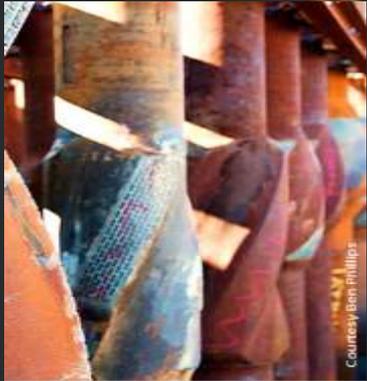


Geothermal Technologies Office

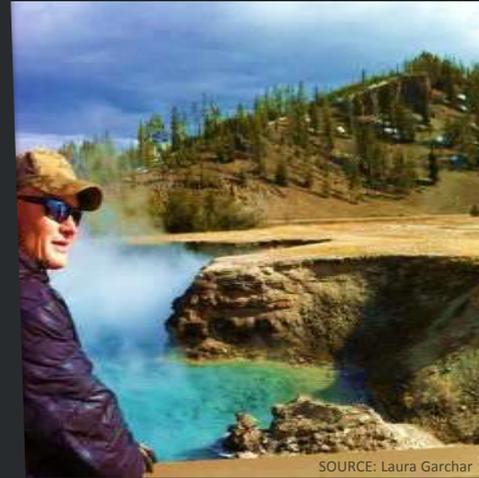
March 12, 2015



Courtesy Ben Phillips



SOURCE: Enel Green Power North America



SOURCE: Laura Garchar



SOURCE: TAS Energy



SOURCE: AltaRock Newberry EGS, E. Mercatle



SOURCE: Akutan Fumeroles, GRC

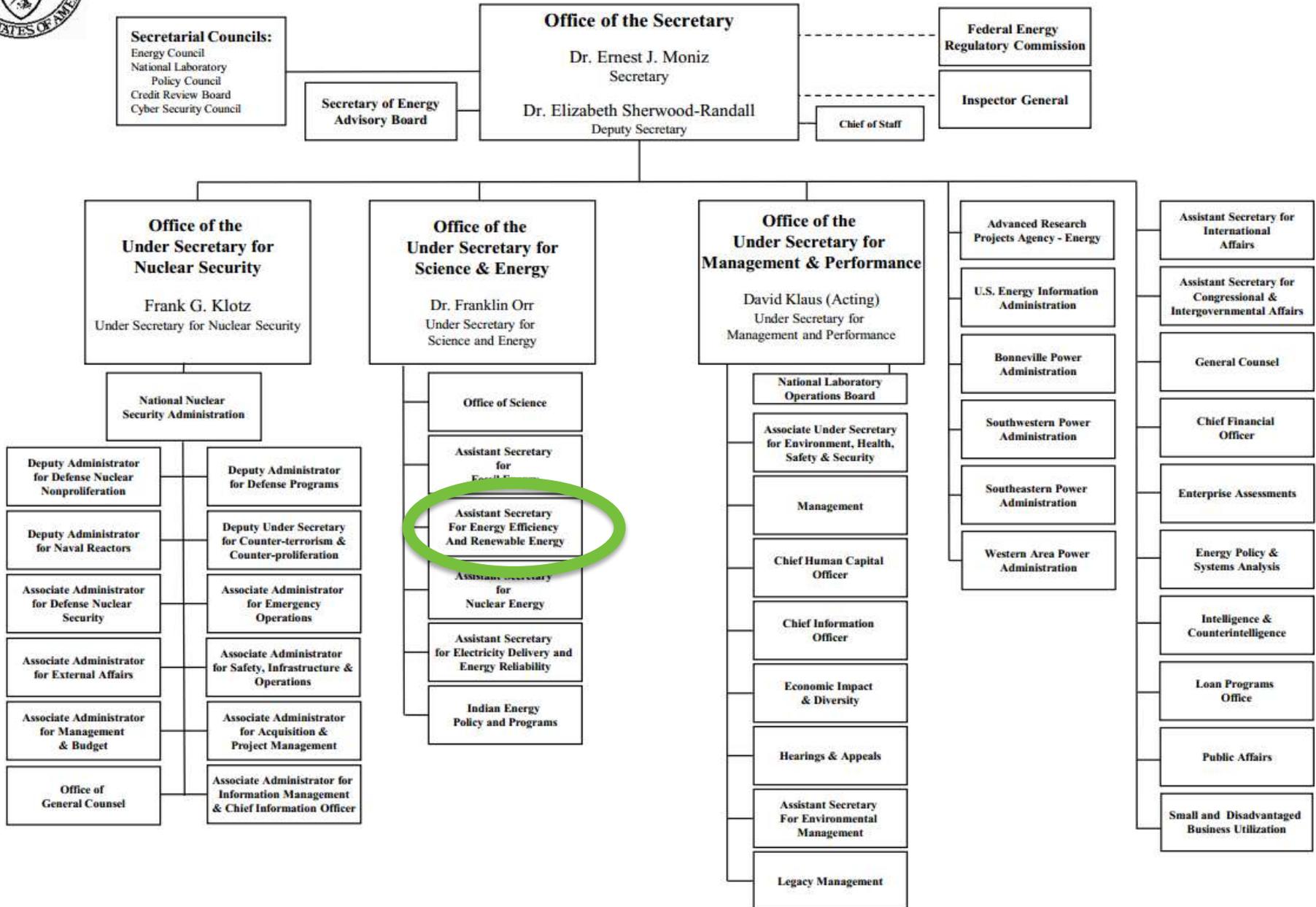


SOURCE: Old Faithful Geyser, Laura Garchar

Laura Garchar, Fellow



DEPARTMENT OF ENERGY



Office Mission

To accelerate the development and deployment of clean, domestic geothermal power that will promote a stronger, more productive economy; support a cleaner environment; and improve energy security.

