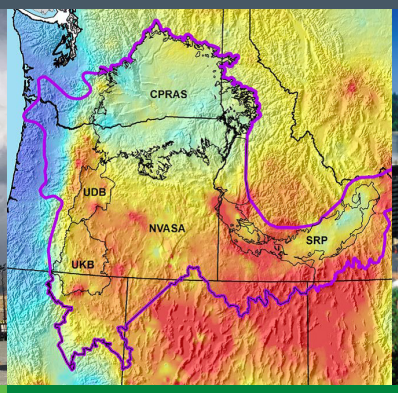
U.S. DEPARTMENT OF
ENERGY

Office of ENERGY EFFICIENCY
& RENEWABLE ENERGY



2017 Annual Report

Geothermal Technologies Office

January 2018

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GTO 2017 Annual Report Content

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This report spans calendar year 2017.

A Letter from the Director

Dr. Susan Hamm
GTO Director

Geothermal technologies today – like all high-potential technologies – are driven by research and development platforms that focus not only on what's required now, but where the needs are five, ten, even twenty years down the road. Geothermal energy continues to show tremendous potential, with worldwide investment reaching new levels The Geothermal Technologies Office (GTO) remains dedicated to establishing geothermal as an "everywhere solution", capable of providing baseload power to communities across America.

***GeoVision*: A Path Forward**

For decades, U S research efforts have served as a benchmark for geothermal innovation. Sustaining this leadership is vital with the expansion of geothermal – a clean, safe, always-on renewable resource – serving as a key component of America's electricity grid.

To address the need for forward-thinking leadership, our office spearheaded an initiative to guide geothermal technology advancement over the next decade and beyond. This comprehensive geothermal study - dubbed GeoVision - addresses geothermal potential within both the electrical and non- electric market sectors. Applications include geothermal electricity generation, geothermal heating and cooling, and district geothermal direct-use The *GeoVision* analyses support projections as far ahead as 2050, and show that within 30 years hydrothermal capacity could more than double, while enhanced geothermal systems could deliver more than 8% of our nation's electricity generation.

The GeoVision report will be published in 2018, with an accompanying roadmap that addresses three critical areas of performance: improved access, reduced costs, and increased value.

Technology Highlights

Expanding geothermal energy to all corners of the U S requires leveraging geothermal reservoirs of various temperatures. Our office is currently funding six Deep Direct-Use (DDU) feasibility studies to determine the viability of lower temperature geothermal systems at depths exceeding 1,000 meters. The opportunity here is vast –DDU resources could deliver direct geothermal to regions lacking access to conventional hydrothermal, and much of the U S features subsurface conditions favorable to lower temperature resources. When fully deployed, DDU could replace conventional heating and cooling in large-scale facilities, such as university campuses, industrial complexes, and military installations.

GTO's Enhanced Geothermal Systems (EGS) subprogram continues to drive advancements in geothermal energy development. The Frontier Observatory for Research Geothermal Energy (FORGE) initiative continues to target deeper, high- temperature reservoirs conducive to enhanced geothermal – ideal for generating large-scale electrical power. In 2017, EGS launched the Collab effort at the Sanford Underground Research Facility (SURF) in South Dakota. Collab researchers have completed the drilling phase, and are now monitoring stimulation using a variety of geophysical techniques. Data gathered via Collab will help bridge laboratory-scale work and large field experiments forthcoming at the final FORGE site, in either Nevada or Utah, to be announced in 2018.

Our Play Fairway Analysis (PFA) effort continues to pursue new ways to reduce the risk and cost associated with geothermal exploration and early-stage development, with test drilling to occur in 2018. Using advanced data analytics and geophysical interpretation methods, PFA researchers actively target regions that predict a higher probability of drilling success. PFA is key to expanding the use of hydrothermal resources in geothermally-complex basins

This annual report expands on these highlights, and provides an overview of additional GTO projects and initiatives.

Our goal of establishing geothermal as an "everywhere solution" requires the efforts of many talented individuals. I want to thank everyone who has worked to support geothermal research and innovation over the past year – our program managers, technical experts, support staff, consultants, EERE colleagues, industry allies, and partners at numerous national laboratories and universities.

GTO welcomes all questions and feedback. Please visit us at energy.gov/eere/geothermal and submit comments to geothermal@ee.doe.gov.

Dr. Susan Hamm
Director, Geothermal Technologies Office

Geothermal Technologies Office at the Department of Energy

Geothermal energy is clean, secure, reliable, flexible, and constant. It continues to be one of America's best choices for low-cost renewable energy in power generation and in direct-use applications for heating and cooling of American homes and businesses.

The Geothermal Technologies Office (GTO) at the U.S. Department of Energy (DOE) focuses on harnessing this natural resource to generate electricity and direct-use heating and cooling. GTO accelerates hydrothermal and low-temperature adoption and boldly pursues EGS as a transformative player by creating a commercial pathway to large-scale, reproducible systems. By developing and demonstrating innovative technologies, GTO's efforts help stimulate the growth of the geothermal industry within the renewable energy sector and encourage quick adoption of technologies by the public and private sectors.

