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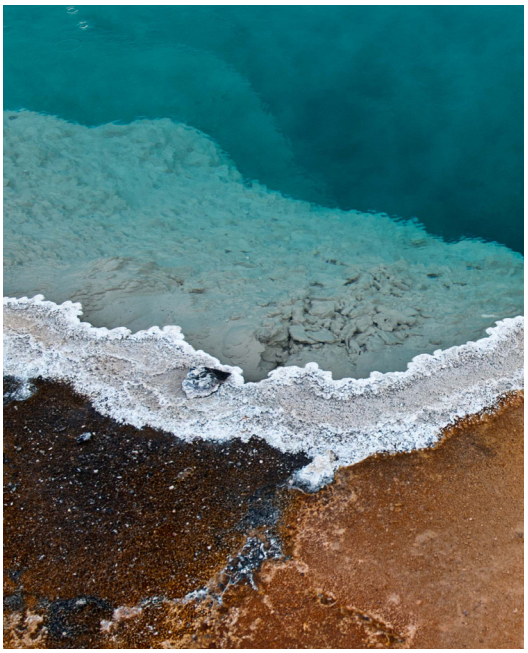

2014 Annual Report Geothermal Technologies Office

March 2015

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

2014 Annual Report

Geothermal Technologies Office

The *2014 Annual Report* of the Geothermal Technologies Office is a product of the United States Department of Energy, Office of Energy Efficiency and Renewable Energy.

DOE/EERE-1160 • March 2015
This report spans calendar year 2014 achievements. Photographs are accredited herein.

back cover photo: Geothermal heat at Pilgrim Hot Springs, Alaska. *Source: C. Pike at the Alaska Center for Energy and Power*

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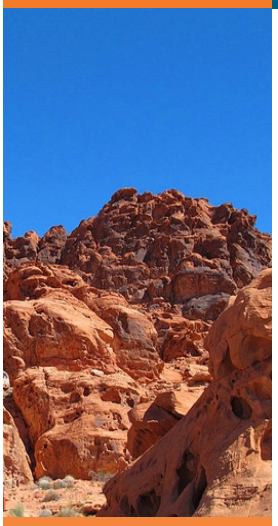

Rock formations. *Source: Geothermal Resources Council (GRC)*

2014 Achievements
Geothermal Technologies Office

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COVER ART:

Top left – Newberry Caldera, Oregon, *Source: Laura Garchar*; top right – geothermal pool, *Source: Benjamin Phillips*; lower right – EGS demonstration project at Newberry Volcano, *Source: Elisabet Metcalfe*; lower left – JASON scientists begin the SubTER study, *Source: Benjamin Phillips*; center left – Novel waste heat recovery unit, Beowawe geothermal plant, Nevada, *Source: TAS Energy*.

right: Fumaroles at the Akutan exploration project in Alaska, *Source: GRC*

Doug Hollett (r) meets with geothermal stakeholders following his presentation at the Geothermal Resources Council (GRC) Annual Meeting in September. Source: GRC

Year in Review

In 2014, the Geothermal Technologies Office (GTO) made significant gains—increased budgets, new projects, key technology successes, and new staff. As we move into the new year, the Fiscal Year (FY) 2015 budget is at $55 million—roughly a 20% increase over FY 2014, and a strong vote of confidence in what the sector is doing to advance economically competitive renewable energy. GTO also remains committed to a balanced portfolio, which includes new hydrothermal development, EGS, and targeted opportunities in the low-temperature sector.

The arrival of our 13th Energy Secretary, Ernest Moniz, in 2013 brought a renewed commitment to the so-called "forgotten renewables"—including geothermal. He demonstrated his support via tours of two active geothermal sites: a power plant facility in Nevada and a combined power and direct use project in Alaska.

I was able to accompany the Secretary on his trip to Nevada, and we visited the Steamboat Springs Geothermal Complex and the University of Nevada, Reno, where graduate students are working on exciting breakthroughs in geothermal science. It's clear that geothermal has the attention of our chief executive, and I believe our project portfolio and future plans are well positioned to continue this momentum.

This past year was a year of firsts in other ways as well. After a several year hiatus, GTO put out four major solicitations in exciting new technology areas, for a total immediate commitment of $18 million.

Our flagship effort over the next five years is the FORGE initiative—the first dedicated field site of its kind for testing targeted enhanced geothermal systems (EGS) R&D. The intent is to use this collaborative site for transformative science that will create a commercial pathway for large-scale, economically viable EGS.

In collaboration with the National Energy Technology Laboratory, the EGS team worked tirelessly to set up the scope and schedule of this revolutionary undertaking. We look forward to the next steps in 2015 when the team will select applicants and their candidate sites to compete for locating the new federal observatory.

Alongside the FORGE initiative, the EGS team also awarded twelve collaborative projects on EGS R&D in 2014. Awardees will develop novel techniques to increase the precision and accuracy of measuring critical underground reservoir properties.

In the Hydrothermal Program, a new funding opportunity could help more accurately pinpoint geothermal resources hidden beneath the Earth's surface. Play fairway analysis, adapted from a proven, successful practice in the oil and gas sector, could dramatically lower development costs by improving success rates for exploration drilling. Projects will model play fairways in a range of settings from the West Coast to the East. In the future, we look forward to the opportunity to test these models through drilling.