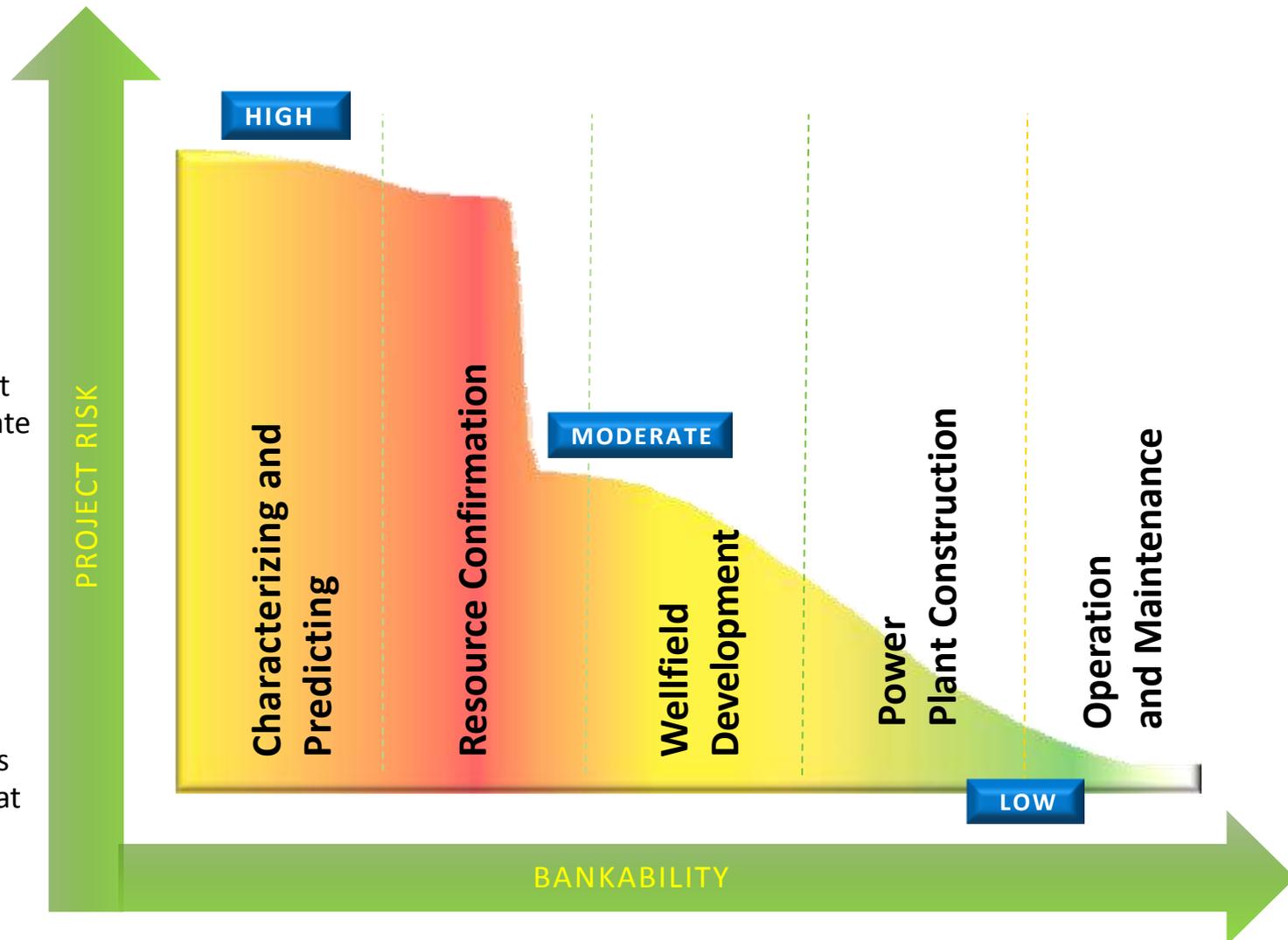


Geothermal Lifecycle Costs and Risk: Stages to Deployment

The Energy Department addresses geothermal challenges at every stage of development

with a full complement of projects to accelerate the adoption of geothermal energy:

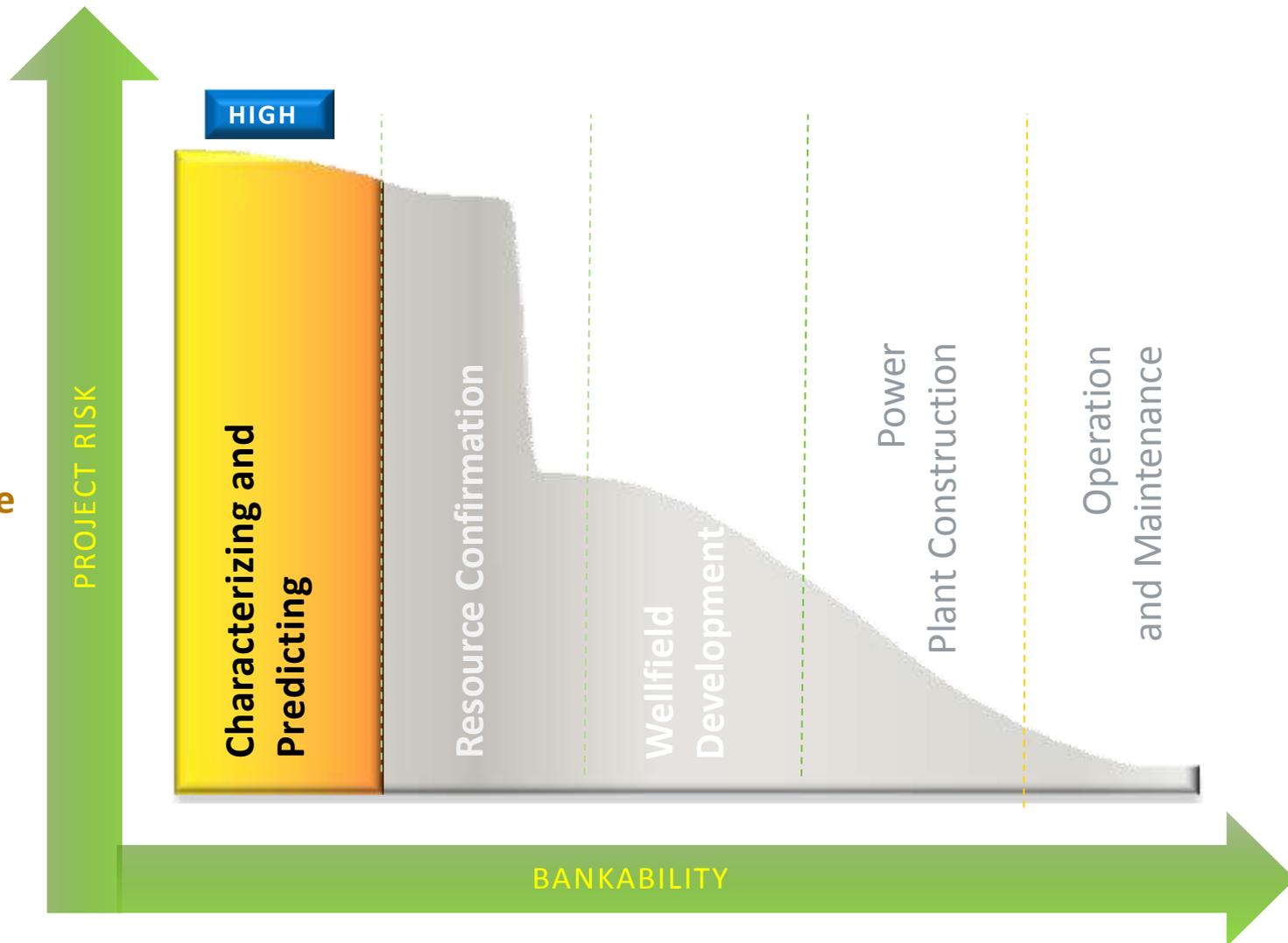
- Better targeted drilling
- Improved understanding of the subsurface
- Innovate new tools and techniques that improve the value equation
- Lower upfront costs