GTO is committed to conducting early-stage research and development of innovative technologies and methodologies for domestic power generation, as well as continuing to support the expansion of the geothermal industry across the United States GTO funds activities that support DOE's continued efforts towards:

- ✓ Innovative technologies
- ✓ Domestic energy security
- ✓ Increasing U.S. economy and jobs
- ✓ Expanding geothermal development

GTO works to reduce costs and risks associated with geothermal development by supporting innovative technologies that address key exploration and operational challenges in the following areas:

Hydrothermal Resources

A geothermal resource requires fluid, heat, and permeability to generate electricity. Conventional hydrothermal resources contain all three components naturally. These geothermal systems can occur in widely diverse geologic settings, sometimes without clear surface manifestations of the underlying resource. GTO continues to address the overarching theme of uncertainty quantification and reduction in geothermal exploration for hydrothermal resources.

Enhanced Geothermal Systems (EGS)

EGS are man-made reservoirs created to produce energy from geothermal resources that are otherwise not economical due to lack of water and/or permeability. EGS are created when fluid is injected into the low-permeability, fluid-poor hot rocks to enhance the size and connectivity of fluid pathways.

Low Temperature & Coproduced Resources

Low Temperature & Coproduced Resources represent a small but growing sector of hydrothermal development in geothermal resources below 150°C (300°F). Considered non-conventional hydrothermal resources, these technologies are bringing valuable returns on investment in the near-term, using unique power production methods.

Systems Analysis

The Systems Analysis subprogram identifies and addresses barriers to geothermal adoption in the U.S. and validates technical progress across the geothermal sector.

GeoVision Analyses Project Impacts of Geothermal Growth

The geothermal industry is primed for strong growth. It stands ready to provide a diverse array of technology solutions to meet America's 21st-century demands for grid stability, reliability, and resiliency, as well as domestic and commercial heating and cooling needs. In order to identify a vision for growth of the domestic geothermal industry across the full range of geothermal energy applications, GTO has engaged in a multi-year research collaboration among national laboratories, industry experts, and academia.

The *GeoVision* study includes analysis of the economic, social, and environmental impacts of geothermal energy deployment, including effects on job creation, water use, consumer energy prices, domestic economics, and air quality. It also investigates opportunities for technology transfer, desalination, mineral recovery, and hybridization with other energy technologies for greater efficiencies and lower costs.

GTO is looking forward to sharing exciting growth potential for the geothermal energy sector. Geothermal deployment at the study scenario levels would have clear-cut economic and societal benefits for the nation. Projections of the potential impact on the U.S. energy industry include:

Reliable, affordable, secure, and constant renewable electric power generation with flexible and load-following capabilities that provide a range of essential services contributing to grid stability and resiliency

Nationwide energy applications through unique capabilities in electricity generation, such as microgrids, as well as residential, commercial, and district heating and cooling

Cost-effective commercial technologies that are ready to deploy, backed by developing technologies with vast potential for increased electricity generation and direct-use applications

Job creation in both the manufacturing and energy sectors

Revenue generation potential for state, local, and federal stakeholders.

GEOVISION

The *GeoVision* effort will culminate in a report, and will include a roadmap summarizing technical advances and other actionable items to achieve the outcomes of the *GeoVision* and ensure maximum benefit to the nation. The roadmap is a far-reaching, industry-wide call to action intended to engage all key stakeholders toward the common goal of realizing the *GeoVision* and its full potential benefit to the nation.

Innovative Technologies

Sandia National Laboratories Improving Drilling Technologies

Geothermal technologies tap an immeasurable amount of energy lying deep beneath our feet But engineers seeking to tap geothermal resources often encounter extreme temperatures and extreme pressures That's where highly advanced drilling technologies and techniques come into play.

To overcome these challenges, Sandia National Laboratory (SNL) is working to develop a groundbreaking downhole motor for geothermal drilling, one designed for these critical conditions

With funding from GTO, SNL has designed, conducted engineering modeling of, and analyzed concepts for the downhole motor SNL plans to continue the project by completing the design and construction of a motor concept prototype for demonstration.

The downhole motor aims to improve multi-lateral completions in high-temperature environments, including enhancing the rate of penetration, a key drilling metric, which improves the performance and economics of the drilling operations Multi-lateral completion is the next frontier of geothermal drilling in that it will increase a single drilling operations' subsurface access, while keeping the surface footprint the same Improving reservoir access at an economic rate is paramount to geothermal energy success.

Improved drilling techniques could enhance geothermal resource recovery, decrease environmental impact, and reduce well construction costs Development of a high temperature motor will also enable EGS development. As this this cutting-edge technology is developed and then adopted by the geothermal industry, SNL's research in drilling technology could help put our nation on a path toward improved energy security and a stronger economy.

SNL is developing a downhole motor to improve geothermal drilling techniques and reduce barriers to geothermal resource recovery.

Source: Sandia National Laboratories

PNNL Code Comparison Wraps Up

In 2017, the Pacific Northwest National Laboratory (PNNL) Code Comparison Study, funded through EGS, concluded.

Over the past three years, PNNL has supported GTO in organizing and executing the first-of-its-kind geothermal code comparison study This project sought to test, improve, and diagnose differences among a worldwide collection of cutting-edge numerical simulators available to support geothermal energy development.