Our Low Temperature Program announced a new initiative—mineral recovery from geothermal brines—that could increase the value proposition of geothermal energy production through the extraction of rare earths and other critical materials, like battery-grade lithium. Ongoing research and demonstration over the next couple of years should give us an idea of the market potential and a replicable methodology for commercial production nationwide.

Finally, a new crosscutting initiative throughout the U.S. Department of Energy (DOE) is teaming energy technology offices that rely on the subsurface for power production and storage. The offices of fossil energy, nuclear energy, environmental management and science, along with geothermal, are collaborating on the big technical challenges, which are common across these sectors. We expect this exciting effort to grow in coming years.

We have had significant movement in the office this year as our funding opportunities open doors for new areas of research and oversight. And while the success of these burgeoning efforts remains my highest priority, I will be overseeing them from a new perspective at DOE in 2015. In November, I assumed the role of Deputy Assistant Secretary for Renewable Power. I leave the geothermal office in very good hands and look forward, with your help, to another banner year for this dynamic sector.

Doug Hollett

Old Faithful Geyser, Yellowstone. *SOURCE: Laura Garchar*

"We've turned the corner … the potential growth curve for geothermal is extremely exciting."

Douglas Hollett, Deputy Assistant Secretary for Renewable Power, Office of Energy Efficiency & Renewable Energy, United States Department of Energy

Rig inspection. *Source: GRC/Joe LaFleur*

Engineered reservoirs—created where there is hot rock but limited pathways through which fluid can flow—could unlock a potential 100 gigawatts of clean, reliable geothermal energy nationwide.

EGS Overview

Enhanced geothermal systems (EGS) are engineered reservoirs, created beneath the Earth's surface where there is hot rock but limited pathways through which fluid can flow. During EGS development, underground fluid pathways are safely created and/or their size and connectivity increased. These enhanced pathways allow fluid to circulate throughout the hot rock and carry heat to the surface to generate electricity.

The United States Geological Survey (USGS) estimates that more than 100 gigawatts (GW) of geothermal energy could be accessed through EGS in the United States alone.

EGS involves a broad spectrum, starting with medium risk operations such as improving existing wells and hydrothermal reservoirs within operating fields. In these environments, EGS can be viewed as a reservoir management tool to eliminate losses associated with drilling unproductive or sub-commercial wells.

Development in greenfield settings, where there are no existing geothermal operations, carry higher technical and financial risk. To surmount these hurdles, GTO actively engages in research and development (R&D) and field demonstrations to facilitate new, innovative technology deployment and validation to reduce costs and improve performance.

GTO currently funds four active, field-based EGS demonstration projects—accelerating the adoption of EGS in "near-field" environments, proximal to existing geothermal development—and more than 100 lab-scale research efforts to develop technologies that address critical challenges to commercialization. The newest EGS program initiative, the Frontier Observatory for Research in Geothermal Energy, or FORGE, is focused on holistically addressing those barriers.

DOE investments are advancing technologies that will enable economical production of energy from natural and engineered geothermal systems. This greenfield EGS field site near Bend, Oregon constitutes the largest federal investment in the geothermal energy portfolio. *Source: Elisabet Metcalfe*

FORGE Initiative Drives Innovation

In July 2014, DOE proudly announced an initial $31 million funding opportunity for a geothermal field observatory dedicated to researching the most relevant questions in the field of subsurface science and engineering.

As a first-of-its-kind initiative, the Frontier Observatory for Research in Geothermal Energy (FORGE) builds off of technical successes in GTO's EGS demonstration portfolio that promote transformative science and engineering through collaboration centered around a fully equipped, permitted, and characterized field site.

The site will enable cutting-edge research, drilling, and technology testing, allowing collaborating scientists to identify a replicable, commercial pathway to EGS. Ultimately, the field site will yield breakthrough tools and technologies for geothermal energy production, in critical research areas such as reservoir characterization, creation, and sustainability. The FORGE effort will also include a robust instrumentation component and be equipped to capture and share data in real time.

FORGE R&D will focus on strengthening our understanding of the key mechanisms controlling EGS success—specifically, how to initiate and sustain fracture networks in basement rock formations.

Someday, GTO will apply these discoveries to the design and testing of methods to develop large-scale, economically sustainable heat exchange systems. These achievements, in turn, will facilitate EGS commercialization through a rigorous and reproducible approach to reducing industry development risk. Activities include innovative drilling, reservoir stimulation, well connectivity, and flow-testing efforts. The selected operations team will also continuously monitor geophysical and geochemical signals. Additionally, dynamic reservoir models will play an integral role

in FORGE by allowing the site operator to synthesize, predict, and verify reservoir properties and performance.