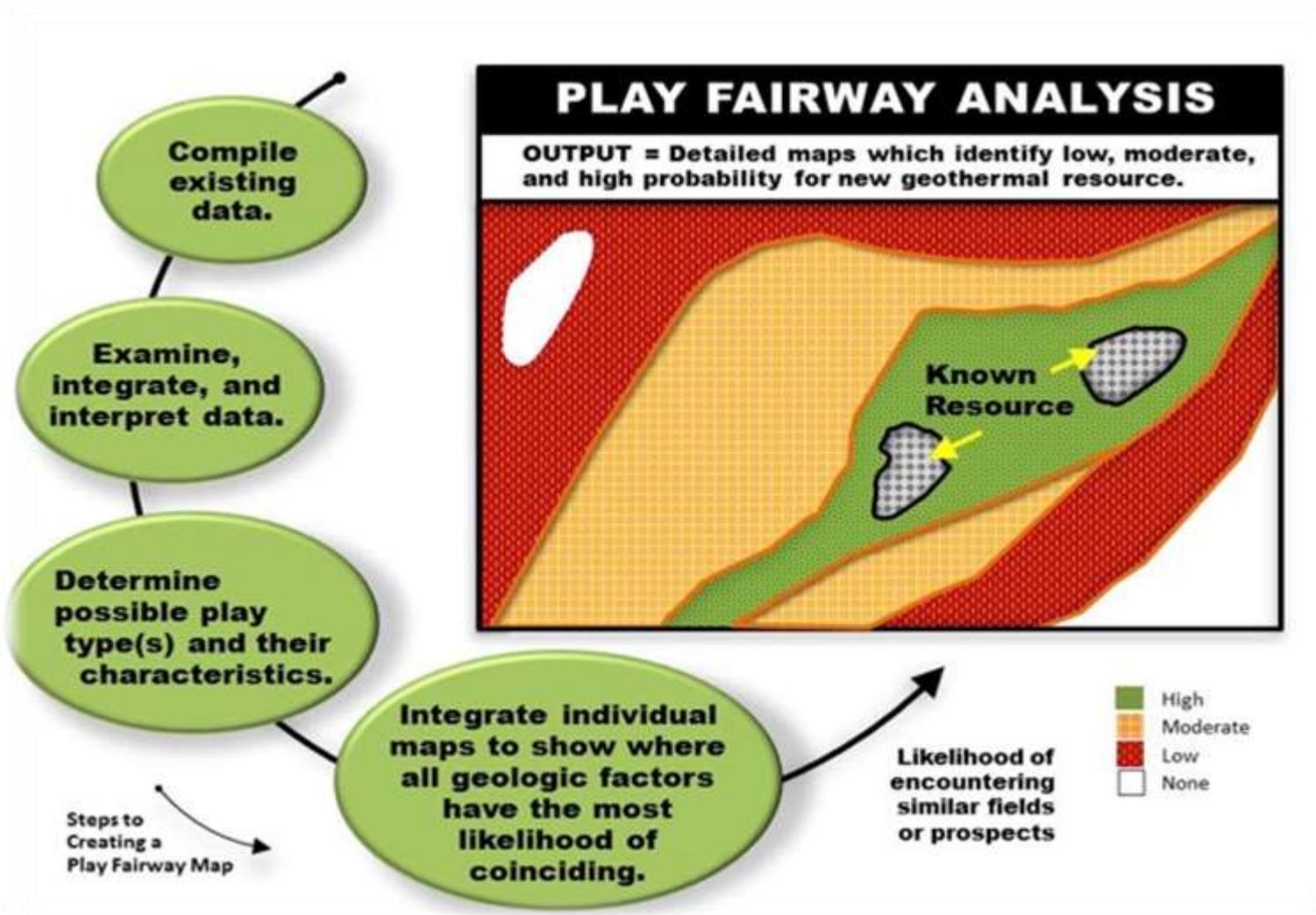
Stage One: Characterize the Subsurface

Mitigate the risks of geothermal exploration

- National Geothermal Data System
- Play Fairway Analysis
- New Subsurface Signals
- Geochemical/Geo-physical Tools
- Exploration Decision Tree



Play Fairway Analysis (PFA)



Play Fairway Analysis (PFA)

Before disturbing the ground, PFA reduces uncertainty and grades levels of prospectivity

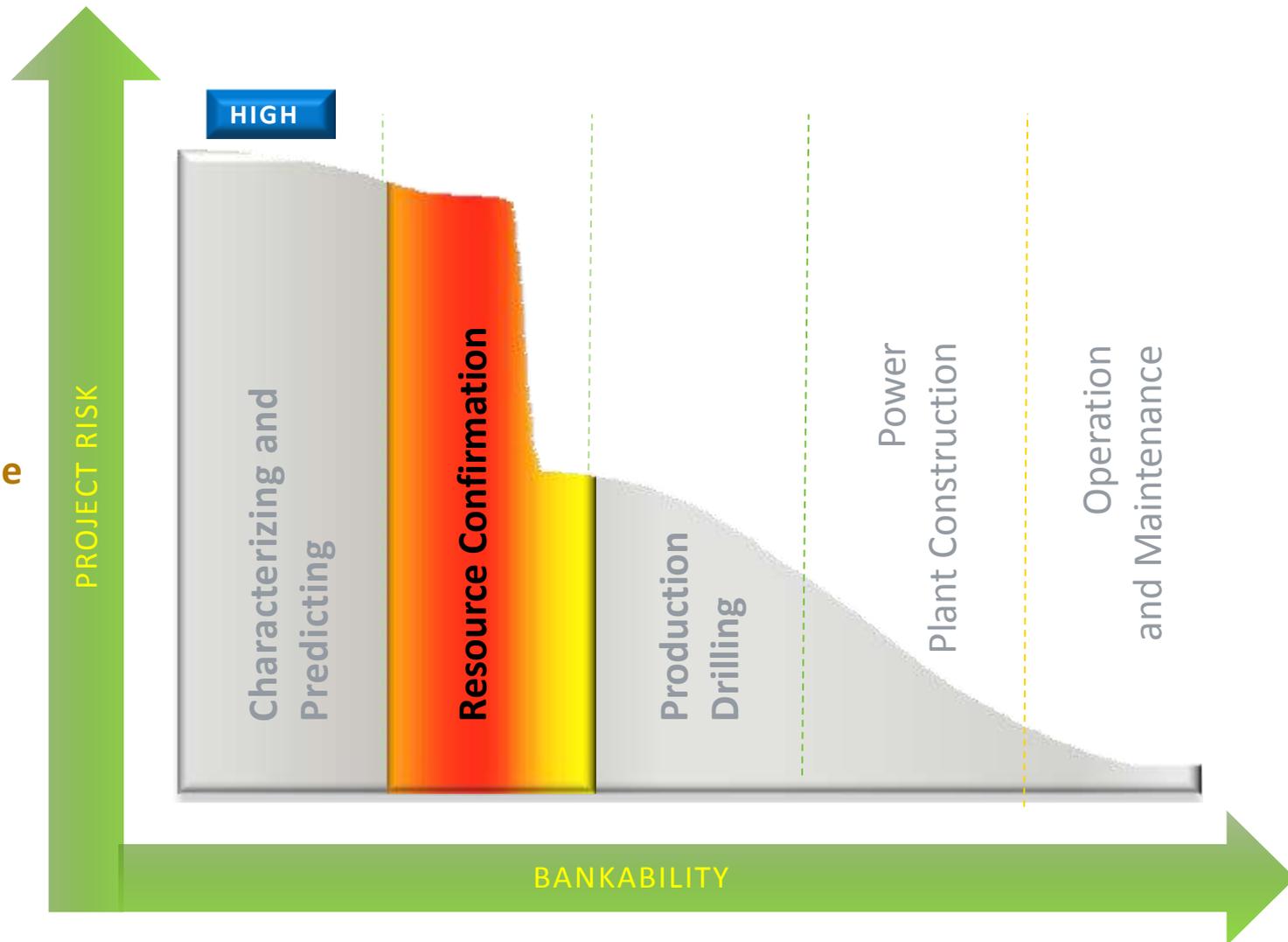
- Focuses initially on unexplored and underexplored known geothermal regions
- Identifies locations that have the highest probability of success
- Phase II: new data collection & drilling



Stage Two: Resource Confirmation

Validate and confirm the resource with:

- Innovative exploration drilling
- Micro-drilling
- Novel downhole tools
- Flow testing



Innovative Exploration Drilling and Testing



Courtesy Greg Kaufman

Validating prospective blind resources

- On-site active drilling projects
- Reduces risk through improvements in geothermal exploration
- USGS estimates 30 GW potential in blind hydrothermal systems in America
- Rigorous public-private collaboration
- Promotes economic viability of geothermal exploration technologies
- Identifies potential surface signals that can reveal deeper, hidden systems
- Play Fairway Validation Initiative - Phase II

Innovative Exploration Drilling and Testing - Alaska

Courtesy of Mike Weathers



Courtesy of GRC



Pilgrim Hot Springs:

To finish in March. 2MW PPA signed with the city of Nome.

Akutan:

Volcanic island in the Aleutian chain. Recently passed phase 1 (field surveys), preparing to drill exploratory well in the summer.

