

American Rock Mechanics Association: DOE's Geothermal Technologies Office

Lauren Boyd, Acting Office Director, Enhanced Geothermal Systems Program Manager
U.S. Department of Energy, Geothermal Technologies Office

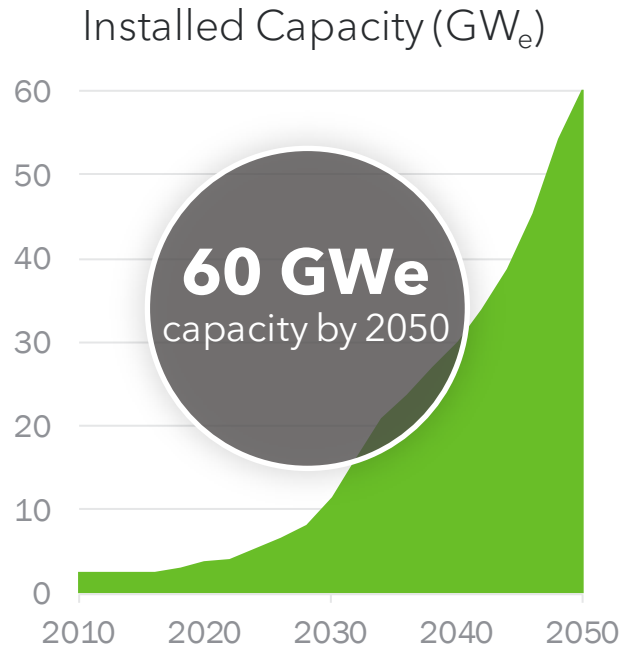
June 27, 2022



Geothermal Can Do Big Things

ELECTRIC

 **8.5%** of all U.S. generation by 2050

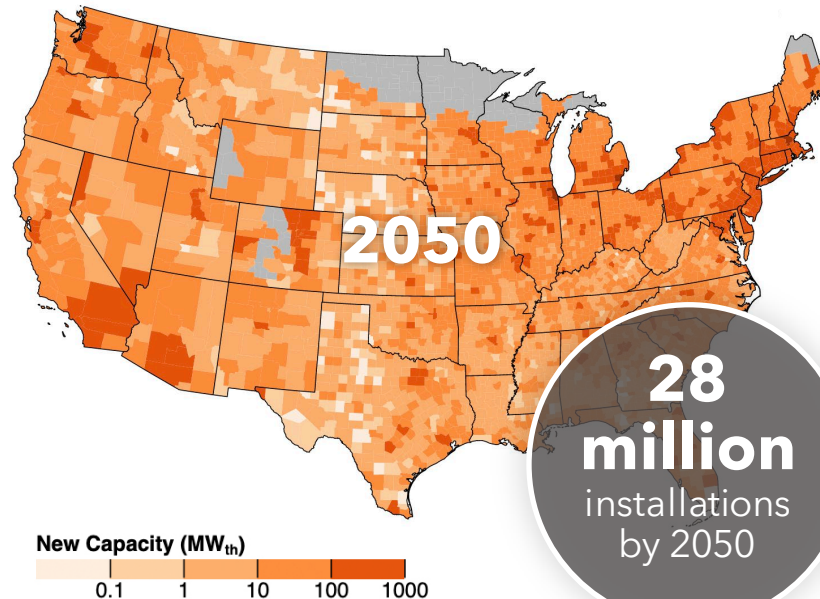


Source: Augustine et al. 2019

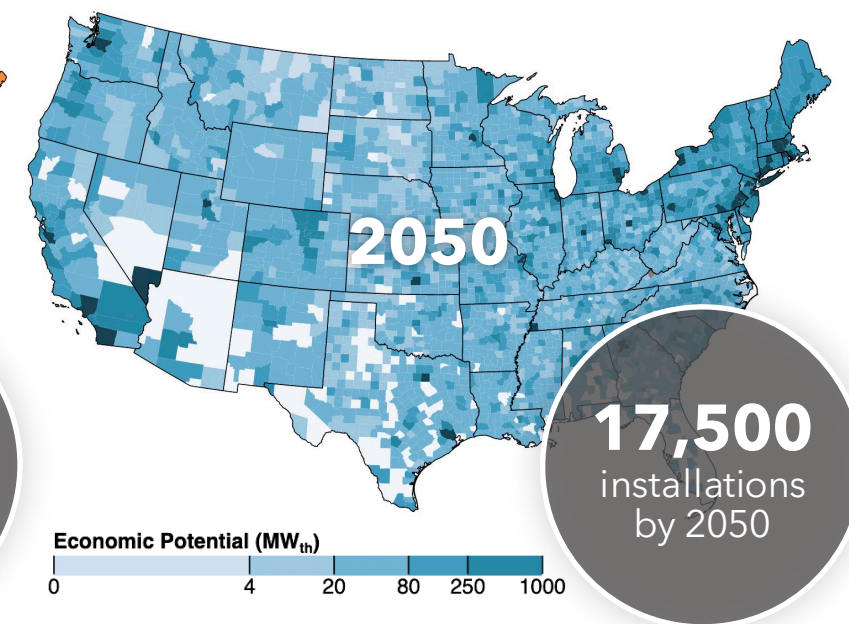
HEATING & COOLING

 **23%** of U.S. Heating and Cooling market by 2050

Geothermal Heat Pumps



District Heating



up to **516 MMT**
of avoided CO₂e

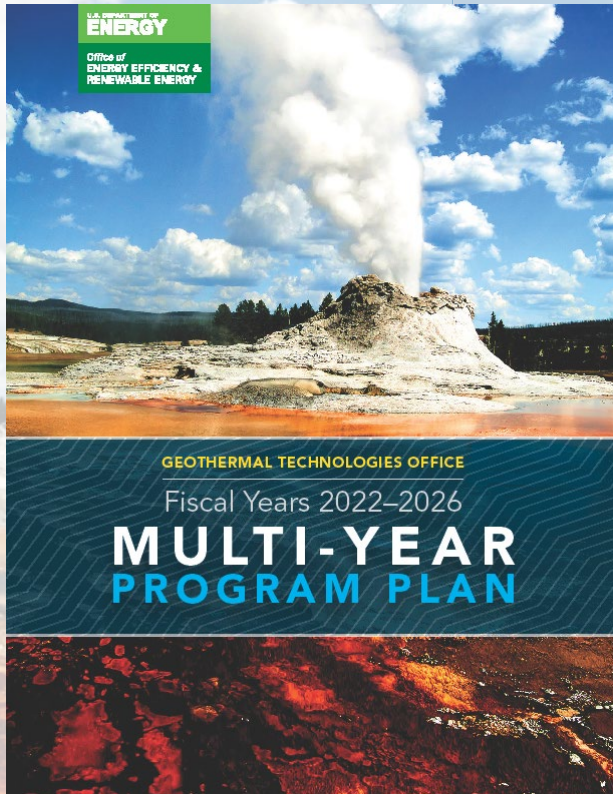


up to **1,281 MMT**
of avoided CO₂e

Total Emissions Reductions =
removal of **26 million** cars per year

Achieving Decarbonization Priorities: 5-Year Strategy for GTO

The Multi-Year Program Plan is a 5-year plan of activities GTO will pursue to support the growth and long-term contribution of geothermal energy to the U.S. electricity grid and American homes and buildings.



<https://bit.ly/GTOMYPP>