Renowned modeling experts from the national laboratories and universities, 11 institutes in total (see text block to the left for a complete listing), collaborated to benchmark current codes, enable improvement and verification, build confidence in the suite of available numerical tools, and ultimately identify critical future development needs for the geothermal modeling community to accelerate the development of understanding the subsurface for optimizing EGS development and accessing this domestic, baseload energy.

Take a look at the effort's technical reports and other materials here.

Participating teams on the study are principally from the United States and include those from universities, industry and DOE National Laboratories: Pacific Northwest National Lab, Idaho National Lab, Lawrence Berkeley National Lab, Lawrence Livermore National Lab, Los Alamos National Lab, Oak Ridge National Lab, University of Nevada-Reno, University of Oklahoma, Penn State University, Stanford University, University of Texas at Austin, and Itasca Consulting Group.

Innovative Technologies

Small Business Collaboration with National Labs Announced

Small businesses developing advanced technologies often need unique facilities and experts to test, develop, and validate their innovative products. DOE national labs house these capabilities, but accessing the labs is a challenge most small businesses can't overcome. The Small Business Vouchers (SBV) pilot program facilitates access to the DOE national labs for qualified small businesses by making the contracting process simple, lab practices transparent, and the labs' unique facilities available.

At Earth Day Texas 2017, the DOE announced 38 small businesses that will collaborate with national lab researchers through the SBV pilot. SBV facilitates access to the DOE national labs for American small businesses, enabling them to tap into the intellectual and technical resources they need to overcome critical technology challenges for their advanced energy products and gain a global competitive advantage Eight DOE national laboratories will receive funding to partner with 38 competitively selected small businesses across the country.

One collaboration in the geothermal area will integrate a solar topping cycle at the Raft River Geothermal Power Plant in Idaho. Idaho National Laboratory and the National Renewable Energy Laboratory (NREL) will work with small businesses on this project - creating a profitable Geothermal-Solar hybrid cycle. This project joins GTO's many other tech-to-market activities including two other projects investigating different variations of Geothermal-Solar hybrid cycles at the Coso Geothermal Field in California and at San Emidio II in Nevada.

Since its inception, the SBV initiative has forged partnerships between 114 American small businesses and the national labs. A full list of SBV projects and participating DOE national labs is available at www.sbv org.

Small Business Vouchers Pilot
U.S. DEPARTMENT OF ENERGY

Small Business Vouchers Pilot – Reducing Costs in GHPs

Geothermal heat pump systems allow homeowners and businesses to use the heat beneath their feet for cooling and heating their buildings. DOE supports research to make this energy source more affordable and accessible.

Geothermal heat pumps (GHPs) can be used to heat and cool residential, commercial, and institutional buildings, providing consumers with significant energy savings. In fact, a report published by Oak Ridge National Laboratory (ORNL) notes that GHPs save more than $50 billion in domestic energy costs (48 2% savings) and reduce peak summer electricity demand by 216 gigawatts (56 1% reduction). Additionally, GHPs support thousands of manufacturing, installation, and inspection jobs.

Upfront installation costs, however, create a barrier for accessing GHPs. GTO took this challenge head on through the SBV Pilot program. SBV funded a Cooperative Research and Development Agreement between ORNL and Geothermal Design Center, Inc, a small business that specializes in GHP system and product engineering, to develop a new method for reducing initial testing times during GHP installation. This new method helps reduce the cost of the geothermal ground loop.

GHPs use natural heat stored in the shallow subsurface of the Earth to provide space heating and water heating, and they use the ground as a heat sink for space cooling. The new testing approach can quickly and more accurately determine the effective ground thermal conductivity (GTC) based on thermal response test results. GTC is an important parameter for sizing ground heat exchangers used by GHP systems to transfer heat. While conventional GTC testing typically requires a 48-hour test period with a constant electric power supply, ORNL and Geothermal Design's new method reduces the required test time by 40% or more. It can also determine GTC even with an unstable or intermittent power supply.

Costs associated with GTC testing are significantly being reduced with this approach, in conjunction with increased usage, which enables a more optimal design of GHP systems. Further, ORNL and Geothermal Design's approach provides more information about the thermal properties of the ground heat exchangers than previous techniques, which can lead to further advancements and cost reductions in the GHP field and eventual reductions in costs to U S consumers.