* Expected



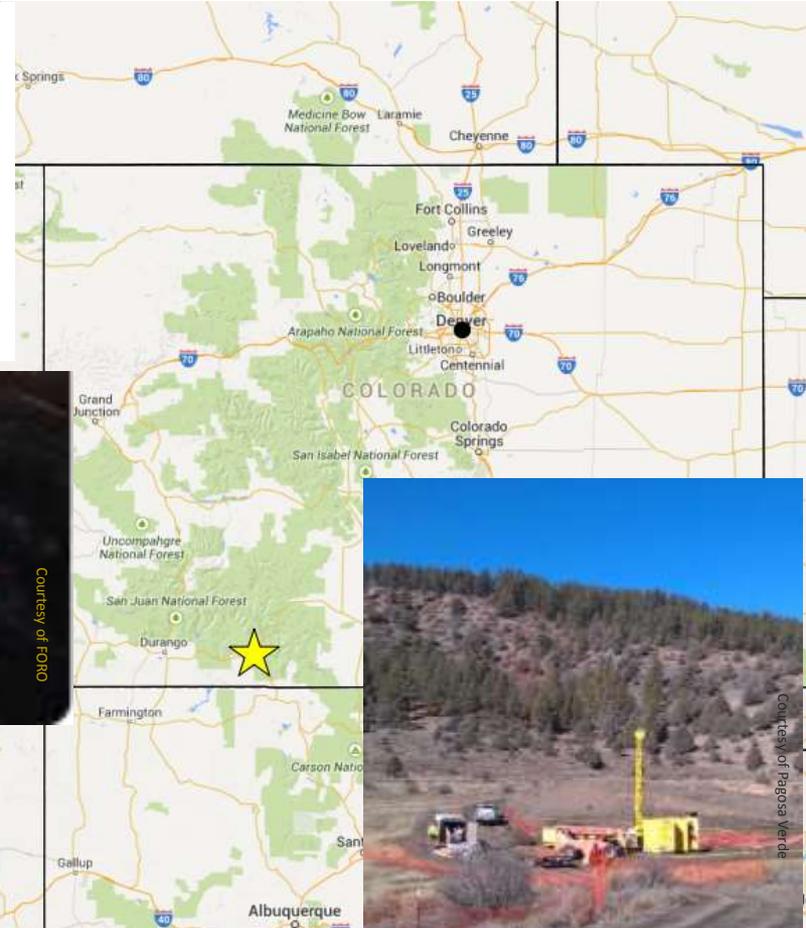
Energy Efficiency & Renewable Energy

Innovative Exploration Drilling and Testing



US Geothermal: using seismic and radar methods to image large aperture fractures to expand the San Emidio geothermal field.

Foro: Drill bits with laser beams attached to their heads. ARPA-E project (drilling) continued by GTO for completions. In preparation for field test.

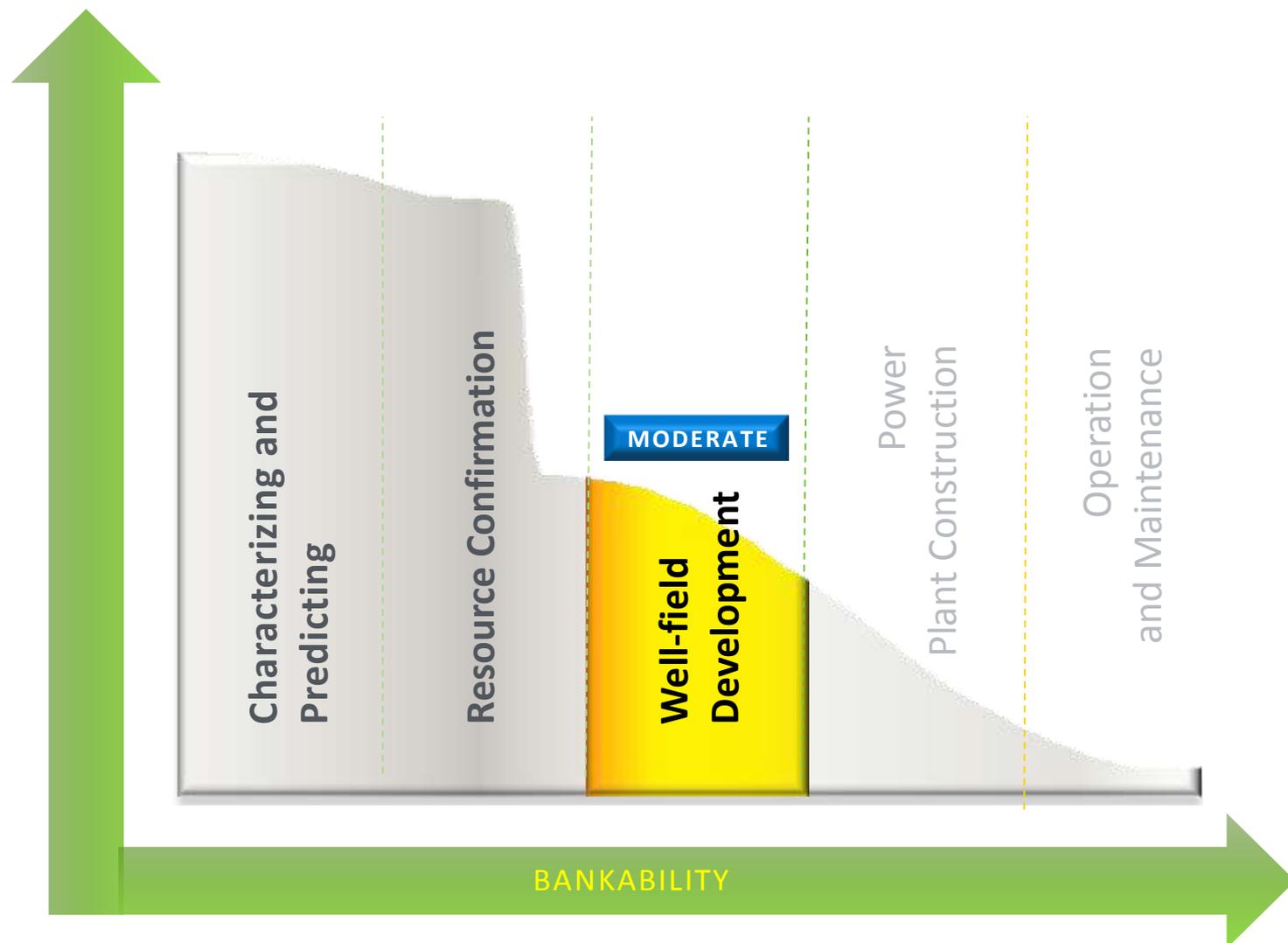


Pagosa Verde: GTO's \$3.9 million matched by \$1.98 million state bond, with a bill signed by Colorado Governor Hickenlooper in May 2014. Recently drilling.