STRATEGIC GOAL 1

Drive toward a carbon-free electricity grid by supplying 60 GW of EGS and hydrothermal resource deployment by 2050.

STRATEGIC GOAL 2

Decarbonize building heating and cooling loads by capturing the economic potential for 17,500 GDH installations and by installing GHPs in 28 million households nationwide by 2050.

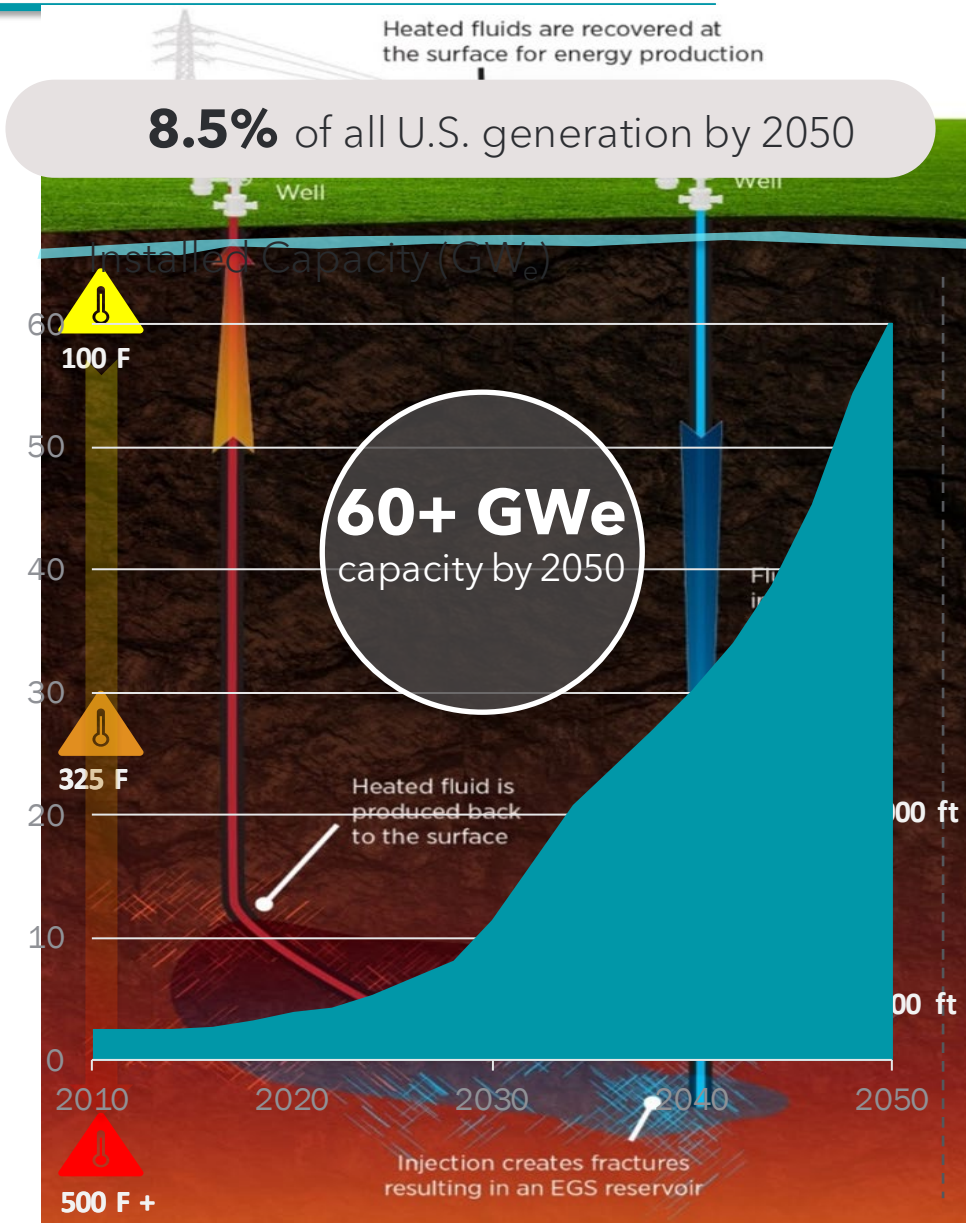
STRATEGIC GOAL 3

Deliver economic, environmental, and social justice advancements through increased geothermal technology development.

GTO: Enhanced Geothermal Systems Program

Enhanced Geothermal Systems (EGS) are human-made extract the abundant, stranded heat resource tens of thousands of feet below the surface for beneficial use.

- Relative to other geothermal resources, EGS resources have the potential to provide the most growth in the electric sector.
- EGS supports significant growth within the non-electric sector for district heating and other direct-use applications.
- GTO invests in early-stage RD&D, field testing, and other innovative research to advance EGS and support deployment.