Innovative Technologies

"Seeing Underground" – PNNL Subsurface Software

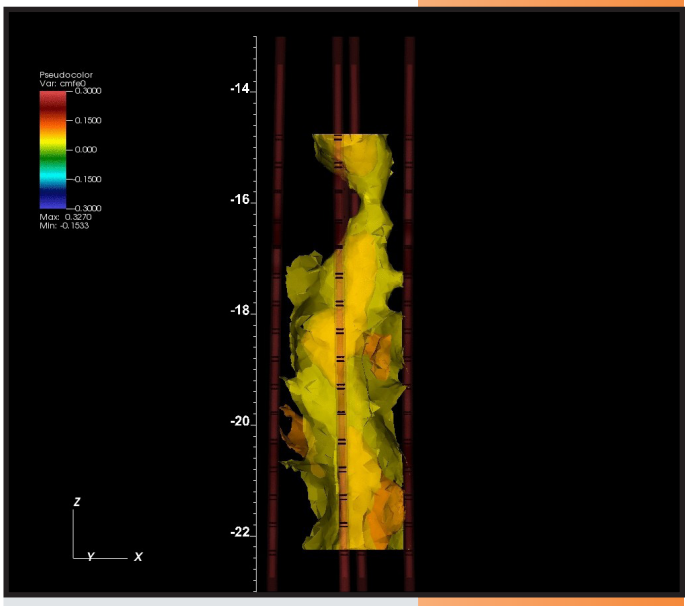
The Subsurface R&D Initiative is providing solutions to subsurface challenges by dramatically accelerating technology development with the aim of achieving mastery of subsurface processes. Next generation advances in subsurface technologies will enable increases in domestic energy supplies, including renewable geothermal energy from conventional hydrothermal and EGS.

Before the widespread development of EGS can occur, however, the high upfront exploration and installation costs must be reduced dramatically. Moving one step closer, researchers funded by DOE at PNNL successfully developed a tool called E4D-RT processing with the ability to "see" underground, or better image the subsurface. This tool provides faster, more accurate interpretations of data from simulation models, and improves the cost competitiveness of EGS development. PNNL and SNL successfully imaged a fracture network that was created using SNL's explosive technology in a Subsurface Technology and Engineering Research & Development (SubTER) project titled "Imaging Fracture Networks Using Joint Seismic and Electrical Change Detection Techniques".

As a co-principal investigator, PNNL used E4D-RT to image the fractures in real time. Using the data generated by the E4D-RT tool, researchers are able to improve current models used to predict fracture networks. Through the use of E4D-RT, snapshots of subsurface conditions are collected by measurements made at the surface or by electrodes inserted in boreholes that pass an electrical current through the material being studied and record how difficult it is for that electrical current to move through the material.

These models are important for geothermal energy investors, decision makers, and stakeholders because it reduces uncertainty and helps to more accurately target where geothermal wells should be drilled. Using this technology is one of the many steps that will help reduce these costs and make widespread EGS and geothermal power production a reality.

The software accomplishes what no other existing commercial subsurface modeling software accomplishes: it combines supercomputers to analyze large-scale problems with data processing; and provides real-time imaging that allows investigators to understand subsurface processes at the time they are occurring while enabling the modeling of buried metallic infrastructure.



This photo is a view "underground". This Real-time Four-Dimensional Subsurface Imaging Software created at the Pacific Northwest National Laboratory utilizes E4D-RT to image fractures in real time. This software provides faster, more accurate interpretations of data from simulation models, and improves the cost competitiveness of EGS development.

Innovative Technologies

A Path to FORGE – Collab Experiments in the Mine

The EGS Collab, a GTO-funded project designed to address fundamental challenges surrounding our understanding of permeability enhancement and evolution in crystalline rocks, continued its work at a small-scale field site, at staging facilities, at lab benches, and at computer terminals throughout the Department of Energy's National Lab complex. Announced in 2016, the Collab addresses barriers to EGS advancement by facilitating direct collaboration between the geothermal reservoir modeling community, experimentalists, and geophysicists in developing and implementing well-field characterization and development, monitoring, and stimulation methods in a state-of-the-art experimental facility. Led by Lawrence Berkeley National Laboratory, the project brings together world-class scientists - representing 8 national labs and 7universities - in subsurface process modeling, geophysical monitoring, and experimentation.

A group of geothermal scientists set up the Collab Laboratory deep inside the mine at SURF.

In 2017, the Collab Team initiated field experiments 4850 feet below the surface at the Sanford Underground Research Facility (SURF), which is operating in what was once one of the largest and deepest gold mines in all of North America Following intensive planning and 3D modeling, eight 60 meter long boreholes (six monitoring wells with one injection and production well) were drilled at optimized spatial orientations for fracture creation and capturing high-resolution monitoring data Drilling operations at the SURF site began in the fall 2017. Stimulation and flow testing are scheduled to occur in the winter and spring of 2018.

The EGS Collab works to act as the bridge between laboratory-scale stimulation and rock mechanics studies to the large field scale experimentation at the future FORGE site.

FORGE
U.S. Department of Energy

FORGE Phase 2 – Drilling Ahead

The two FORGE teams continue advancements towards the establishment of the world's first permanent EGS laboratory. FORGE, GTO's flagship EGS initiative, will establish an underground field laboratory to conduct cutting edge research and development of EGS and aims to develop the technologies needed to create large-scale, economically sustainable, and commercialized enhanced geothermal systems.

In 2016, teams led by SNL and the University of Utah were selected to continue into Phase 2 of the FORGE initiative. In this phase, the teams will acquire new data to better characterize the subsurface, obtain all necessary permits, and finalize induced seismicity mitigation plans. Phase 2 will result in the selection of a final location for FORGE Both teams continue extensive site characterization activities in Phase 2B such as LiDAR, gravity, and fault mapping surveys, as well as background seismic monitoring and updating their geologic models Both will also drill deep characterization and monitoring wells that will allow them to conduct additional critical characterization activities to bolster their understanding of each respective candidate FORGE site, in anticipation of a down select to one site in spring 2018.

