insufficient natural permeability or fluid saturation.

Fluid is injected into the subsurface under carefully controlled conditions, causing pre-existing fractures to re-open, creating permeability.

Fluid is then circulated throughout the now-fractured rock and heat transported to the surface, where electricity is generated.

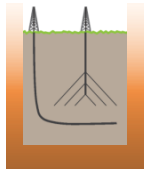
Benefits

A potentially important contributor to the US energy portfolio

- Baseload, non-intermittent energy source
- Minimal, environmental footprint, low emissions, and virtually carbon-free
- An incredible 100+ GW potential

EGS Field Lab

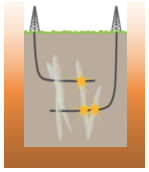
- Enable cutting-edge research, drilling, and testing.
- Directly benefit existing technologies in all areas of research in the geothermal space.
- Ultimately validate and optimize EGS technology into a replicable model for commercial scale-up.



BARRIERS

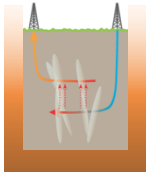
Reservoir Access

New well geometries and concepts, optimized drilling



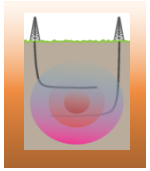
Reservoir Creation

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

SOLUTIONS

- Hard/Hot-rock drilling, completion technologies
- Horizontal wells – a first for geothermal
- Rotary steering
- Stress-field diagnostics
- Smart tracers
- Advanced Reservoir Modeling
- Zonal Isolation
- High-T sensors
- Cross-well monitoring
- Diverter technologies

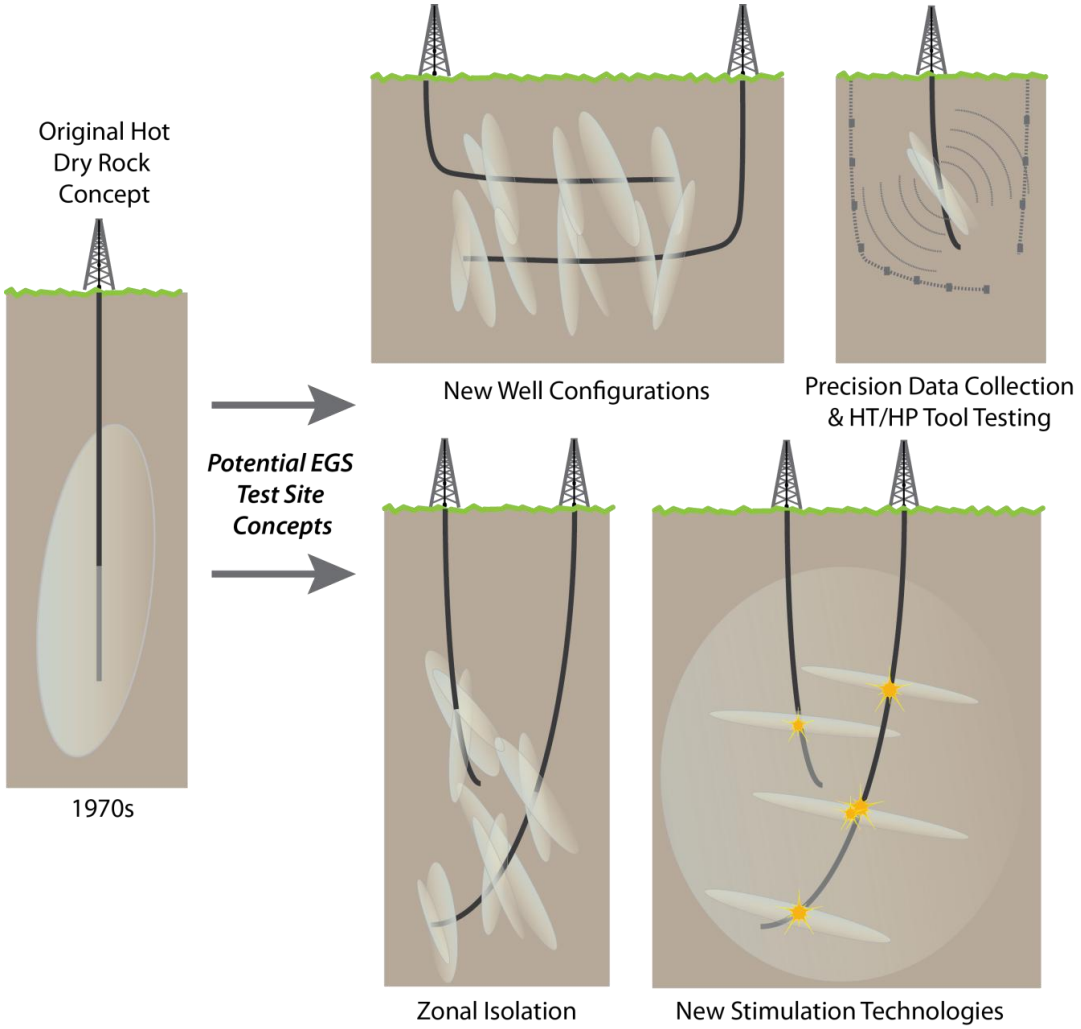
Ideal Characteristics:

Technical

- **Well characterized: 1-2 prior wells**
- **Hi T, some fractures, moderate permeability and porosity**

Logistics

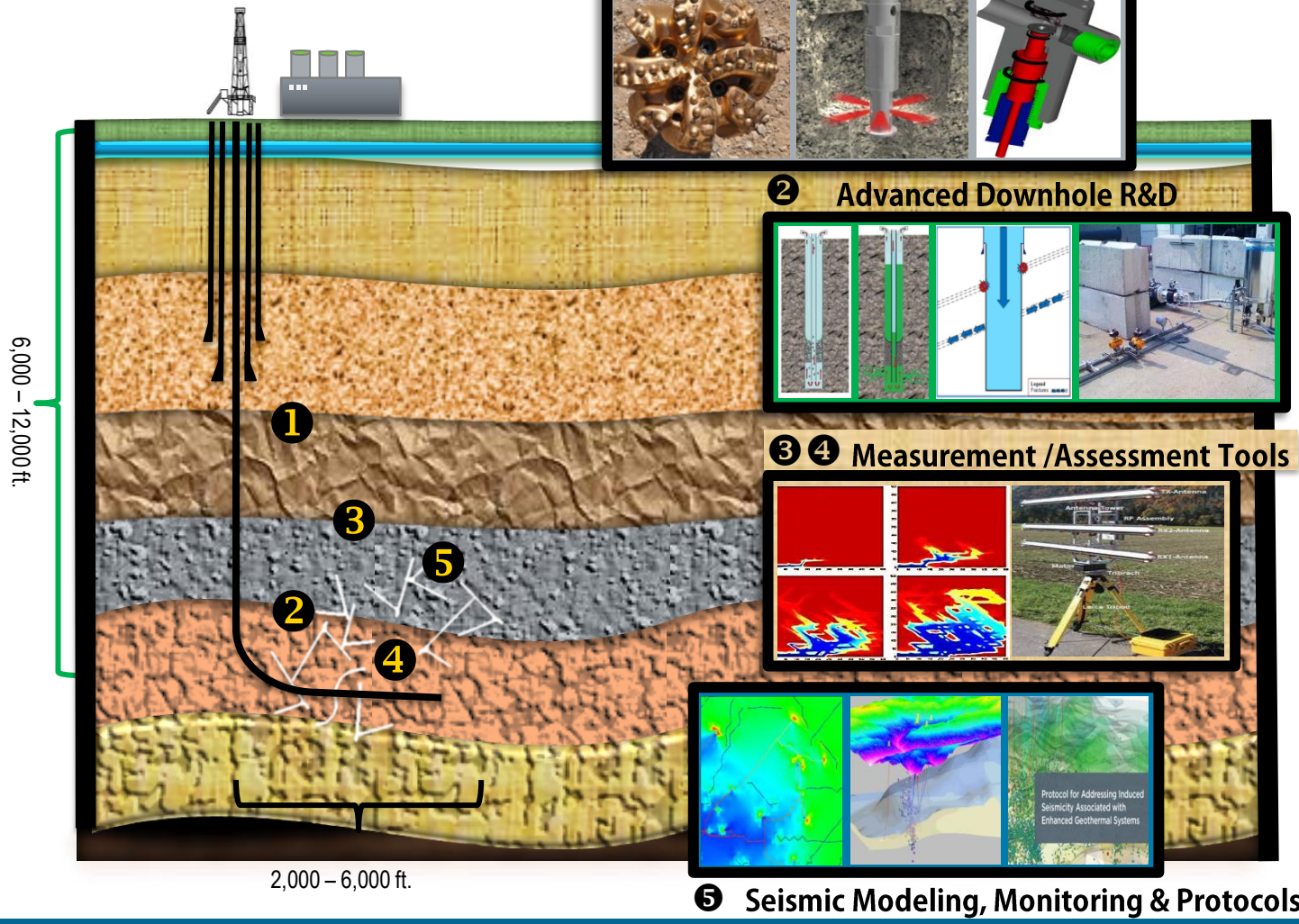
- **Existing or nearby infrastructure/assets**
- **Permitting pathway**
- **Minimal on-site facilities**
  - **NOT a long-term, permanent facility**



Challenges → **Innovative Solutions**

Barriers

1. High Cost of Drilling
2. Creating a Reservoir
3. Subsurface Characterization
4. Sustained Reservoir Production
5. Risk Management & Mitigation



EGS Underground Field Observatory

A few of the scientific challenges

1. **What are the critical characteristics of natural hydrothermal reservoirs that must be translated to EGS for a reservoir to sustainably produce heat for 20-30 years? How can hydrothermal reservoirs be improved for optimal heat extraction?**