GTO's Multi-Year Program Plan: Six Research Areas



Exploration and Characterization

Technical Objective:
Improve resource targeting for all geothermal resource types

Key Activities

- Geophysics and Remote Sensing
- Geochemistry
- Geology



Accessing the Resource

Technical Objective:
Improve drilling costs toward the “ideal” cost curves used in the *GeoVision* analysis

Key Activities

- Drilling Time
- Well Components
- Enabling Technologies



Subsurface Enhancement & Sustainability

Technical Objective:
Enhance and sustain geothermal energy recovery

Key Activities

- Reservoir Response
- Reservoir Development and Management Technologies
- Reservoir Characterization and Monitoring



Resource Maximization

Technical Objective:
Accurately capture the value of geothermal energy resources

Key Activities

- Heating and Cooling
- Grid Valuation
- Thermal Storage and Utilization
- Value Streams



Data, Modeling, and Analysis

Technical Objective:
Expand the capabilities of using data to identify and address barriers to geothermal deployment

Key Activities

- Economic Analysis and Validation
- Data Collection, Access, and Analysis Tools
- Policy and Regulatory Analysis



Geothermal Integration & Awareness

Technical Objective:
Expand stakeholder education and outreach to improve understanding of geothermal energy and advance geothermal technologies

Key Activities

- Machine Learning
- Advanced Manufacturing
- Technology Commercialization
- Energy Transitions
- Stakeholder Engagement

EGS Science and Technology Challenges

DEEP

4,000 to
>10,000 feet
in the
subsurface!



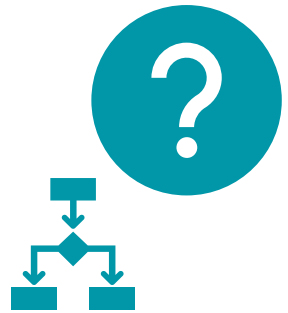
EXTREME

Hot, hard, abrasive
rock, corrosive
conditions



UNKNOWN

- Lack of data
- Lack of models necessary to approximate the subsurface



How Do We Make EGS Cheaper



Resource Characterization

- Improved data gathering
- Improved resource identification with fewer wells
- Integration of High-Performance Computing



Well Construction

- Faster drilling
- More + larger wells
- Reduced cement and casing costs



Reservoir Production

- Higher fluid flow from wells
- Advanced wellbore completions (zonal isolation)



Plant

- Larger plants to accommodate higher fluid flow rates

Characterization, well construction, and reservoir production are interconnected and tightly coupled activities

How Do We Make EGS Cheaper—cont.



Resource Characterization

- Hidden Systems Initiatives 2020
- Machine Learning Portfolio 2019
- EGS Collab 2017
- FORGE 2018
- Geophone Prize 2022



Well Construction

- FORGE 2018
- EDGE 2018
- Drilling Technology Demonstration Portfolio 2022
- Well Construction Working Group 2022
- EGS Pilot Demos 2022



Reservoir Production

- Zonal Isolation 2018
- Hydraulic Properties 2021
- EGS Collab 2017
- FORGE 2018
- GEODE 2022
- EGS Pilot Demos 2022

Geothermal in the Bipartisan Infrastructure Law

OPEN
SOON!

SEC. 41007. Enhanced Geothermal Systems Demonstrations (\$84M)

- Four demonstration projects, different geologic settings, potentially commercially viable locations
- For power production or direct use (heating/cooling)
- At least 1 east of the Mississippi River

Topic 1: Enhanced Geothermal Systems (EGS) Proximal Demonstrations

Topic 2: EGS Green Field Demonstrations

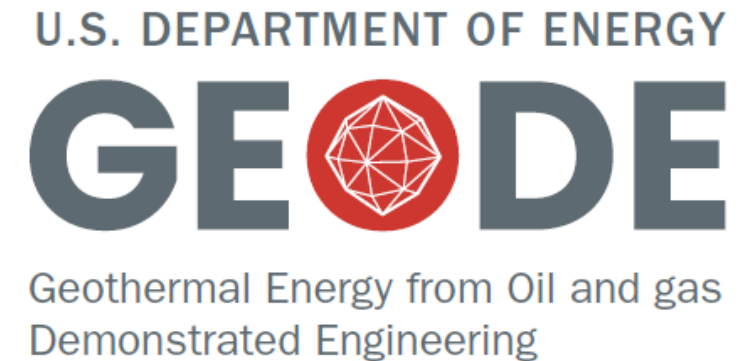
Topic 3: Super-hot / Supercritical EGS Demonstrations

Topic 4: Eastern U.S. EGS Demonstrations



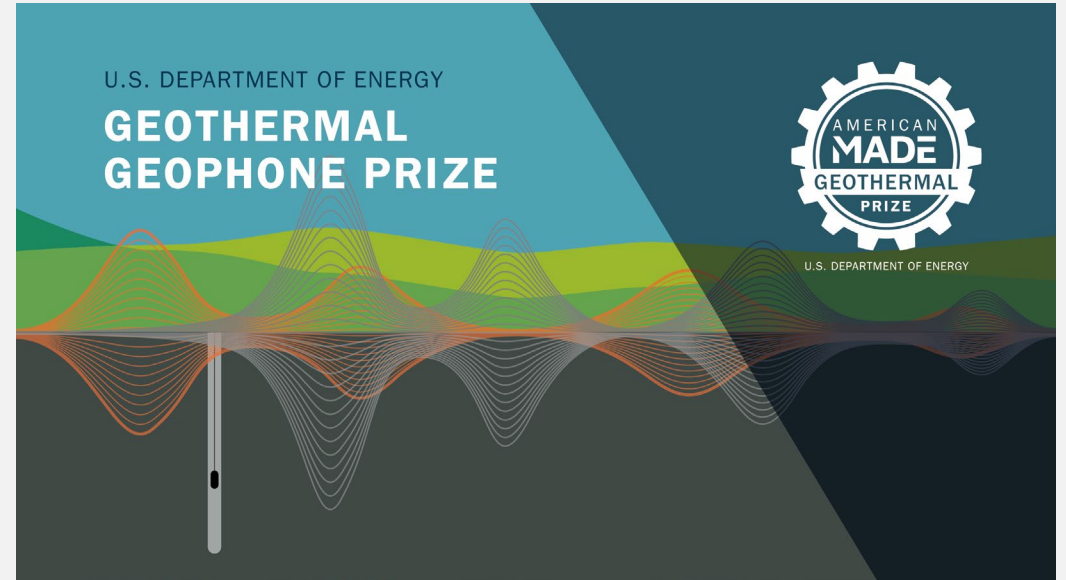
Visit [DOE Launches \\$84 Million Program to Demonstrate Enhanced Geothermal Energy Systems | Department of Energy](#)