In the long term, EGS could enable utilization of a significant, geographically diverse energy resource FORGE seeks to surmount existing technical challenges and make EGS a major contributor to the domestic energy portfolio.

Domestic Energy Security

PFA Continues to Work towards Exploration Cost Reduction

In July 2017, GTO announced it will continue funding 5 projects aligned with Phase III Play Fairway Analysis (PFA) activities. GTO awarded up to $5 million in additional funding to five of the original 11 projects from the 2014 PFA Funding Opportunity Announcement. The awards will address the overarching theme of uncertainty quantification and reduction in geothermal exploration risk, specifically through the development of geothermal play fairways.

The concept of "play fairway analysis" has been used to identify potential locations of blind hydrothermal systems in the U.S. Play fairway analysis defines levels of uncertainty with respect to the presence and utility of geothermal system elements and translates them into maps to high grade the geographic area over which the most favorable combinations of heat, permeability, and fluid are thought to exist. Phase III moves the projects into an exploratory drilling campaign that will test the Phase I and II developed models' ability to discover new resources. Once identified, hydrothermal resources can be brought online quickly with current technologies, supporting the near-term expansion of domestic energy in America.

This systematic approach early in the exploration process can reduce costly drilling by increasing target efficiency and improve the probability of successfully tapping the vital mix of high temperatures and sufficient water flow necessary to generate electricity from geothermal energy. By improving success rates for exploration drilling, this data-mapping tool will help attract investment in geothermal projects and significantly lower the costs of geothermal energy.

THE SELECTED PHASE III AWARDEES:

Nevada Bureau of Mines and Geology, University of Nevada Reno
– Reno, Nevada

Utah State University
– Logan, Utah

University of Hawaii
– Honolulu, Hawaii

University of Utah - EGI
– Salt Lake City, Utah

Washington Division of Geology and Earth Resources
– Olympia, Washington

SPOTLIGHT: Award Winning PFA Research

Nicole Lautze, Principal Investigator, is Honored

Nicole Lautze, Principal Investigator for the PFA University of Hawaii team, was honored this year for her work in clean energy. Nicole received a Clean Energy Education & Empowerment Award, awarded to outstanding mid-career women who are advancing clean, renewable sources of energy, related technologies, or clean energy policy. Nicole's PFA project has provided an updated geothermal resource assessment across the State of Hawaii. Her continued work could lead to a reduction in exploration barriers, including time and cost, and usher in additional geothermal development in Hawaii.

Domestic Energy Security

Subsurface R&D

GTO continues to play a central role in Subsurface R&D technology efforts. Subsurface energy sources satisfy over 80% of total U.S. energy needs. Finding and effectively exploiting these resources while mitigating impacts of their use constitute major technical and socio-political challenges. Opportunities in subsurface technology and engineering have immediate connection to energy security needs. Increasing domestic energy supply from the subsurface enhances national security and fuels economic growth. The subsurface is also called upon in a variety of ways for environmentally responsible management and disposal of hazardous materials and other energy waste streams.

Meeting current and future energy challenges requires significant advances to ensure safe, sustainable, and affordable access to natural resources and storage in the subsurface. The Subsurface R&D effort will improve access to subsurface resources and accelerate dynamic management of the subsurface by:

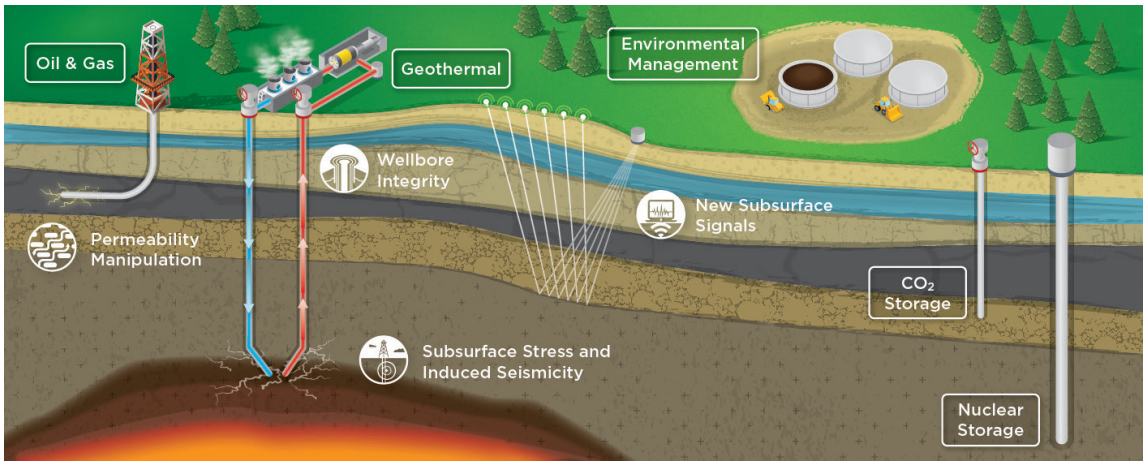
- Identifying subsurface challenges and advancing solutions;
- Facilitating both intra-departmental and interagency collaboration of cross-cutting subsurface R&D activities; and
- Engaging industry stakeholders operating in the subsurface.