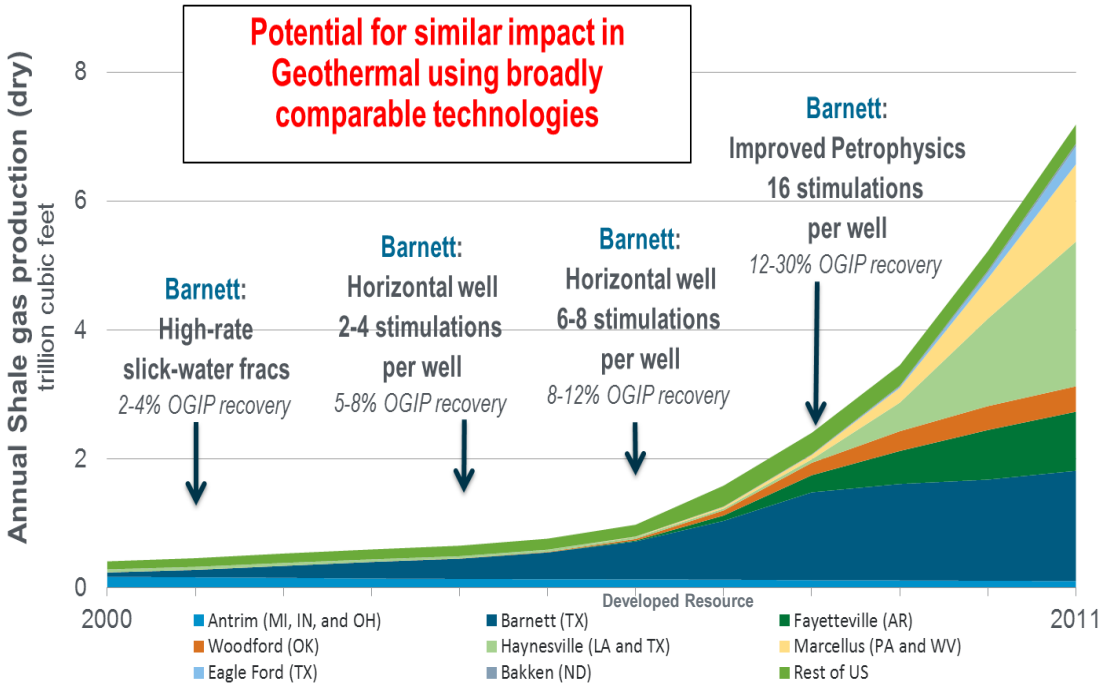
2. **What are the observational limits for imaging fracture creation and propagation?**

3. **Are there novel materials that could be emplaced in the reservoir to improve sustainability?**

4. **Are there novel methods for permeating a rock matrix far field from the borehole?**

Pathway to Transformative Change

Shale Gas: Technology Innovations Spawned Sector Transformation



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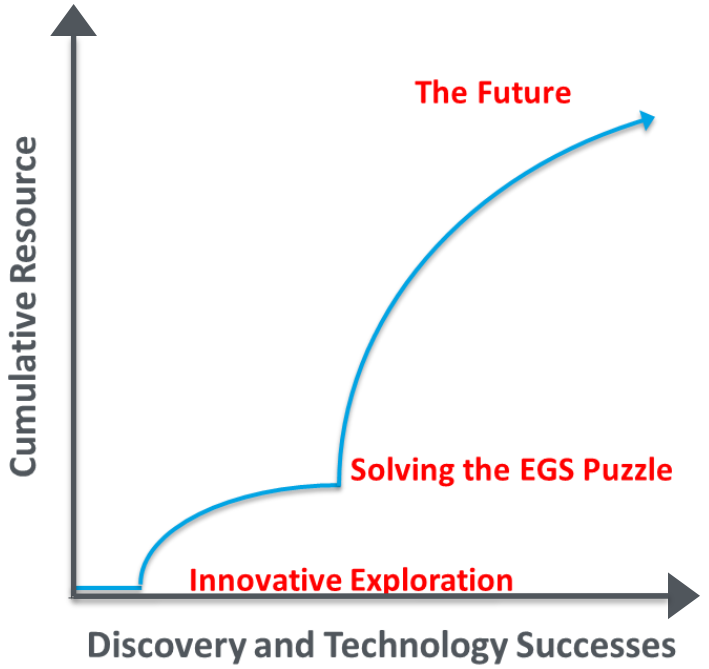

Sources: Lippman Consulting, Inc. 2011. Technology advances from King, 2012 (SPE 152596)

Position all major initiatives for initiation and execution over next 2 years

- **EGS Field Observatory:**
  - Competitive Solicitation end FY13
- **Horizontal well Project**
  - 1st activity Q4 2013
- **Play Fairway mapping**
  - 1st go-by completed 2013
- **Regulatory Roadmap**
  - Completion Q2 and support optimization
  - 5 of 10 white papers on key topics
- **Strategic Materials**
  - Project kickoff with key agency stakeholders
- **DOE-DOD collaboration**
  - Site selection and path forward
- **Oil and Gas Co-Production deployment**
  - Equipment in the field Q3, first data by year end