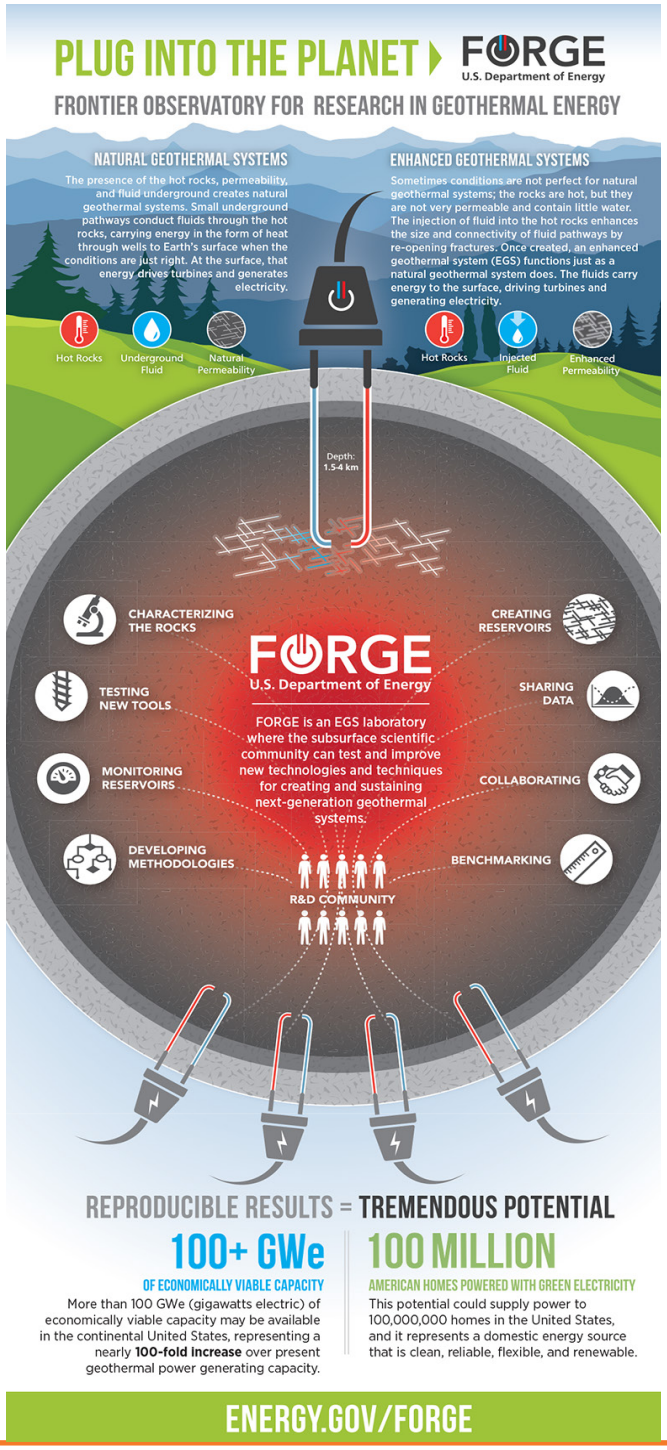
R&D activities will encourage open participation via competitive solicitations to the broader scientific and engineering communities. As advancements in EGS are made over the course of the operation, R&D priorities are likely to shift and change in response.

As a result, FORGE will be a dynamic, flexible effort that can adjust to and accommodate the newest and most compelling challenges on the energy frontier.

The FORGE management model is based on broad collaboration between DOE and industry, national laboratories, academic institutions, and service companies, via a proposed Science, Technology, and Analysis Team (STAT). The selected site operator will manage day-to-day administrative and financial operations while DOE maintains final decision-making authority on all priorities and approaches.

The FORGE initiative comprises three phases. The first two phases focus on selecting a suitable site and the operations team that will prepare and fully characterize the site. In phase one, $2 million will be available over one year for selected teams to perform analysis on the suitability of their proposed site and to develop plans for phase two. Up to $29 million in funding is planned for phase two, during which teams will work to fully instrument, characterize, and permit candidate sites.

During phase three, the EGS team will select a single site where FORGE will be fully implemented by a site operations team, pending appropriations. A collaborative research strategy will guide the FORGE work through annual R&D solicitations at this stage, and partners will interact dynamically onsite to conduct new and innovative R&D in critical research areas such as reservoir characterization, creation, and sustainability.



As FORGE advances EGS, this next generation technology holds the potential to be a game-changer in the energy sector on the order of 100 GW, enough to power about 100 million homes. The field lab will help scientists better understand and resolve fundamental technical issues associated with a range of subsurface energy technologies.

Ultimately, the discoveries and outcomes from this initiative will drive down the cost of deployment and promote successful adoption of EGS by domestic energy producers, investors, and utilities. FORGE will also promote understanding and resolution of fundamental technical issues pertinent to all subsurface energy sectors.

Solicited nationwide in March and closed to applicants in November, FORGE has generated a significant level of interest and guidance by Congress, DOE leadership, and state and local stakeholders. Award announcements are expected by mid FY 2015.

Geothermal drilling in the Imperial Valley, California. *Source: Ram Power*

"The FORGE initiative is a first-of-its-kind effort to accelerate development of innovative EGS technologies, which could help power our low carbon future."

David Danielson, Assistant Secretary for Energy Efficiency and Renewable Energy

Mudpots in the Imperial Valley, California. *Source: GRC*

"EGS in particular holds the key to long-term sector transformation."