- This **5-year, \$165 million* consortium** is designed to leverage oil & gas subsurface assets, technologies, and expertise to help solve geothermal energy's toughest challenges, while providing clean energy employment opportunities and environmental benefits for communities.
- The GEODE initiative will develop a strategy and establish an organizational framework to effectively **transition and adapt oil and gas technologies and workforce into geothermal.**
- The initial funding opportunity will be released this summer.



Geothermal Geophone Prize: Offers \$3.65 million in incentives to develop high-temperature seismic sensors (geophones) that collect real-time data monitoring for enhanced geothermal systems.

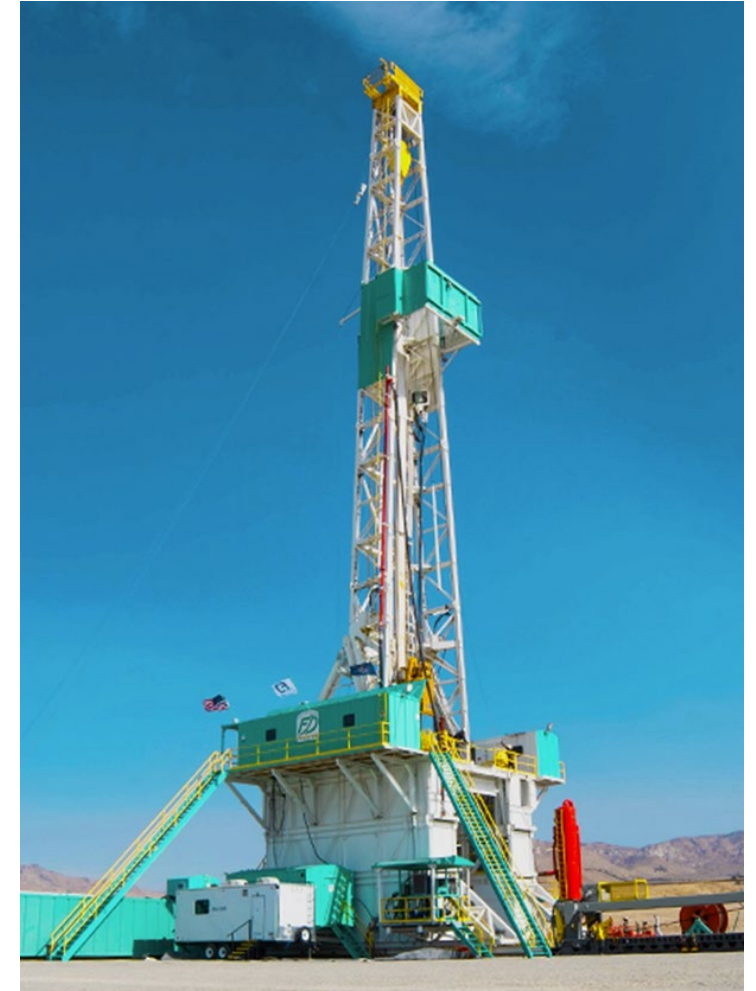
- Submissions due by Sept. 29
- More information → <https://www.herox.com/GeophonePrize>



Other Announcements

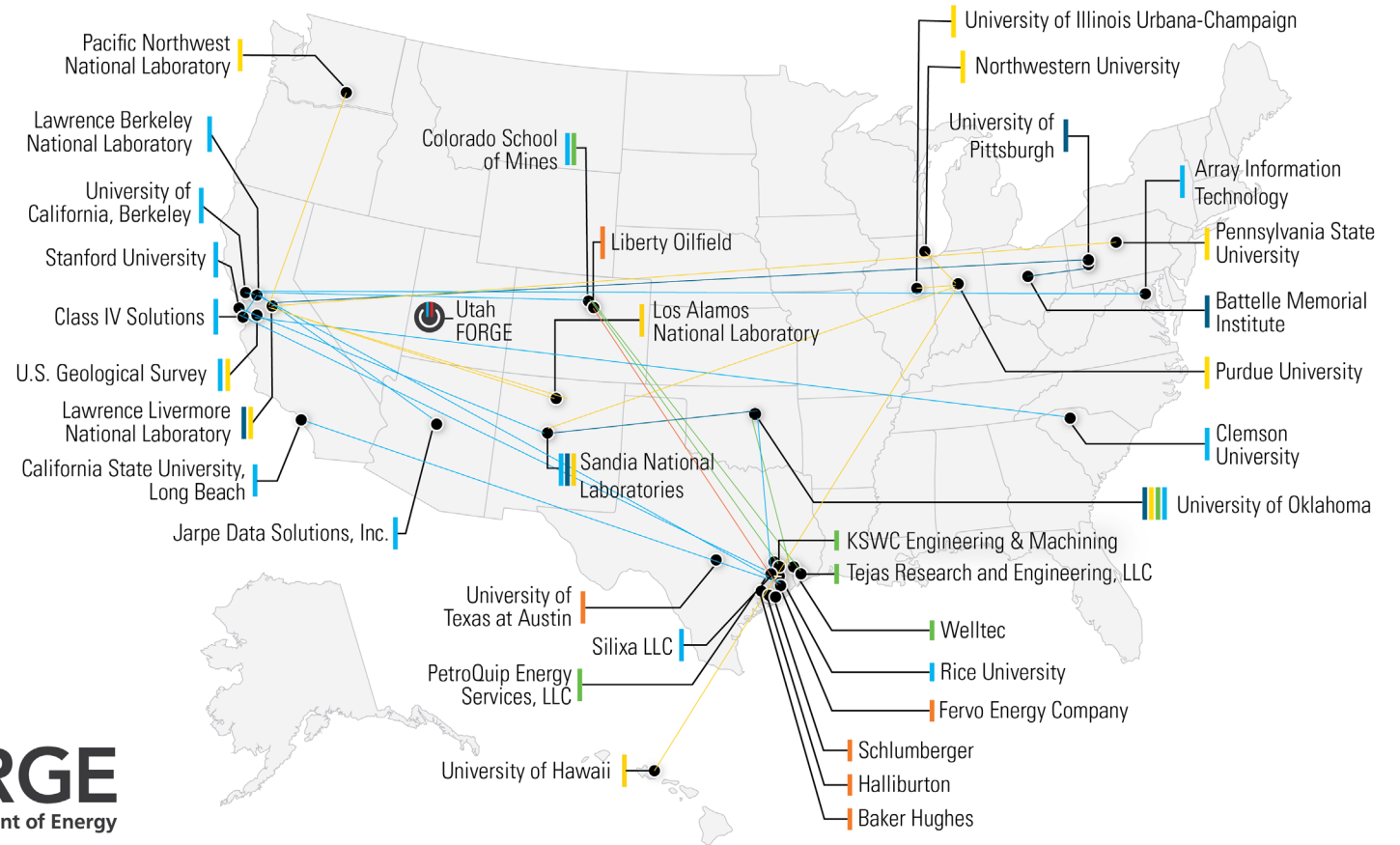
- **Drilling Technology Demonstrations:** This initiative targets technology developments to provide significant improvements in drilling performance in commercial geothermal settings
 - Funding opportunity closed June 3; selections expected in the fall