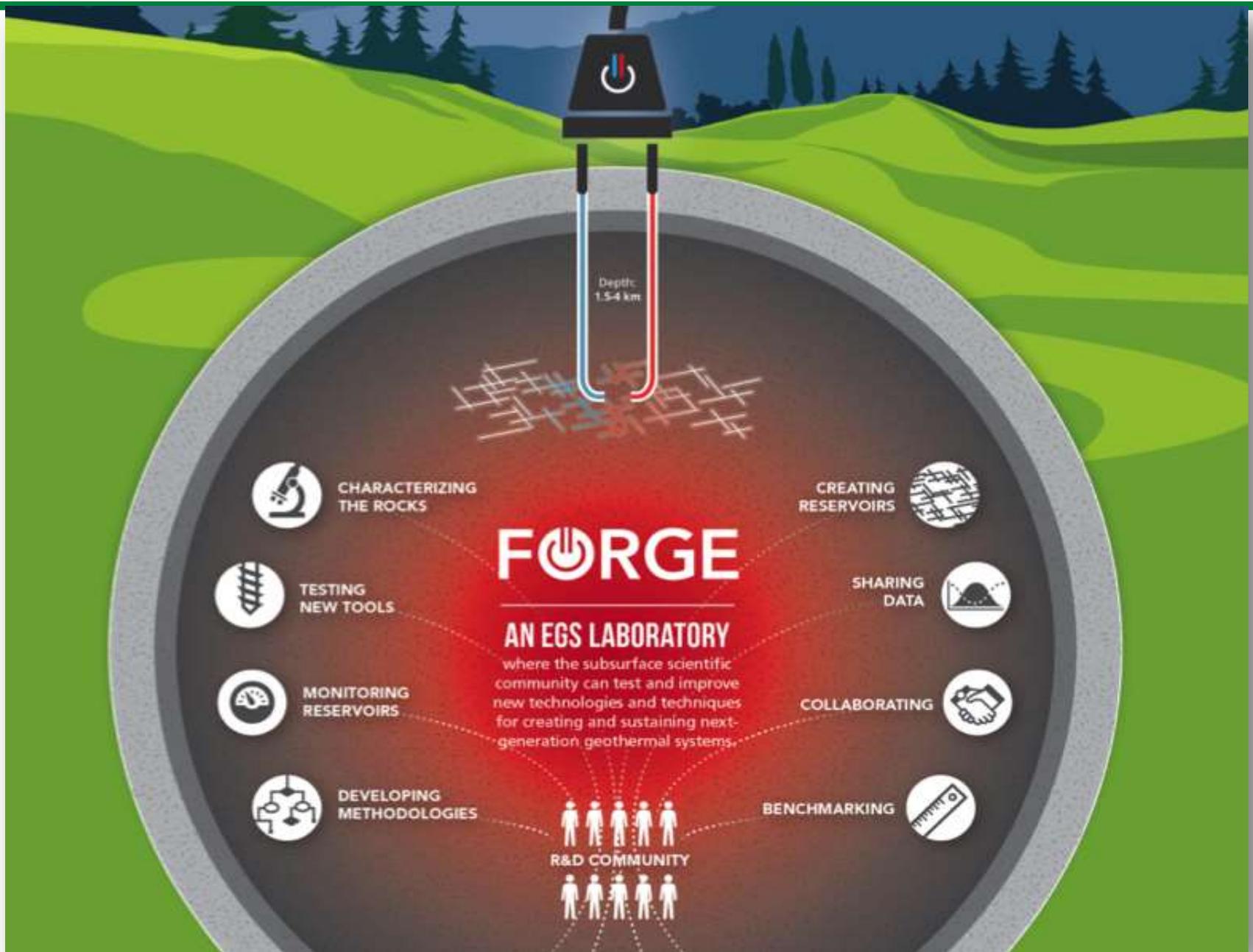
Stage Three: Wellfield Development

Reservoir engineering & optimization

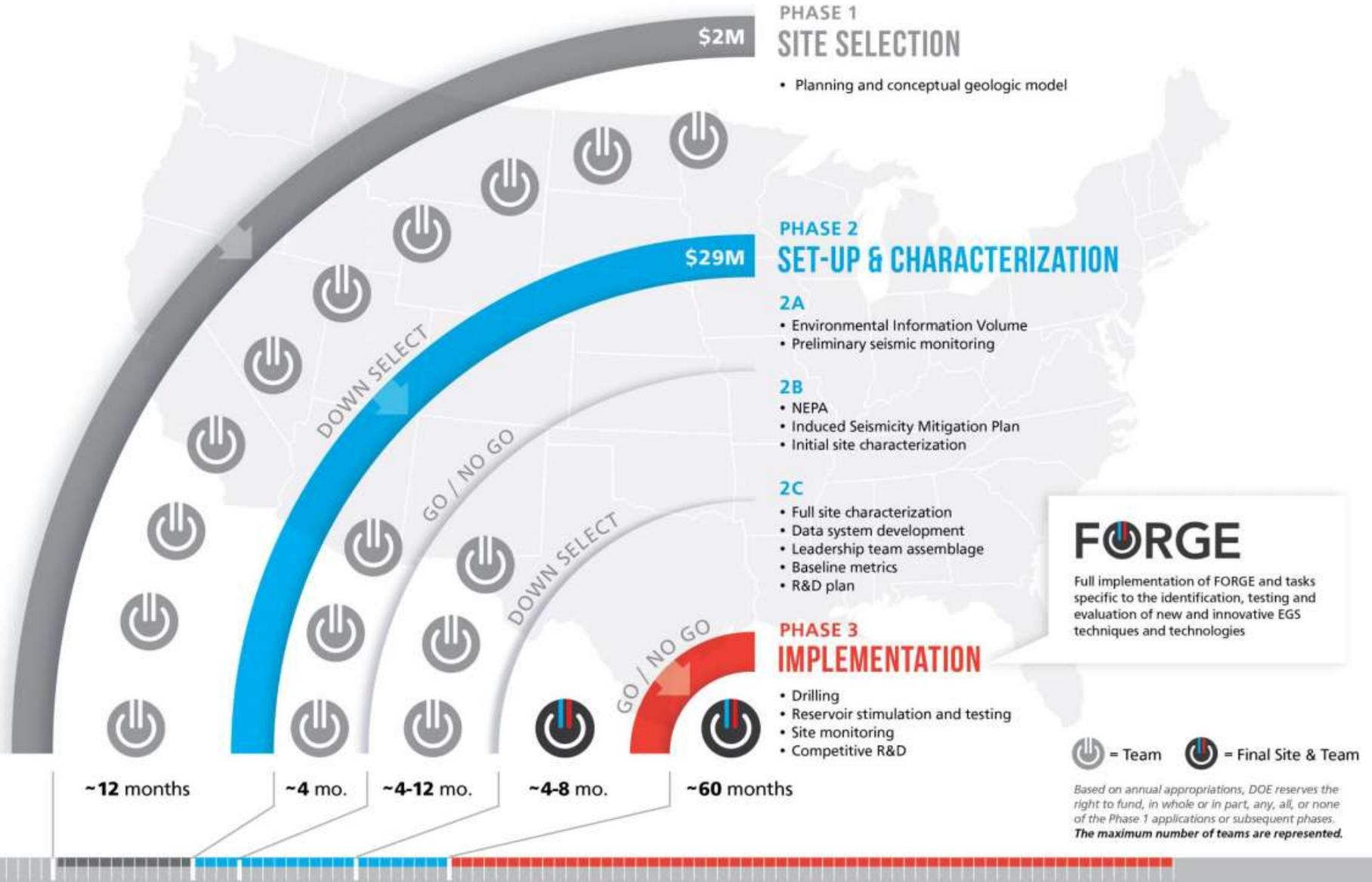
- EGS R&D
- FORGE
- Laboratory
- EGS



FORGE Initiative



FORGE Initiative



\$2M

\$29M

~12 months

~4 mo.

~4-12 mo.

~4-8 mo.