Lauren Boyd, EGS Program Manager, Geothermal Technologies Office

Nevada Geothermal Power Plant. *Source: Ted Clutter | National Renewable Energy Laboratory*

$10 Million Awarded for EGS Research

As part of the Administration's all-of-the-above energy strategy, project selections were announced in August to advance EGS. Twelve collaborative EGS R&D projects totalling $10 million will target subsurface science and engineering techniques.

Selected awardees are developing novel techniques such as isotope and tracer analysis methodologies and innovative rock mechanic experiments—integrated with geophysical methods to increase the precision and accuracy of measuring critical underground reservoir properties over time. To precisely engineer geothermal reservoirs, project teams are focusing on laboratory feasibility studies to characterize critical EGS reservoir parameters—such as fracture length, fracture aperture, and in-situ stress magnitudes and directions. These awards, officially initiated in September, will yield integrated characterization methods and prototypes ready to be validated in the field at the end of their performance period. Details on the 12 awards follow.

University of Wisconsin–Madison will assess a technology for characterizing and monitoring changes in the mechanical properties of rock in an EGS reservoir in three dimensions. The integrated technology will analyze data including seismic waveforms, ground deformation, specialized radar, and comparisons of well pressure, flow, and temperature to characterize the reservoir.

Pennsylvania State University will explore ways to assess both the characteristics and evolving state of EGS reservoirs prior to stimulation and during production. The project will facilitate estimates of the permeability of reservoir fracture networks in order to understand evolving flow structure and more effectively engineer thermal recovery systems.

A second ***Penn State*** project will focus on the processes governing fracture flow and energy production in EGS reservoirs and examine methods to manage and predict changes in permeability over their lifetimes. Researchers will investigate the mechanisms controlling fluid-induced permeability and develop acoustic methods to image fracture characteristics.

Lawrence Berkeley National Laboratory (LBNL) plans to develop a three-dimensional fluid transport model using radon in order to better characterize fractures in geothermal reservoirs. LBNL will develop a methodology for calculating the size of fractures using the amount of radon present in reservoir fluids.

A second ***LBNL*** project plans to model and simulate an integrated technology using geophysical methods in combination with injection of carbon dioxide for purposes of well monitoring. The technology is designed to characterize fractured geothermal systems.

California State University, Long Beach plans to evaluate hydraulic connectivity among geothermal wells using Periodic Hydraulic Testing (PHT). By creating a pressure signal in one well and observing responding pressure signals in other observation wells, experts can better assess the permeability and capacity of the fracture network, which will help to effectively engineer geothermal reservoirs.

Cornell University will develop and test a chemical tracer procedure for modeling reservoir structures and predicting EGS thermal lifetimes. If successful, this will provide reservoir operators with the ability to evaluate proposed reservoir management practices and to quantify the probability of successful deployment, including cost.

University of Oklahoma is integrating several techniques for characterizing full-sized EGS reservoirs under realistic stress and temperature conditions, including simultaneous monitoring of acoustic emissions, fluid-flow tracers, and changes in reservoir pore pressure and fluid/rock temperature. This research could provide essential data and information to understand induced fractures and will help improve reservoir performance.

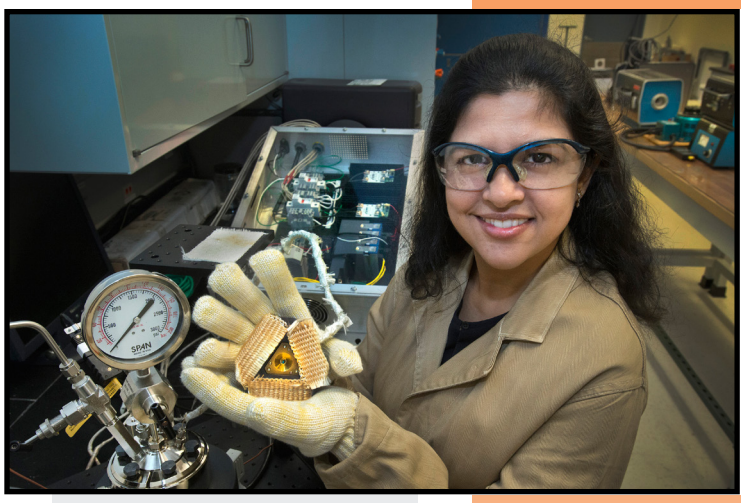
Los Alamos National Laboratory will develop high-precision characterization techniques to model fluid-flow pathways in EGS reservoirs. The project will facilitate development of high-accuracy 3D models and produce high-resolution images of fracture zones in EGS reservoirs. If successful, this research will provide a new methodology for mapping and characterizing fluid-flow pathways in EGS reservoirs.

Array Information Technology will develop an integrated approach to track injected fluid during EGS development. The company will monitor the system prior to and during EGS injection, evaluate fracture density and dimensions, and determine the fluid-flow velocity in the activated fracture network.

University of Nevada, Reno will use a technique to detect interference between pairs of seismic signals in order to gain useful information about the subsurface. Existing and newly acquired seismic survey data will be used to compare data from this cost-effective, non-invasive, seismic exploration method

with data from a comprehensive geoscience study of the geothermal system in Dixie Valley, Nevada. This proposed technology has the potential to enhance the ability to characterize subsurface fracture, stress, and other physical reservoir properties at a variety of geothermal fields.