The Subsurface R&D effort identifies common research, development, and demonstration and policy challenges across DOE and enables programs to work together toward solutions. Initiative partners include DOE programs and national labs, academia, industry, and other federal agencies.

In response to subsurface challenges, Subsurface R&D is planning and implementing jointly-funded targeted research, development, and field demonstrations emphasizing the following four topic areas:

- Intelligent wellbore systems
- Subsurface stress and induced seismicity
- Permeability manipulation
- New subsurface signals

For more information visit: www.energy.gov/subter



Domestic Energy Security

GTO and Fossil Energy Partner to Advance Subsurface Technologies

GTO and Fossil Energy's Carbon Capture and Storage Office partnered to award up to $15 million for a Lab Call under the SubTER Crosscut. The Lab Call was open to DOE National Laboratories and focused on developing innovative subsurface technologies and collaborative approaches to address challenges with wellbore integrity and ensuring sustained integrity of the wellbore environment.

A key energy challenge today is to ensure safe, sustainable, and affordable availability of natural resources in the subsurface. The SubTER Lab Call is providing solutions to these challenges by dramatically accelerating technology development with the aim to achieve mastery of subsurface processes.

The Lab Call is part of a larger effort to address technical challenges associated with operating in the subsurface. In response, DOE has established an integrated technology team that encompasses DOE offices involved in subsurface activities that are aligned with energy production/extraction, subsurface storage of energy and carbon dioxide, subsurface waste disposal and environmental remediation, as well as analysis associated with the subsurface.

Meeting current and future energy challenges requires dramatic advances in technology to ensure sustainable, and affordable availability of natural resources and storage in the subsurface.

THE FY 2017 SUBTER LAB CALL AWARDEES INCLUDE:

Sandia National Laboratories
- Advanced Downhole Acoustic Sensing for Wellbore Integrity

National Energy Technology Laboratory
- Embedded Sensor Technology Suite for Well-Bore Integrity Monitoring

Los Alamos National Laboratory
- High-Resolution 3D Acoustic Borehole Integrity Monitoring System
- Autonomous Monitoring of Wellbore Integrity Applying Time Reverse Nonlinear Elastic Wave Spectroscopy (TR NEWS) and Fiber Optic Sensing and Communication

Lawrence Berkeley National Laboratory
- Wellbore Integrity asSEssment with Casing-based Advanced SenSING (WISE-CASING)

SBIR/STTR Funding for Subsurface R&D

The Office of Basic Energy Sciences, in collaboration with GTO, announced three topics in the latest Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) funding opportunities that seeks to develop advanced methods to access the subsurface.

The SBIR/STTR program is a highly competitive program that encourages domestic small businesses to engage in federal R&D that has the potential for commercialization. Through a competitive awards-based program, SBIR/STTR enables small businesses to explore their technological potential and provides the incentive to profit from its commercialization.

This SBIR/STTR topic seeks applications in subsurface permeability manipulation and fluid control for geothermal energy production. In the future we have the potential to generate gigawatts of baseload electrical power from domestic geothermal energy sources.

While subsurface sources constitute the nation's primary source of energy, they are also critical to the nation's low-carbon and secure energy future. Next generation advances in subsurface technologies will enable improved access to renewable geothermal energy, as well as safer development of domestic natural gas supplies.

Domestic Energy Security

Deep Direct-Use Technology – Expanding Geothermal Resources

Deep Direct-Use (DDU) is an emerging technology area in the geothermal sector that utilizes lower temperature geothermal resources that are located deeper than resources used for geothermal heat pumps (GHPs) and conventional direct-use systems.

In the U.S., a good deal more energy than is needed is used to heat and cool certain residential and commercial buildings and facilities. These processes account for about 25% of U.S. energy use. If feasible, DDU could provide direct heating and cooling for large-scale U.S. district energy systems using lower temperature geothermal resources and less heat in regions lacking conventional hydrothermal resources.

At a large scale, DDU applications can potentially be used to replace old, or develop new, district heating and cooling systems in hotels, office buildings, hospital complexes, military installations, and other large energy end-uses and expand geothermal as a renewable thermal energy in large portions of the U.S.

DDU: New Projects

GTO funded six DDU Feasibility Studies that began on October 1, 2017. Each team's study will evaluate the feasibility of using a low-temperature geothermal resource to heat and cool large-scale end-uses. Teams are collaborating to validate the common assumptions used to develop a Levelized Cost of Heat (LCOH) for the DDU projects and other critical metrics.

The research teams selected represent a range of partners who will share the cost of performing the feasibility analysis with DOE. Lead organizations and their technology concepts include the following:

CORNELL UNIVERSITY:

Ithaca, New York: Direct geothermal for a variety of applications at the Cornell Campus.

NATIONAL RENEWABLE ENERGY LABORATORY:

Golden, Colorado: Direct Geothermal for turbine inlet cooling at Eastman Chemical's Longview, TX Natural Gas Combined Cycle operations

PORTLAND STATE UNIVERSITY:

Portland, Oregon: Thermal Energy Storage to directly heat and cool downtown hospitals.

SANDIA NATIONAL LABORATORIES:

Albuquerque, New Mexico: Whole-system analysis of direct geothermal to power the Hawthorne Nevada Army Depot and Surrounding Community.