~60 months

DOWN SELECT

GO / NO GO

DOWN SELECT

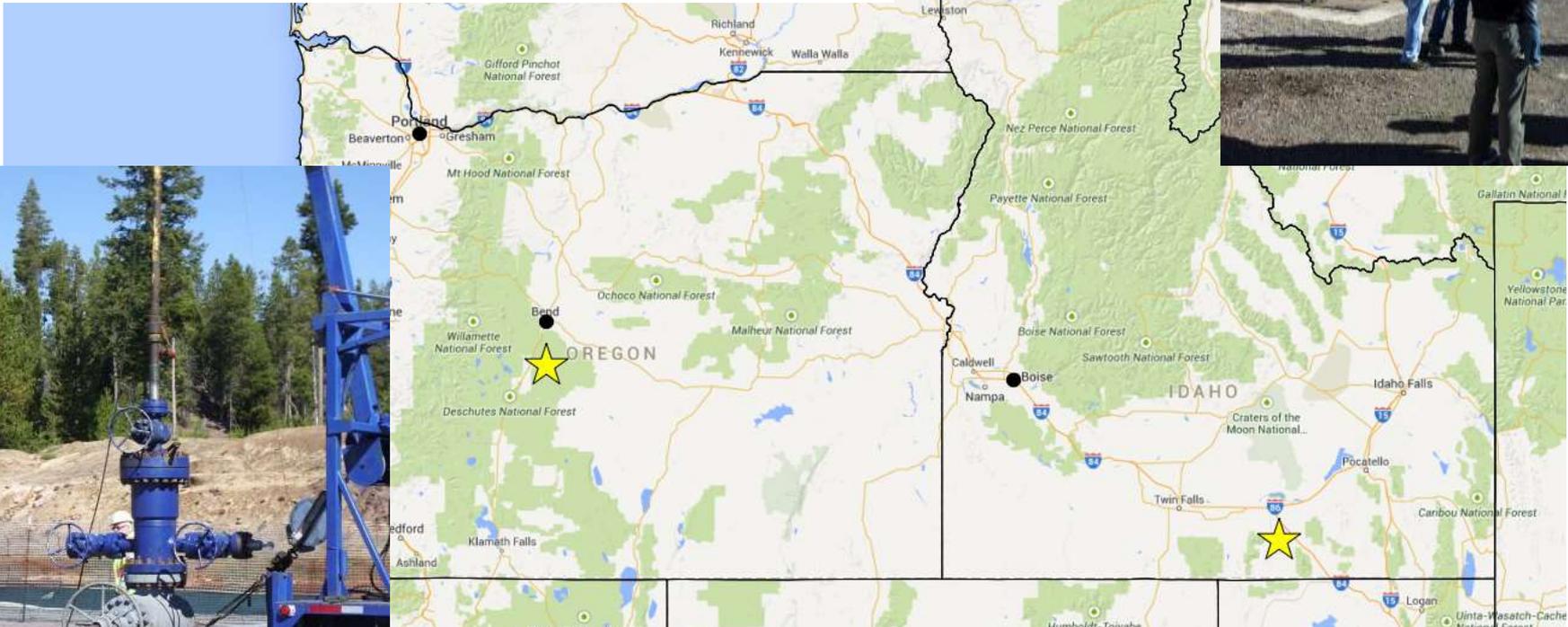
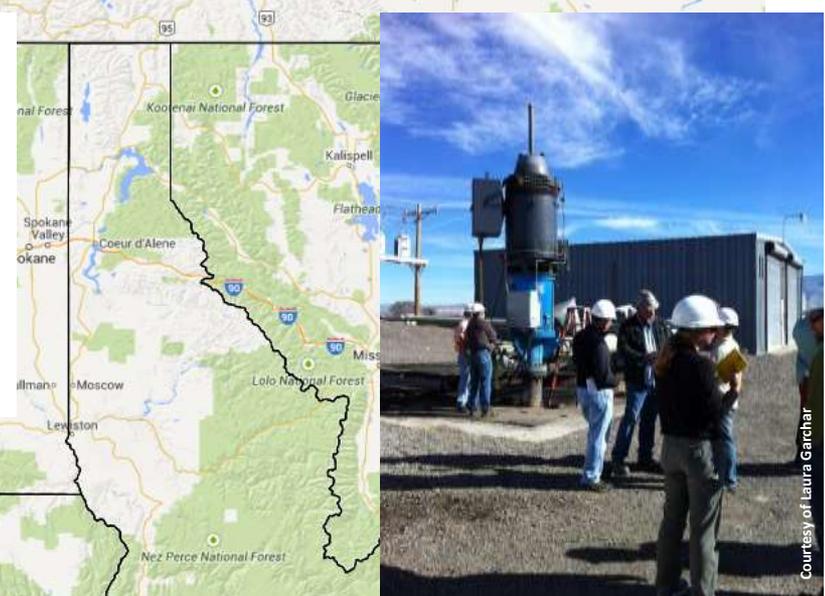
GO / NO GO

EGS Demonstrations

AltaRock EGS demonstration project : September 2014 – Stimulation was repeated after installing new casing.

Raft River EGS demonstration project in Idaho

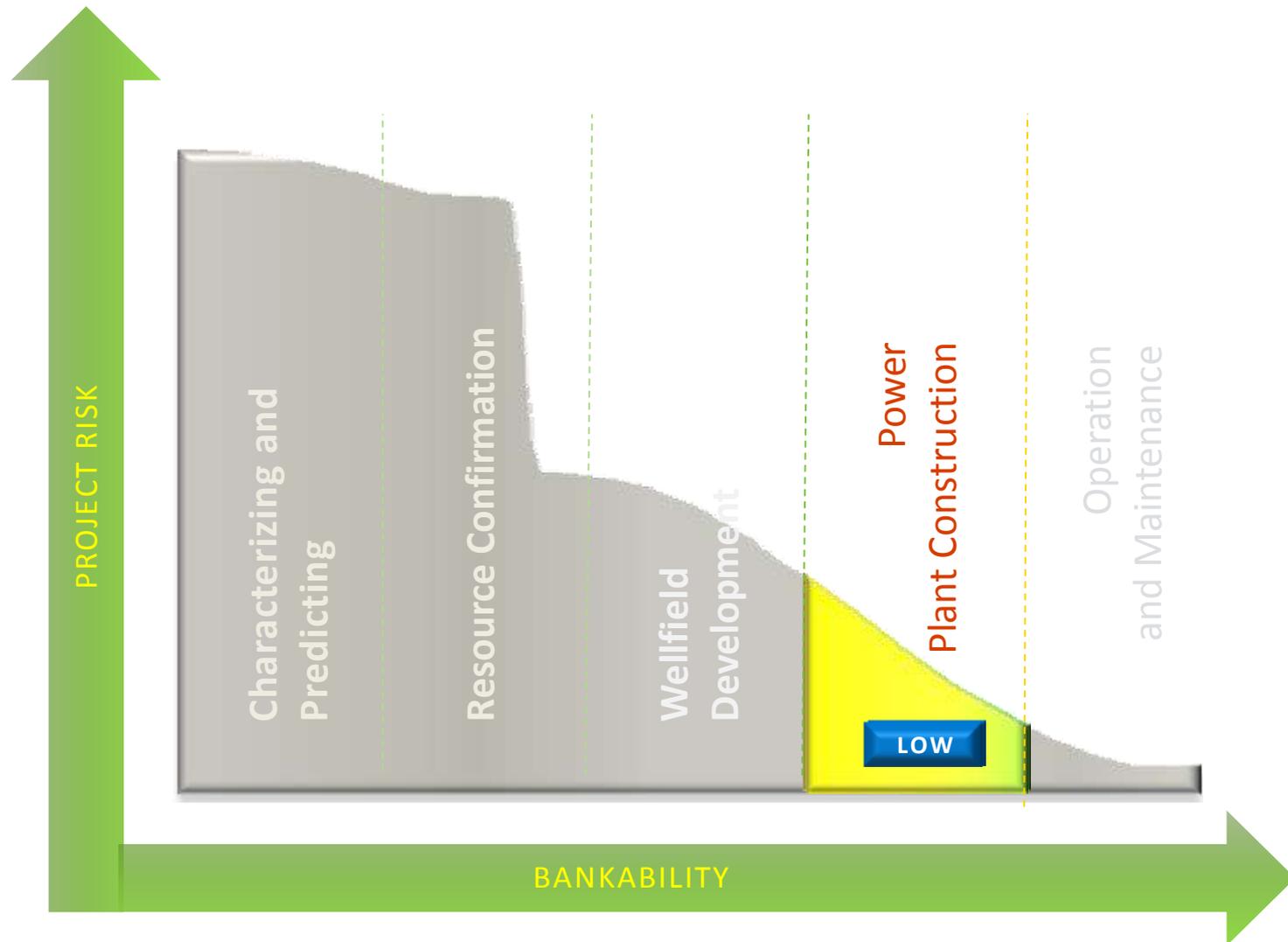
As of Jan 2015 over 666 million liters (176 million gallons) have been injected