Sandia National Laboratories is developing a system of nanoparticle-based chemical tags for EGS reservoirs. The gradual release of these unique tags will mark both the location of the reservoir and flow rates for above-ground assessment. This previously unavailable information will provide engineers the ability to closely monitor many subsurface flows simultaneously, leading to production efficiencies, and will provide for longer term monitoring without interfering with active wells.



Simerjeet Gill of the Brookhaven National Laboratory works on materials in extreme environments, to advance applied energy technologies for nuclear and enhanced geothermal systems. *Source: Brookhaven National Laboratory*

New Technique Improves Earthquake Detection

GTO announced a novel approach to microseismic detection, developed by a team of researchers at Lawrence Livermore National Laboratory (LLNL), which significantly improves earthquake detection in difficult signal processing environments.

Seismic detection and location techniques are often employed to identify microearthquakes in geothermal regions, especially when mapping subsurface structures. Traditional earthquake monitoring techniques, however, may miss events if the seismic signal of the earthquake is small relative to the background noise level. Levels can become elevated by moving vehicles, nearby storms, localized machine noise, or if the microearthquake occurs close in time to a larger event.

Between October and December 2012, DOE partnered with AltaRock Energy to employ conventional earthquake detection techniques during stimulation of hot rock beneath the Newberry Volcano. During the process, 234 microseismic events were identified.

Through DOE funding, LLNL researchers, led by Dr. Dennise Templeton, significantly improved those results by applying a novel Matched Field Processing (MFP) earthquake detection technique to AltaRock's seismic dataset. MFP successfully identified an additional 166 microseismic events, revealing 70% more events than conventional techniques.

The improvement is of momentous significance to the geothermal energy sector and benefits other subsurface fields as well—including oil and gas, carbon capture, and energy storage. Coupled with the lab team's improved velocity model of the subsurface and knowledge of statistical earthquake relocation methods, this novel tool will help scientists and operators to more precisely map events and better characterize subsurface structures that were previously undetected. When employed during reservoir stimulation, as in this demonstration project at Newberry, Dr. Templeton's technique improves the reservoir stimulation strategy that will optimize heat extraction and maximize economic return.

Dr. Templeton's groundbreaking research is already being incorporated into the broader subsurface research community.

Industry, as well as other disciplines within LLNL—carbon capture and storage and risk analysis, for instance—have absorbed this novel algorithm into their own investigations and projects. GTO anticipates this game-changing technique will become a new standard in seismic processing, at a critical time for the subsurface community and America.

GTO promotes high-risk/high-reward science and engineering that the private sector is not financially or operationally equipped to undertake.

Field research. *Source: Lawrence Livermore National Laboratory*

EGS research, through our national laboratories, research universities, and industry partnerships, is securing more competitive economics for geothermal energy production.

Portable ground-based interferometric radar monitoring equipment, like this one at the AltaRock Newberry EGS demonstration, can detect ground deformation at a very small scale. *Source: Elisabet Metcalfe*

Code Comparison Study

In collaboration with GTO, Pacific Northwest National Laboratory (PNNL) is performing a geothermal code comparison study for the modeling community. This project is focused on testing models, diagnosing differences, and demonstrating capabilities of a worldwide collection of numerical simulators for evaluating geothermal technologies.

Numerical simulation codes have become critical to the understanding of complex processes in geologic media. Today, these tools help to assess technology feasibilities, design geologic systems, evaluate field observations, and guide operational procedures. The growing need for numerical simulation stems from a spectrum of uses:

- Continued validation of numerical simulators against laboratory experiments and field observations, yielding growing confidence in numerical simulation
- A need for evaluating coupled processes in geologic systems, driven by geologic sequestration of greenhouse gases and unconventional energy sources
- Advances in computing technologies, enabling increased model complexity and grid resolution.

To become a trusted analytical tool for geothermal technologies, numerical simulation codes must be tested to demonstrate that they adequately represent the hydrologic, thermodynamic, geochemical, and geomechanical processes of concern.

Through this initiative, PNNL is guiding 10 university, national laboratory, and industry teams through the execution of seven test problems. Participants formulated problems that include thermal, hydrological, mechanical, and chemical processes with fracture shearing and opening behavior motivated by EGS settings. Results to date indicate that the suite of codes utilized by the community yield reliable solutions to EGS problems and are being cataloged on GTO Velo, a wiki-based interface developed and maintained by PNNL.

The array of information provided includes detailed problem descriptions, results, associate discussion boards, and characteristics of participating codes.

Velo is used by current participants and will ultimately serve as a repository for materials that will help maintain a productive geothermal modeling community. Next steps for the modeling consortium include documenting results of the test problems through publications, and developing a set of more advanced problems to further challenge the suite of geothermal numerical simulation tools.

Small Business Innovations Span Technology Sectors

GTO is supporting Perma Works LLC, a small business with offices in Texas and New Mexico, with a Phase II Small Business Innovation research grant. Under this award, Perma Works is developing a high-temperature geothermal well logging camera. The research has yielded high-temperature electronics on multiple fronts—for a 32-bit microprocessor and solid-state battery.