UNIVERSITY OF ILLINOIS:

Champagne, Illinois: Leveraging data from deep carbon storage wells to directly heat and cool in the Illinois Basin

WEST VIRGINIA UNIVERSITY ENERGY INSTITUTE:

Morgantown, West Virginia: District geothermal to heat and cool the WVU campus..

DDU: Public Input

During public workshops, GTO acted on input received from the oil and gas industry, HVAC trades, Green Buildings Developers, Sustainability Coordinators, and others. Feedback included the need to preserve high-end fossil fuels (such as natural gas) for extreme energy demands.

Domestic Energy Security

Recovering Rare Earths and Critical Materials

Geothermal brine has the potential to contain relatively high concentrations of rare earth materials.

GTO continues to invest in clean energy technologies to strengthen our domestic energy independence. To improve technologies from the onset, GTO is focusing on rare earths and critical materials recovery—the building blocks in many clean energy applications. One exciting area of this research is examining how to recover critical materials from fluids, or "brine", produced from the Earth's subsurface by geothermal and other energy or mining projects. Recovering such materials provides a value-added use of the geothermal process. In addition, this work broadens the stakeholder base, expanding into mining interests, oil and gas operations, and specialized product sectors.

Most of the projects launched in 2014 under this effort completed their planned work this year, demonstrating the ability to recover low concentrations of rare earth elements and valuable minerals such as lithium and manganese from elevated temperature fluids. Four projects selected in 2016 are continuing to expand the public database of information about the presence of dissolved minerals in the U.S and demonstrate pilot scale operations.

From the onset of assessing the presence of rare earth elements in geothermal brines, the effort has expanded to characterize the presence of critical, high value and strategic materials in other elevated temperature fluids such as those from produced fluids from oil and gas or mining operations. The effort also includes the development of predictive models for future exploration. Results from the oil and gas regions of the US are being utilized to develop a potential tool for geologic prospecting based upon statistical screening.

Additionally, through networking with other agencies such as the United States Geologic Survey, the Critical Materials Institute, and the DOE Office of Fossil Energy, collaborative efforts are expected to build a broader constituency to speed extraction development and broaden the overall knowledge base for mineral resources in the U.S.

This continued research and development aims to enhance current applications of geothermal energy, support planned development, and potentially open additional U.S. regions for future projects. Further development in recovering rare earths and critical materials will not only create another revenue source for geothermal energy, but will also reduce foreign dependency on these materials.

Expanding Geothermal Energy

Mexico Geothermal Workshop – Promoting Geothermal Growth

The Mexican geothermal sector is poised for growth with a much improved framework in place to facilitate the issuance of permits for site studies, as well as concessions for exploration and development of geothermal resources. In March 2017, to better connect businesses to these emerging opportunities, the DOE and the Institute of the Americas organized a Mexican Geothermal Opportunities Workshop highlighting the country's geothermal sector.

This workshop was designed to help U.S. power producers, technology providers, and other companies better understand how these policy and regulatory changes have created new business opportunities in Mexico, and the role of various federal agencies in Mexico and the United States in facilitating entry into the Mexican market. These types of dialogues foster greater collaboration for advancing cutting edge R&D in enhanced geothermal systems that can translate to commercial opportunities for both the United States and Mexico.

California Geothermal Growth Potential

California is privileged to have access to a variety of robust energy resources, particularly geothermal energy. It currently produces more geothermal power than any other state, and alone accounts for more than 20% of total geothermal energy production worldwide. Additionally, NREL demonstrated the importance of adding even more geothermal energy to California's grid, which could translate to potentially hundreds of millions of dollars saved annually in operations, maintenance, and statewide utility bills.

Even with this firm potential, developing new geothermal energy in a competitive California energy market faces emerging challenges. To address these concerns, in 2017, GTO partnered with the California Energy Commission (CEC), the Department of the Interior (DOI), and several private foundations. These agencies continue to collaborate on innovation advancement and barrier reduction for geothermal production growth in California.

New thinking continues to surface around key points of innovation – developing hybrid systems as a means to respond to an increasingly flexible grid; recovering critical materials from geothermal brines such as lithium and manganese for use in high-tech industries; and cascading uses such as desalination or even steam storage. GTO continues to guide the way in several key areas and across various key regions, including California.

GHPs Contribute to Major Factor in New Net Zero Local High School

In the spring of 2016, the City of Falls Church, Virginia was awarded a grant through the DOE to conduct a Geothermal Feasibility Study at the Falls Church Campus Redevelopment site. The project, conducted in partnership with Oak Ridge National Laboratory and the Metropolitan Washington Council of Governments, included evaluating the geothermal potential of a redeveloped high school. The study estimated a payback of initial installation expenses in a period of just 3-5 years due to annual operations and maintenance cost savings. As a result of a successful study, the City of Falls Church plans to move forward with building a new, highly energy efficient high school to include geothermal heating and cooling.

The energy efficient campus will also serve as a learning lab, promoting possibilities for advanced sustainability solutions – exploring how a net zero energy high school could help support that purpose. Geothermal is a leading energy solution implemented in net zero energy schools.