- Frontier Observatory for Research in Geothermal Energy (FORGE), GTO's largest funding initiative, is enabled by \$200 million+ in federal investment and decades of public and private research.
- The FORGE initiative, located near Milford, Utah and initiated in 2015, is a dedicated site where scientists and engineers can develop, test, and accelerate breakthroughs in enhanced geothermal systems technologies and techniques.
- **FORGE has achieved several notable successes**
 - One of the best characterized geothermal sites in the world
 - Six wells drilled including 1st of its kind highly deviated well in hard/hot granite
 - Fastest drilling of hard hot granitic rock to date
 - Successful three-stage reservoir stimulation with in situ seismic monitoring
 - ~\$49M in R&D awards aimed at advancing EGS



- In the past year, FORGE kicked off its **first portfolio** of research and development projects.
- **17 projects** →
 - testing and evaluation of new and innovative enhanced geothermal systems tools and techniques
 - a combined total funding of **\$49 Million during the next 3 years.**

Utah FORGE 2022 R&D Partnerships



| Topic 1 | Topic 2 | Topic 3 | Topic 4 | Topic 5 |
|--|---------------------------------|--|--|--|
| Devices suitable for isolating zones of a well at temperatures greater than 225° | Estimation of stress parameters | Field-scale characterization of reservoir stimulation and evolution over time, including thermal, hydrological, mechanical, and chemical effects | Stimulation and configuration of the wells at Utah FORGE | Integrated laboratory and modeling Studies of the interactions among thermal, hydrologic, mechanical, and chemical processes |