Perma Works is working with RelChip Inc. to commercially produce the 32-bit, microprocessor module for high-temperature operation. The team successfully tested all electronic components at 300°C (572°F). The microprocessor module will provide image processing and data compression onboard its downhole geothermal well logging camera to fit well imaging tools to standard geothermal logging equipment without cooling the well, thus cutting expense and risk.

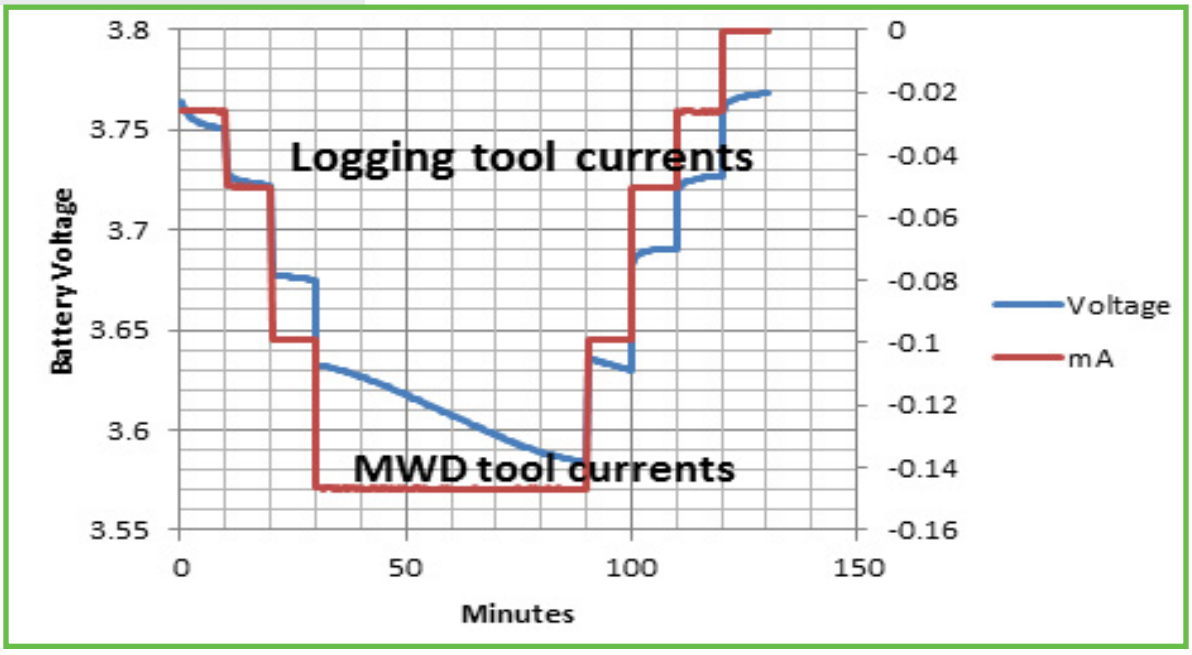
The new heat-resistant electronics are also being used in other industries. The high-temperature microprocessor module, for example, can be mounted directly to the aircraft engine on commercial aircraft as a control system. The new configuration scales the number of wires required between cockpit and engine from 150 down to 40, resulting in a weight savings of more than 600 lbs—and associated gains in efficiency—for large commercial aircraft.

Perma Works is also collaborating with Dr. Alexander Potanin, founder and CEO of High Power Battery Systems, to commercialize solid-state batteries rated to operate in 250°C (482°F) conditions.

The batteries are rechargeable and can withstand a wide range of conditions, from room temperature to extreme temperatures because they produce voltage and current from chemistry while still in a solid form. Until now, the current state of the art in battery technology has used lithium, which is limited to lower temperatures and has a one-time use and a high risk of failure. Lithium batteries exceeding 200°C have the potential to leak toxic lithium metal or even explode. Solid-state batteries, by comparison, are safe to overheat even as high as 500°C, which greatly reduces the risks to powering geothermal logging tools.

Image processing and data compression are executed onboard with a downhole tool with high-temperature 32-bit microprocessor. *Source: PermaWorks*

Voltage and current for solid-state battery at 200°C. In general, currents less than 100mA are needed for geothermal logging tools, and currents 150 milliamps or higher are needed for Measurement While Drilling tools.



Geothermal drilling at Blue Mountain. *Source: GRC*

Stimulation Technologies at Sandia Labs

Sandia National Laboratories is continuing a multi-year program to develop energetic stimulation technologies. Tests were conducted at a series of technology demonstration wells in Socorro, New Mexico, where Sandia's novel stimulation technology proved viable.

During the first set of tests, Sandia injected gaseous fuel and oxidizer into the wellbore, creating a deflagration to detonation transition of the mixture after ignition. This rapid pressurization produced numerous near field fractures in the wellbore across the test zone. Subsequent forensic coring adjacent to the wellbore located a vertical radial fracture emanating from the wellbore and corresponding to the length of the stimulated zone. Video imaging using geometric positioning, recovery of the fractured core section away from the stimulated well, and injection of dye all confirmed an interconnectivity of the fracture, from the wellbore to the exploratory core hole.