Construction of the new school will commence spring 2019. Stay tuned for GTO's update of the groundbreaking. For updates on the progress visit: www.fallschurchva.gov/171/Environmental-Sustainability-Council

GTO Hosts the 2017 Peer Review

2017 PROJECT PEER REVIEW

U.S. DEPARTMENT OF ENERGY
GEOTHERMAL TECHNOLOGIES OFFICE

In November, GTO hosted the 2017 Peer Review. There were 63 public presentations discussing projects in GTO's research, development, and demonstration portfolio. These projects were systematically reviewed by more than 29 external subject-matter experts from industry, academia, national laboratories, and federal agencies.

The biannual Peer Review provides GTO the opportunity to review and evaluate the progress and accomplishments of the Office's core projects in key funded program areas. The event also opens a dialogue with respected researchers in geophysics, geochemistry, modeling, tools, and more. GTO conducts this rigorous review by independent, qualified peers to assess key achievements in geothermal development and to meet strategic DOE guidelines.

Each project represents a growing technology sector in Enhanced Geothermal Systems, Conventional Hydrothermal, Low Temperature & Coproduced Resources, and Systems Analysis.

Feedback collected from these meetings and presentations will be shared in the spring of 2018 with the release of the GTO 2017 Peer Review Report.

GTO's Josh Mengers and Mike Weathers listening in on a presentation at the 2017 Peer Review.

Resources

GTO makes the following tools and resources available for free and public use. Click or visit the links below to learn more about these resources.

Reports

EGS Roadmap—A technology roadmap for strategic development of enhanced geothermal systems: www.eere.energy.gov/geothermal/pdfs/stanford_egs_technical_roadmap2013.pdf

Exploration Roadmap—A roadmap for strategic development of geothermal exploration technologies: geothermal.energy.gov/pdfs/exploration_technical_roadmap2013.pdf

Geothermal Technologies Peer Review Presentations—Complete collection of technical presentations from GTO's 2017 Peer Review: https://energy.gov/eere/geothermal/downloads/gto-peer-review-2017?=123

GTO 2015 Peer Review Report: energy.gov/eere/geothermal/downloads/2015-peer-review-report-geothermal-technologies-office

JASON Study on EGS—A report conducted by the JASON group on EGS: eere.energy.gov/geothermal/pdfs/jason.final.pdf

JASON Study on Subsurface Technologies—Findings from a study on subsurface technologies: energy.gov/articles/2014-jason-report-state-stress-engineered-subsurface-systems

Quadrennial Technology Review (QTR): energy.gov/quadrennial-technology-review-2015

Staff Report to the Secretary on Electricity Markets and Reliability: energy.gov/downloads/download-staff-report-secretary-electricity-markets-and-reliability

Tools

DOE Geothermal Data Repository—The Geothermal Data Repository (GDR) is the submission point for all data collected from researchers funded by GTO: gdr.openei.org/

Geothermal Prospector—A mapping tool developed for the Geothermal Power industry. This tool is designed to help developers site large-scale geothermal plants by providing easy access to geothermal resource datasets and other data relevant to utility-scale geothermal power projects: maps.nrel.gov/geothermal-prospector/

Geothermal Regulatory Roadmap—A centralized information resource on the permitting processes for geothermal development in Alaska, California, Colorado, Hawaii, Idaho, Montana, Nevada, Oregon, and Texas: en.openei.org/wiki/RAPID/Roadmap/Geo

The Geothermal Electricity Technology Evaluation Model (GETEM)—A detailed model of the estimated performance and costs of currently available U.S. geothermal power systems: energy.gov/eere/geothermal/geothermal-electricity-technology-evaluation-model

The Jobs and Economic Development Impact (JEDI) Geothermal Model—Allows users to estimate project costs and direct economic impacts for both hydrothermal and EGS power generation projects based on exploration and drilling activities, power plant construction, and ongoing operations: nrel.gov/analysis/jedi/about_jedi_geothermal.html

Subsurface R&D Twitter—@SubTERCrosscut

Subsurface R&D LinkedIn—linkedin.com/groups/7017263

Subsurface R&D websites—subter.lbl.gov and energy.gov/subter

Acronyms

AOP	Annual Operating Plan
CRADA	Cooperative Research and Development Agreement
DDU	Deep Direct-Use
DOE	U.S. Department of Energy
EERE	Office of Energy Efficiency and Renewable Energy
EGS	Enhanced Geothermal System
FORGE	Frontier Observatory for Research in Geothermal Energy
GHP	Geothermal Heat Pump
GTO	Geothermal Technologies Office
GW	Gigawatt
LCOE	Levelized Cost of Electricity
LCOH	Levelized Cost of Heat
ORNL	Oakridge National Laboratory
NREL	National Renewable Energy Laboratory
PFA	Play Fairway Analysis
PNNL	Pacific Northwest National Laboratory
R&D	Research and Development
RD&D	Research, Development, and Demonstration
SBIR/STTR	Small Business Innovative Research and Small Business Technology Transfer
SBV	Small Business Vouchers
SNL	Sandia National Laboratory
SubTER	Subsurface Technology and Engineering Research, Development and Demonstration

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For more information, visit: energy.gov/eere/geothermal

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