Drill Producer Well: 16B(78)-32

- Planned Timing: Q2-FY2023
- Similar approach/design as injector – 16A(78)-32

Stimulation of Producer

- Planned Timing: Q3-FY2023
- Similar stimulation approach to 16A(78)-32

Long-Term Flow Testing

- Planned Timing: Q4-FY2023
- ~1 year of flow testing

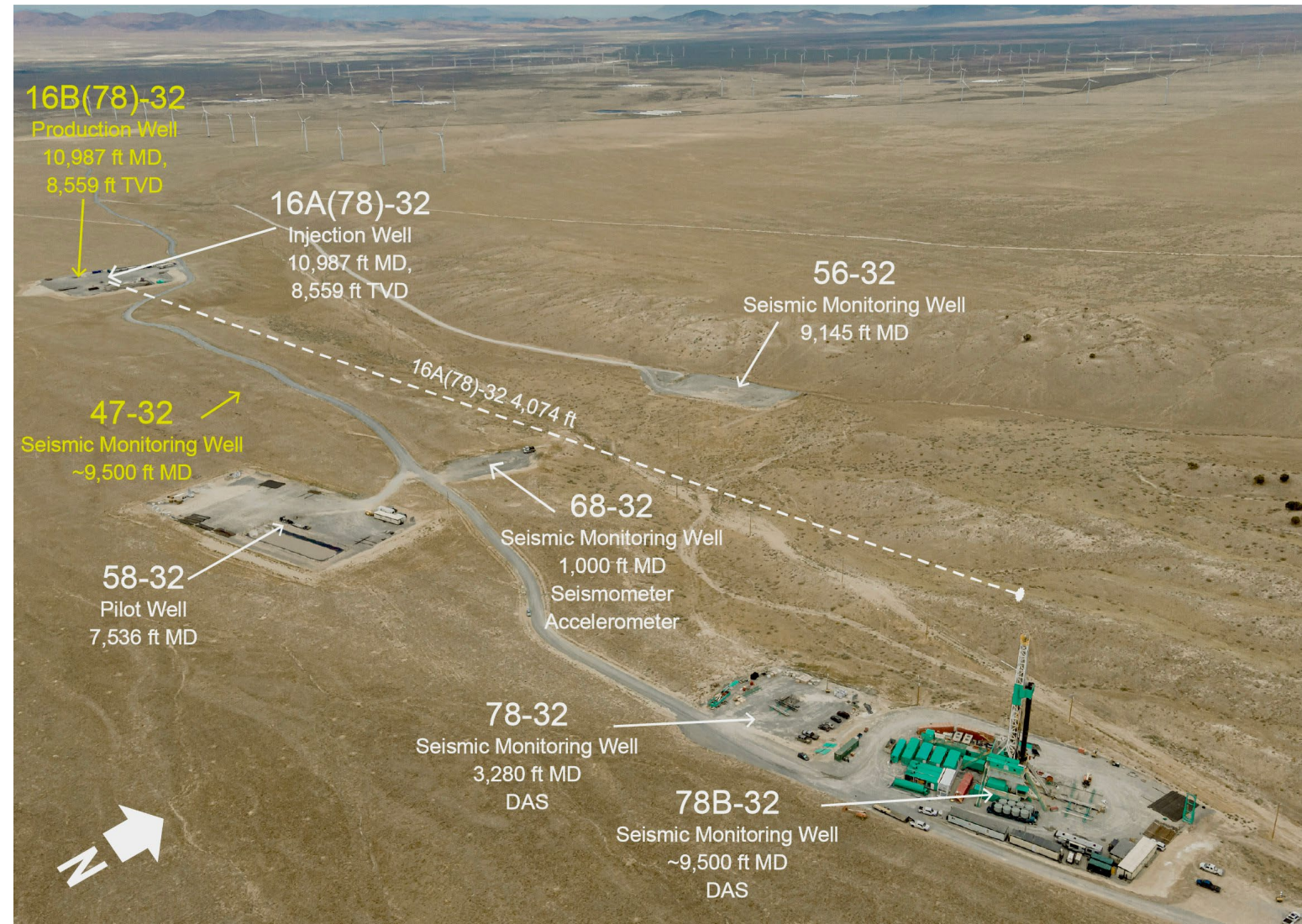


Photo view of Utah Forge site in 2021. Photo Credit: Utah FORGE.

Thank You!



Get the hottest geothermal news from *The Drill Down*, the new monthly newsletter from GTO!

Sign up today:
geothermal.energy.gov



Interested in serving as a merit reviewer for GTO RD&D projects?

Send us your resume or CV:
doe.geothermal@ee.doe.gov

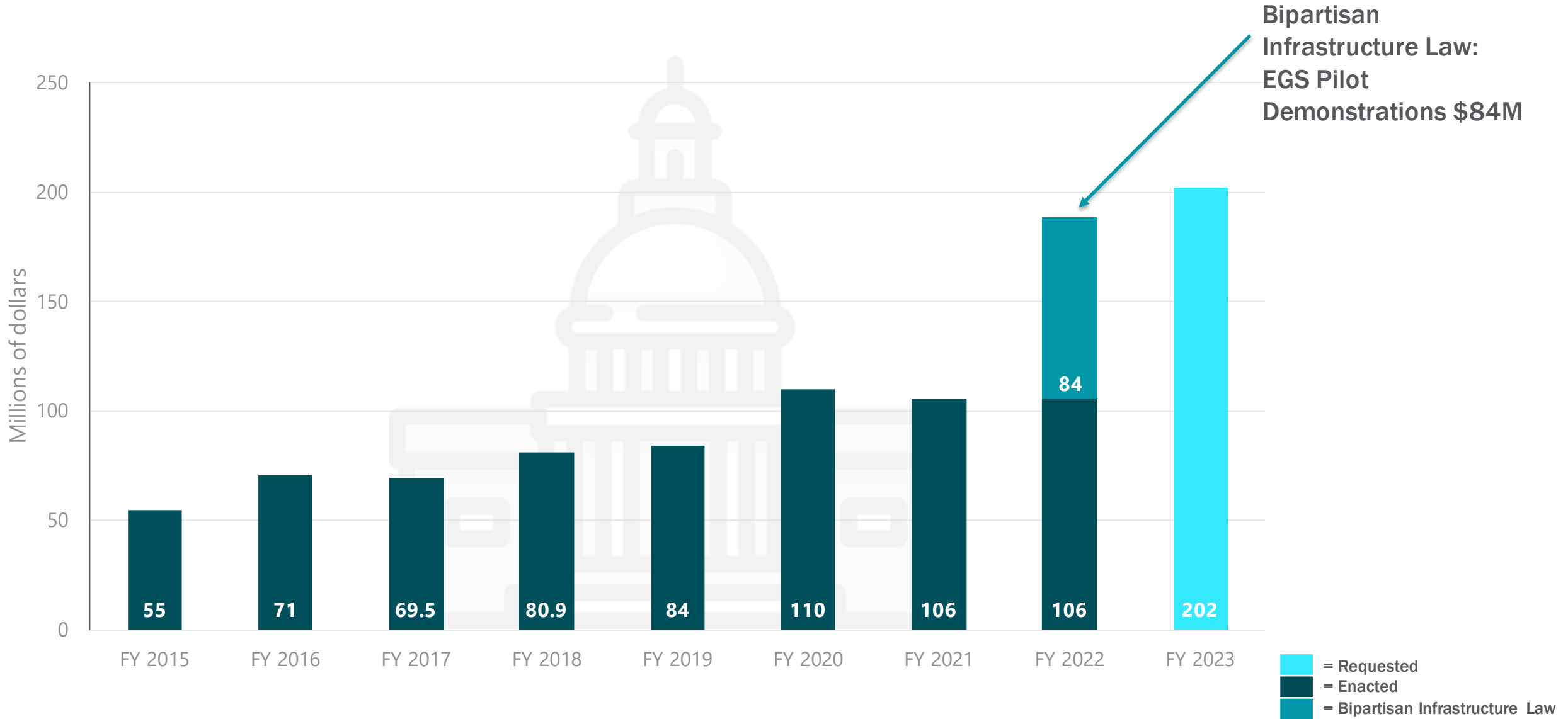


Attend Geothermal Rising Conference, the largest annual gathering of the geothermal community.

GTO plans to have a booth and will host a prize event to share updates and announce winners.

We hope to see you there!