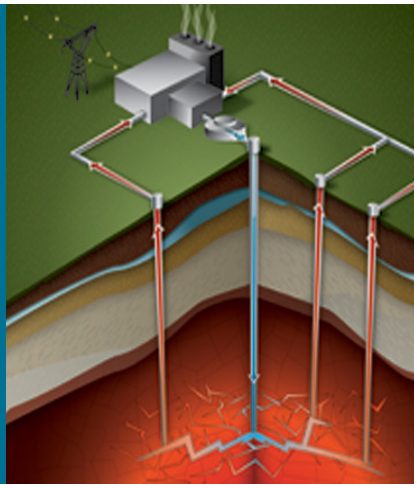
After conducting the initial test series, it was determined that seismic imaging could result in a better understanding of the formation conditions pre- and post-fracturing. A second wellbore was prepared for a new stimulation technique, and four cross-hole seismic imaging holes were cored adjacent to the wellbore to be stimulated. In the second series of tests, solid phase metalized explosive formulations that could more easily be deployed in fluid-filled wellbores were developed and tested at the site.

Through detonation bomb calorimetry, Sandia successfully demonstrated the desired reaction of the explosive products with water in the wellbore. Additionally, the team completed numerical simulations of the shock coupling of the explosive through the wellbore fluid and into the formation. These simulations demonstrated that the explosive charge can still propagate fractures in the surrounding formation, showing a significant increase in permeability while preventing wellbore damage. Successful use of cross-hole seismic imaging indicated an increase in near field permeability surrounding the wellbore. While work continues in analyzing and interpreting preliminary seismic imaging data, new holes are being prepared to conduct further energetic tests that will employ an enhanced explosive, produce a larger energetic charge, and incorporate both seismic imaging and leak down testing to verify the increase in permeability.

In parallel, a computational effort is underway at LLNL to couple the energetic event to a representative formation. This basic parametric study will be used to investigate the effects of energetic release rate and magnitude in order to engineer an optimized stimulation method. This computational work would ideally allow charge sizing to optimally fracture the wellbore while minimizing wellbore damage.

At the Raft River EGS Demonstration project in Idaho, results of stimulation activities show promise for energy production. *Source: Laura Garchar*

Learn more about EGS technologies and the new FORGE initiative: http://energy.gov/eere/geothermal/what-forge



The Newberry Volcano near Bend, Oregon is one of four active EGS demonstration sites nationwide that are funded by the Geothermal Technologies Office. *Source: Elisabet Metcalfe*

Learn more about the benefits of geothermal at energy.gov/eere/geothermal/geothermal-basics.

EGS Demonstration Updates

Four active EGS demonstration projects continued to yield progress in 2014. GTO improvements in or near producing geothermal developments at Bradys Field, Nevada and Raft River, Idaho are augmenting existing capacity there, and The Geysers in California has moved into the long-term monitoring stage of their EGS project. A recent scientific study estimates a potential 5-10 gigawatts of additional electricity in the near-term along the edges of these fields. Additionally, a groundbreaking EGS demonstration in Oregon could access a significantly larger resource as the industry overcomes key technical challenges.

Spotlight on Newberry Volcano

The AltaRock EGS demonstration project at Newberry Volcano near Bend, Oregon—a $21.4 million GTO Recovery Act investment—is currently the only project in our EGS portfolio located in a greenfield setting. Initial stimulation efforts concluding in 2013 were followed by seismic modeling and thermal profile analysis. AltaRock performed several wellbore surveys in early 2014 in order to assess the integrity of the wellbore.

In 2014, continued stimulation of the well—once all well workover tasks were completed—was the main thrust of AltaRock's efforts. During this stimulation, water was pumped at flow rates and pressures to shear existing fractures and increase permeability in the subsurface. New diverter technologies were employed to target multiple zones of rock, increasing the stimulated volume more efficiently and with less fluid.

Based on preliminary analysis of microseismic data, this latest stimulation phase has produced an EGS reservoir with dimensions close to a cubic kilometer, reaching an important goal of the Newberry project, and the measured injectivity of the well has increased by nearly four times. Additional stimulation activities took place in November using perforation shots to increase the connectivity of sheared fractures to the wellbore.

Ongoing analysis of this latest stimulation task, to be completed in early 2015, will provide additional insight into the Newberry Volcano reservoir. The promising work at Newberry Volcano, slated for completion by late 2015, is critical for advancing the state of EGS greenfield technologies and techniques. The geothermal community benefits from the progress in greenfield discovery this year, but there remains a great deal to be done.

Naturalists hike along the caldera of the Newberry Volcano, a landscape that remains largely undisturbed by the EGS project nearby. *Source: Laura Garchar*

Stillwater Geothermal Plant in Fallon, Nevada generates 33 MW of electricity from four turbines. *Source: Enel Green Power North America*

The USGS estimates that 30 gigawatts of geothermal energy lie hidden in the western United States alone—10 times the current installed capacity.

Overview

A hydrothermal 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.

Minimizing the risks and costs of discovering and characterizing new geothermal energy sources is vital to realizing geothermal as a significant contributor to the nation's baseload energy supply. The U.S. Geological Survey (USGS) has estimated that 30 gigawatts electric (GWe) of undiscovered geothermal resource exist in the western United States—10 times the current installed capacity.