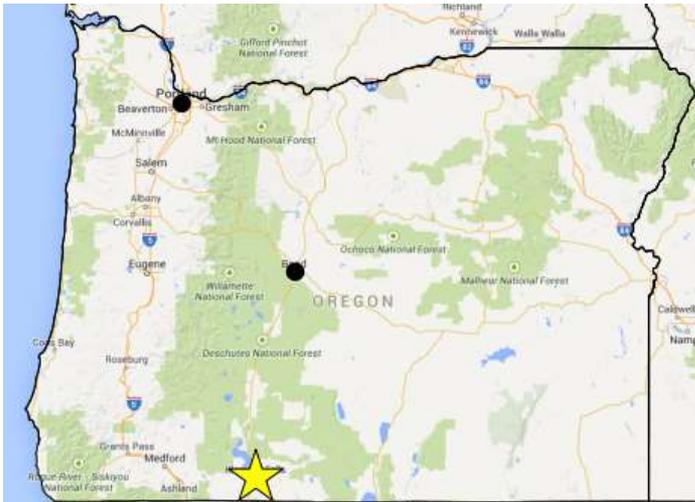
Stage Four: Power Plant Construction

Enhancing efficiencies

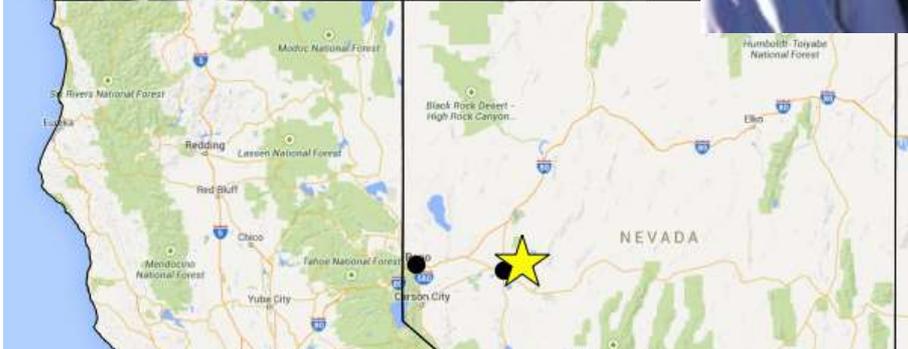
- Hybrid Power Systems
- Advanced heat transfer cycles
- Low-temperature applications
- Direct use & cascaded use



Direct Use and Hybrid Systems



Thermal energy applied directly for heating/cooling, buildings, greenhouses, **aquaculture**, pools and spas at **Klamath Falls**. Resource 100 – 300°F.



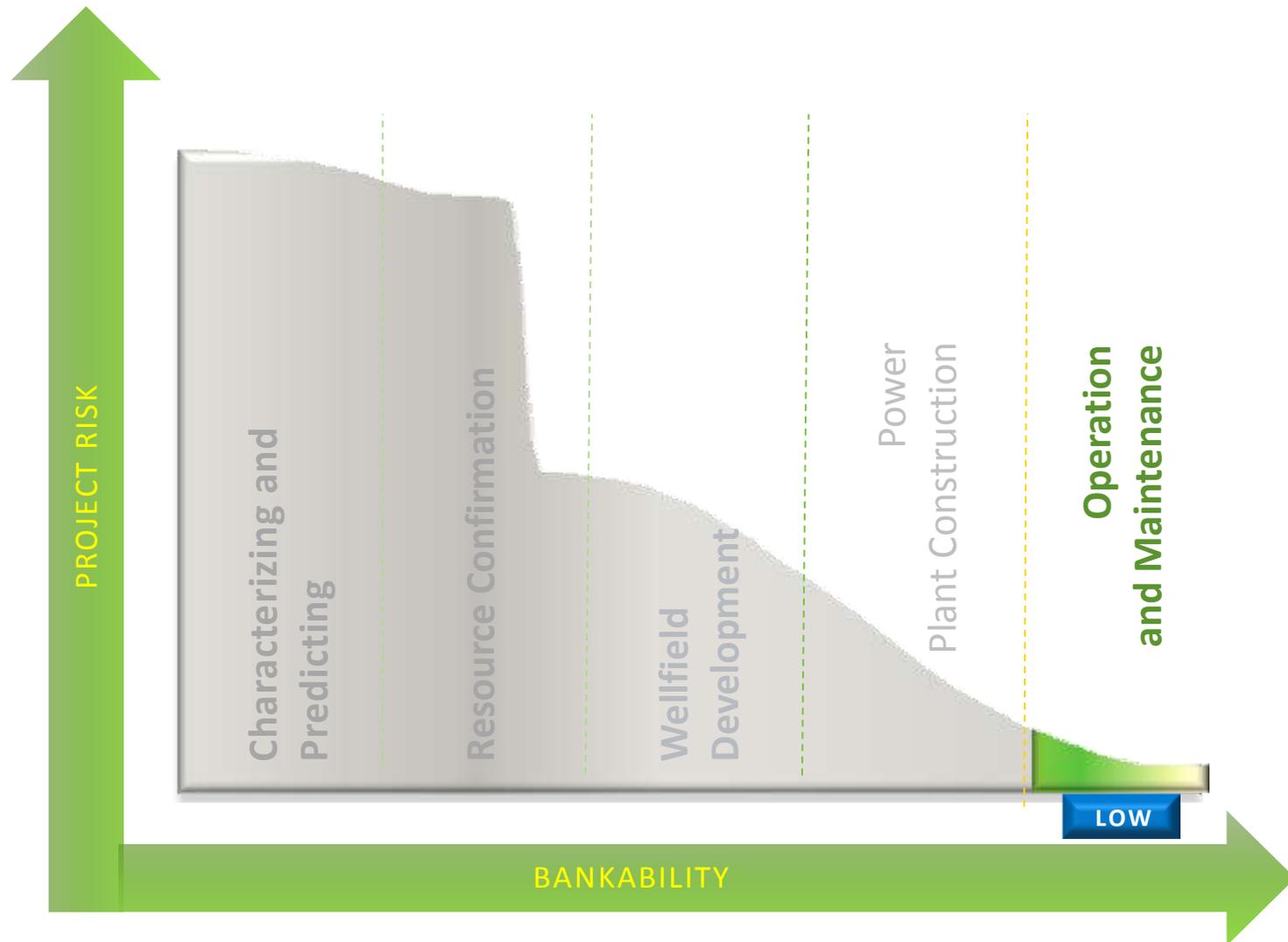
Stillwater geothermal plant (33 Mwe) will be integrated with a 17 MW **solar thermal facility** - the first hybrid plant in the world to combine the continuous generating capacity of binary-cycle, medium-enthalpy geothermal power with solar thermal technology.



Stage Five: Operation & Maintenance and Additive Value

Increasing value propositions to make geothermal more economical

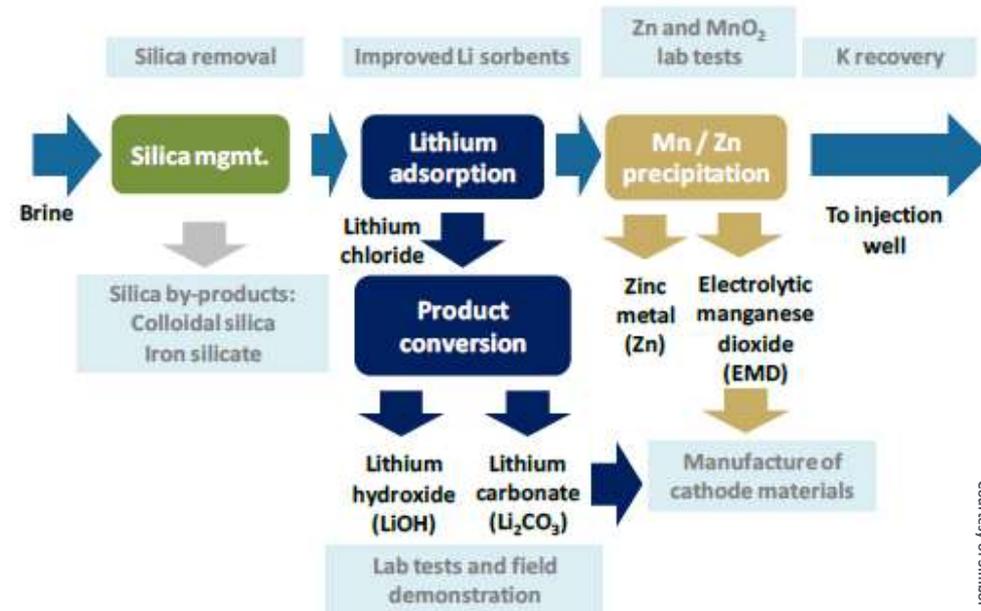
- Mineral recovery
- Innovative O&M Tools, Sensors, Methodology