GTO FY22 Budget Update



FORGE Roadmap Alignment

| | Stimulation Planning and Design | Fracture Control | Reservoir Management |
|------------------|--|--|--|
| Core R&D Actions | <ul style="list-style-type: none">• Develop new well configurations and well field designs for optimal reservoir stimulation and operation• Develop new and adapt existing fracturing technologies and procedures for EGS | <ul style="list-style-type: none">• Optimize design of fracture procedures to reservoir conditions• Develop alternative injection practices and procedures• Understand the effect of different stimulation types on the resulting fracture system• Develop methods for successful zonal isolation during stimulation at high temperatures and pressures | <ul style="list-style-type: none">• Predict and monitor changes in the fractures system over time• Engineer solutions to compromised or other unwanted changes in reservoir permeability that can disrupt operation |

<https://www.ida.org/idamedia/Corporate/Files/Publications/STPIPubs/2019/D-10474.pdf>

Geothermal Technologies Office – FY 2022 Highlights

- **Drilling Technology Demonstration Campaign (\$16.5M from FY 2022; \$3.5M from FY 2021):** This initiative targets technology developments that will provide significant improvements in drilling performance in commercial geothermal settings. Final Applications due: June 3.
- **Frontier Observatory in Research in Geothermal Energy (FORGE) (\$20M):** Utah FORGE drilled the first-ever highly deviated geothermal well at a rate twice the industry standard. In FY 2022, GTO will support the next R&D solicitation, contributing to meeting Administration goals for a carbon-free electric grid.
- **Geothermal Energy from Oil and gas Demonstrated Engineering (GEODE) (\$10M from FY 2022; \$155M for outyears):** This is a new consortium designed to leverage the oil & gas subsurface industry to help solve geothermal energy's toughest challenges.
- **Community Geothermal Heating and Cooling Design and Deployment (\$13M):** This initiative funds technical assistance to demonstrate, deploy, and implement community-scale direct use geothermal district energy systems through installation of geothermal heat pumps (GHP) and/or direct use of geothermal fluids.
- **Federal Partnerships for Geothermal Installations (\$4M from FY 2022; \$2M from FY 2021):** GTO and FEMP will make it possible for federal agencies (DOD, GSA, State, NASA, DOE labs, Park Service) to consider geothermal energy to heat and cool (and, in limited cases, potentially power) their installations.



A drilling rig at the FORGE site outside of Milford, Utah

Geothermal Technologies Office – FY 2023 Highlights & Major Changes

- **EGS Greenfield Demonstration Projects: (\$25M):** Building on the zonal isolation/stimulation learnings of previous GTO initiatives such as Wells of Opportunity, FORGE, and EGS Collab, these new EGS demonstrations will move beyond the near-field environment to get closer to greenfield EGS in multiple environments, helping scale up EGS and ensure its viability throughout the nation.
- **Reservoir Thermal Energy Storage (RTES) (\$12M):** Unlock the terawatt-scale thermal energy storage of using the Earth as our battery. New pilots and demonstrations will build on prior years of early-stage research to demonstrate technical feasibility, grid integration, and long-term storage opportunities for renewable energy systems.
- **EGS Drilling and Well Construction: (\$15M):** This initiative builds on the work of the FY 2022 Hydrothermal Resources Drilling Demonstration projects, targeting drilling and completion technologies that will enhance exploration and development specific to EGS resources.
- **FORGE: (\$25M):** Drill a third, long-reach horizontal well, providing an opportunity to further advance the 5x improvement in drilling speed demonstrated at FORGE in 2021 and enable additional stimulation and zonal isolation testing. These efforts will help demonstrate the viability of EGS as a scalable technology and enabling 60 GWe of geothermal power by 2050.
- **FedGeo Power: (\$12M):** Conduct feasibility studies and site characterization for geothermal power generation opportunities at federal and military sites with a large electricity demand and/or strong energy security and resiliency mandates. The federal government's energy use in 2019 was 889 trillion Btu. Converting even a few of large campuses to geothermal power could have significant impact.
- **GEODE: (\$10M from FY 2022; \$25M requested from 2023):** GEODE will develop the strategy and establish the implementation mechanism to effectively transition the oil and gas technologies and workforce into geothermal. Key focus areas include (1) leveraging oil and gas technologies to lower geothermal costs and (2) workforce training.
- **Community Geothermal Heating & Cooling - Food/Ag Focus: (\$17M):** Fund demonstrations of direct use heating and cooling for both community and industrial agriculture to address local energy scarcity and food security needs in underserved areas of the United States.



Hidden Systems

GTO is investing in identification of potential surface signals that identify deeper, hidden systems, helping reduce cost and risk for geothermal operators

INnovative Geothermal Exploration through Novel Investigations Of Undiscovered Systems (INGENIOUS)

- This project seeks to accelerate discoveries of new, commercially viable, hidden systems across the broader Great Basin region and create a comprehensive guide for geothermal operators and future research teams that includes predictive geothermal maps at both regional and prospect scale.
- Researchers are compiling and synthesizing datasets and plan to complete drilling this summer.

Basin & Range Investigations for Developing Geothermal Energy (BRIDGE)

- This project is investigating areas in Nevada, collecting data and conductive surveys to locate hidden geothermal systems. The work is intended to help drive down costs and risks associated with the discovery of hidden geothermal systems.
- This project aims to improve baseline technology across three main components of the exploration process: efficiency of discovery of new hidden resources; effectiveness of characterization and ranking of resources so that the best ones can be prioritized for detailed study and drilling; and completion of test drilling and resource modeling to determine the probability of success for developing a prospect.
- Researchers are completing their Helitem surveys and development of initial conceptual models, and will begin focused prospect exploration this summer



Hidden Systems—cont.