Strategic Materials

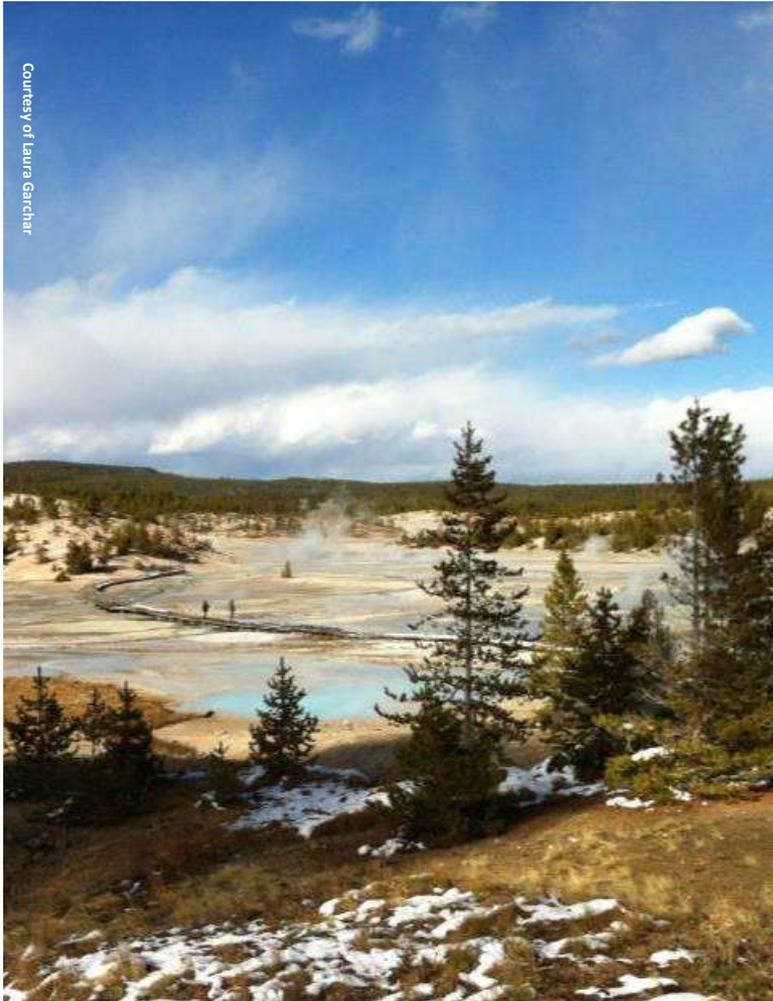
Increasing the value stream of geothermal energy production

- Feasibility studies that include fully developed business plans laying out the **technical** feasibility and **economic** viability of mineral extraction technology(s) combined with geothermal power production at a new or existing geothermal resource.
- Assessments of the current rare earth and near-critical metal resource base, with potential extraction volumes/rates including coupled techno-economic analysis.
- Geochemical modeling and leaching experiments to optimize the composition of down-hole fluids and identify additives that selectively leach high value strategic elements.



GTO Vision Study

By 2016, DOE seeks to develop credible analysis jointly with GEA/GRC:



Courtesy of Laura Garchar

- I. Articulate clear ***GTO investment strategies*** across different sectors and a cohesive plan to attain the goals
- II. Discuss ***geothermal growth scenarios*** for 2020, 2030 and 2050 backed by robust data, modeling and analysis
- III. ***Address all market segments*** existing and potential hydrothermal, electrical and non-electrical usages, new EGS sector, and other value streams
- IV. Analysis will be supported by ***objective and peer-reviewed industry data*** and *available to decision-makers*
- V. Vision is ***aspirational*** and ***inspirational***

SubTER Crosscut

Adaptive Control of Subsurface Fractures and Fluid Flow

Intelligent Wellbore Systems

Subsurface Stress & Induced Seismicity

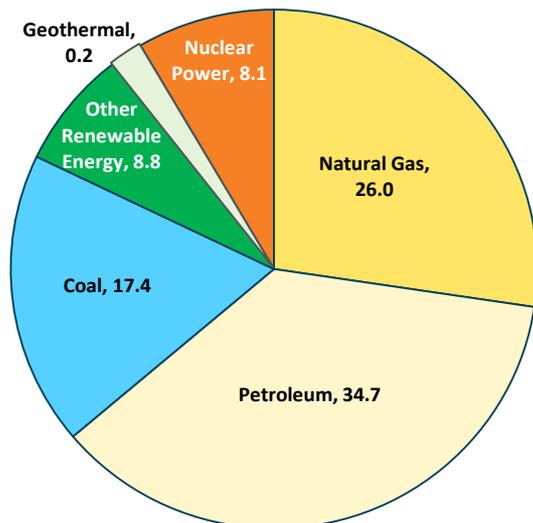
Permeability Manipulation

New Subsurface Signals

Energy Field Observatories

Fit For Purpose Simulation Capabilities

Personnel Needs



Primary Energy Use by Source, 2012
Quadrillion Btu [Total U.S. = 95.1 Quadrillion Btu]

ENERGY PRODUCTION

- Increase U. S. electrical production from geothermal reservoirs
- Increase U.S. unconventional oil and natural gas for industrial and power applications and export
- Enhanced secure domestic supply

ECONOMIC & SOCIAL BENEFITS

- Retain U. S. leadership
- Increased public confidence
- Increase revenues (taxes and royalty) to Federal, State, and local governments

PROTECT THE ENVIRONMENT

- President's Climate Action Plan: Safely store CO₂ to meet GHG emissions reduction targets
- Safe storage/disposal of nuclear waste
- Reduced risk of induced seismicity
- Protect drinking water resources
- Alternatives for energy storage

ENERGY SECURITY

- Hard target defeat
- NNSA core missions



New Prospecting Opportunities

Play Fairway Analysis GO/NO GO decision
Announcing play fairway drilling validation opportunity

Advancing Innovative Geothermal Tools & Techniques

Build upon R&D and demonstration project successes
Initiate Phase I, Frontier Observatory for Research in Geothermal Energy (FORGE)

Geothermal Vision Study

Geothermal continuum
Value proposition and its Impact on the President's Climate Action Plan

Additive Value

Low-Temperature Mineral Recovery
Hybrid systems

Subsurface Engineering Crosscut (SubTER)

Intra- and inter-agency effort to address common subsurface challenges and better leverage DOE R&D

Imperial Valley Potential

GTO seeks to understand and grow the region's geothermal power generation



- GTO perceives a high level of interest in the Imperial Valley area by the US and international geothermal community. GTO would like to have adequate understanding to assist in framing tasks and needed R&D to grow the region in geothermal
- This volume of knowledge may then be used by the DOE as a resource to identify data gaps and potential future roles for DOE GTO involvement in the region as well as to develop National Lab projects or future FOA topics
- DOE is looking to team with ongoing NREL efforts, the geothermal industry, and other state and federal agencies in this effort

1976-2014

The Geothermal Technologies Program annual budget peaked in the late 1970s, helping to drive an increase in installed capacity that lasted about ten years.

Annual Budget for the Geothermal Technologies Office and Installed Capacity

1976 - 2014