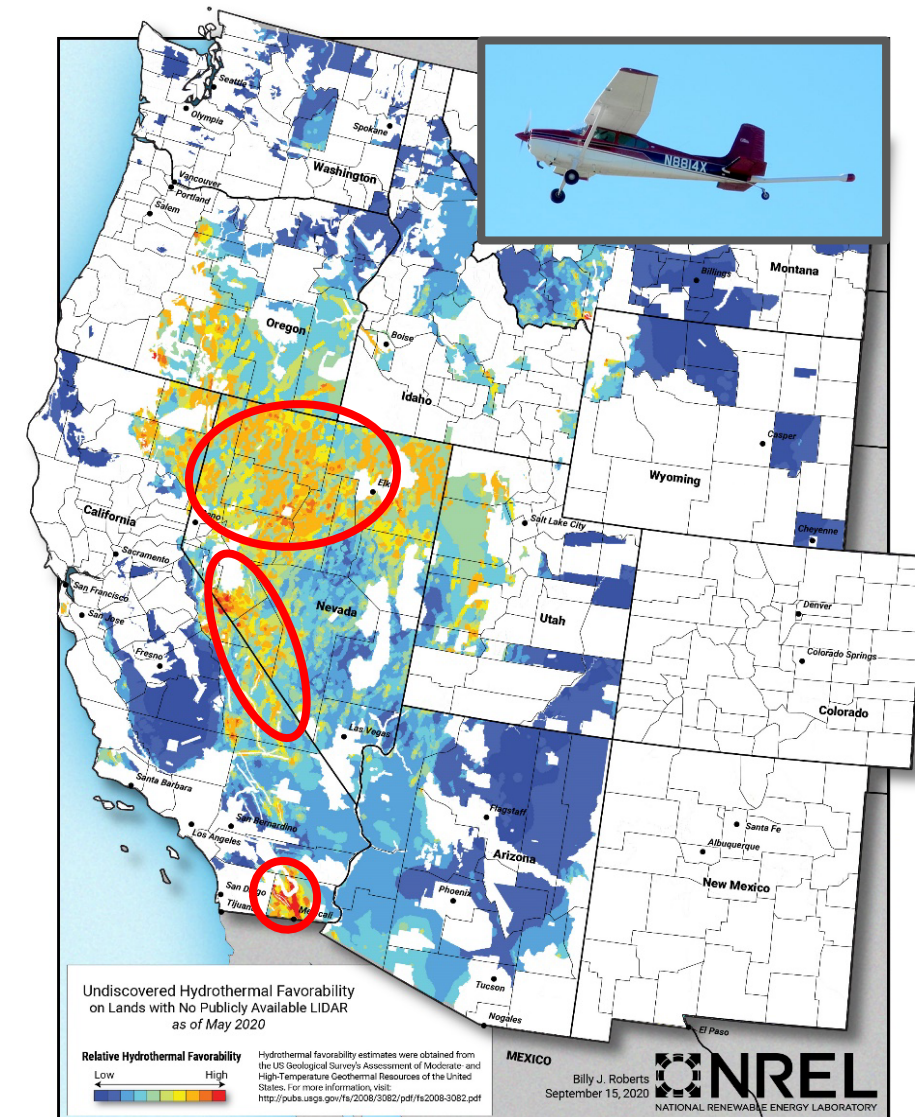
GTO collaborates with the U.S. Geological Survey to help provide solutions to meet U.S. needs for both energy and critical minerals.

Geoscience Data Acquisition in Western Nevada (GeoDAWN)

- Researchers are gathering new subsurface data specifically in the Walker Lane geologic zone in western Nevada, an area that is rich in both geothermal and mineral resources, and they will leverage machine learning to develop deeper understanding of the geologic conditions and stress regime.
- The geophysical data will be used to locate undiscovered geothermal resources while also identifying critical mineral deposits that can be mined for domestic use.

GeoFlight: Salton Trough

- Building on the success of GeoDAWN, the GeoFlight initiative, launched in 2021, seeks to collect data on hidden geothermal systems in California's agriculturally rich Imperial Valley, which includes the Salton Sea.
- Using specially equipped, low-flying aircraft, researchers are surveying to help identify unique surface and near-surface characteristics to create more accurate geologic maps for the area.
- Understanding these characteristics is essential to geothermal exploration and development.

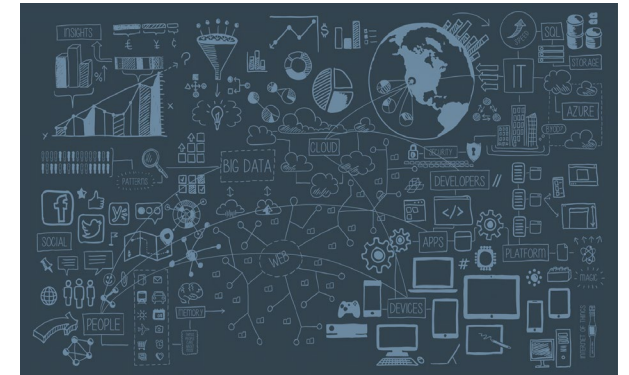


Machine Learning

Machine Learning offers substantial opportunities for technology advancement and cost reduction throughout the geothermal project lifecycle.

R&D Objectives:

- Identify data acquisition targets with high value for future work and development.
- Identify new signatures and pathways for detecting hidden geothermal systems.
- Optimize power production through plant/reservoir monitoring and analytics.
- Improve prediction and detection of trouble events.



Since FY 2018, GTO has invested in projects to apply machine learning techniques to geothermal exploration and production. If applied successfully, machine learning could lead to higher success rates in exploratory drilling, greater efficiency in plant operations, and ultimately lower costs for geothermal energy. Projects, including four funded in FY 2021, have focused on applying machine learning to such topics as:

- Geothermal exploration
- Advanced analytics for efficiency automation in geothermal operations
- Development of deep learning models
- Detection and characterization of fracture zones

Improving Geothermal Permitting Timelines

- Optimizing permitting timelines alone could increase installed geothermal electricity-generation capacity to 13 GWe by 2050.
- GTO is supporting several national laboratory projects to assess the impact of permitting timelines on geothermal development and propose best practices to help streamline timelines and reduce non-technical barriers.
- GTO is funding and participating in a Geothermal Interagency Collaboration Task Force working to improve project development timelines by:
 - Prioritizing and expediting application review and decision-making for eligible projects
 - Improving interagency coordination and information sharing
 - Discussing opportunities and challenges for geothermal project permitting



Low-Temperature and Coproduced Resources

Community Geothermal Heating and Cooling Design and Deployment *Coming Soon!*

- This project will help communities implement technology that can reduce energy burden and fossil fuel dependence, increase grid resilience and stability, and improve environmental quality. The initiative also encourages innovative approaches to community-scale heating and cooling.

It aims to:

- Increase deployment
- Advance environmental justice
- Grow the workforce
- Share best practices
- Provide data



Consider joining the Teaming Partner list: energy.gov/eere/geothermal/community-geothermal-design-and-deployment-teaming-list