Amedee Geothermal Venture in California generates 1.6 MW from binary technology, *Source: NREL*

Learn more about GTO investments in hydrothermal power at www.energy.gov/eere/**geothermal/hydrothermal.**

Energy Secretary Moniz tours the Steamboat Springs Geothermal Complex in Reno on October 22. *Source: Ormat*

Energy Secretary Visits Geothermal Sites in Alaska, Nevada

Since taking office May 21, 2013, DOE's 13th Energy Secretary Ernest Moniz has followed through on his commitment to support the so-called "forgotten renewables"—bioenergy, hydropower, and geothermal. In his first year, the Secretary announced deployment of the National Geothermal Data System and visited two active geothermal sites, at Chena Hot Springs—his first official trip to Alaska—and the Steamboat Springs Geothermal Complex in Reno, Nevada.

On August 17, on his tour of Chena Hot Springs, the Secretary remarked on the "spectacular beauty" of the valley. "Now I know what I've been missing all these years," he said. He applauded founders Bernie and Connie Karl for their novel approach to sustainability and innovation through a unique combination of leisure activities, science and engineering, and agriculture. With a low-temperature geothermal power plant onsite, Chena generates three million kilowatt-hours (kWh) of clean energy per year, displacing 224,000 gallons of diesel per year. The geothermal plant has brought down the cost of energy there from 30 cents per kWh to seven.

Historical investment at Chena Hot Springs—under the DOE-supported Geothermal Resource Exploration and Definition (GRED) Program, which ran from 2000-2007—enabled exploration and technology development that resulted in breakthroughs with low-temperature power generation.

The most striking feature about Alaska, the Secretary noted, is the vast natural abundance existing side by side with [energy] scarcity. Alaska's energy production and potential are unmatched, not only in oil and gas, but also in wind, hydro, geothermal, and other renewables. Yet consumers in Alaska are paying the highest prices for fuel in America, and they

sometimes go without power. He recounted the hardship in 2012 when Nome ran out of diesel, and icebreakers had to bring in fuel.

With its breakthrough low-temperature geothermal power plant technology now being replicated in other communities, the Chena resort plays a pivotal role in deploying geothermal energy. More than 120 remote locations with no access to power grids are currently fueled by expensive diesel and could follow this model.

In addition to energy security and economic considerations, climate impacts are driving decisions about America's energy future.

"Alaska is ground zero for climate change," he said. "Over the past 60 years, it has warmed more than twice as rapidly here as the rest of the United States and is predicted to accelerate even more by the end of this century—another 2 to 4 degrees Fahrenheit by 2050." Its major impacts can be seen in coastal storms and erosion, thawing permafrost, and melting glaciers. The President's Climate Action Plan directly addresses these threats with an all-of-the-above strategy to reduce our carbon emissions, but it will take everyone's full support, urged the Secretary.

Then on October 22, the Secretary visited Nevada and toured the Steamboat Springs Geothermal Complex as part of a presidential initiative to declare October as National Energy Action Month.

With a combined generating capacity of 78 MW, the Ormat complex today supplies the main source of baseload power for the citizens of Reno, Nevada.

DOE investments enabled exploration at the site, which confirmed a geothermal resource sufficient to sustain the six power plants in operation there.

The Secretary closed his day with a visit to the University of Nevada, Reno, where he and Doug Hollett reviewed the graduate thesis projects of a dozen students in geothermal fields. The university's Great Basin Center for Geothermal Energy onsite is a leader in geothermal research. A roundtable with industry leaders followed.

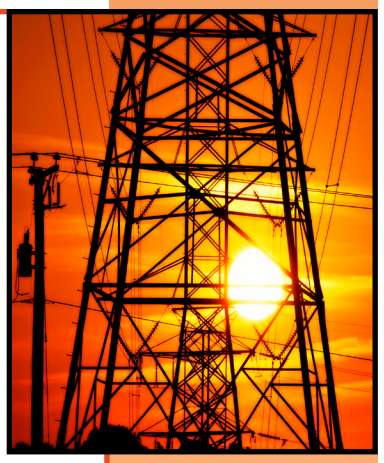
Federal Investment in these States

Over $28 million has been invested in Alaska since 2005. Today, DOE has six active projects there. One of these projects—on the island of Akutan within the Aleutian chain—could yield enough geothermal electricity to offset five million gallons of diesel every year, used to power the largest seafood production facility in North America.

Nevada remains the second-richest geothermal state in America, after California, with a nameplate capacity of 566 MW. Twenty-two geothermal power plants are in operation at 14 locations across the state. Geothermal potential extends roughly 2,000 miles north to south, encompassing the majority of the state with the high heat flow associated with conventional geothermal systems. In addition, Nevada draws on geothermal energy for space heating, spas and pools, and agricultural applications.

A recent industry decision to locate a "gigafactory" in Nevada to manufacture electric vehicle batteries holds promise for tapping geothermal energy as well, both for electricity and for recoverable lithium, a key ingredient in battery production. Since 2005, GTO has invested $72.7 million toward geothermal development and R&D in Nevada and currently has 22 active projects in the state, for a total federal investment of approximately $38.6 million.

The role of federal government—DOE and other federal agencies—is to work as a collaborative partner to help with much-needed research, engineering, and financing to create a sustainable, productive, competitive energy economy. Today, DOE funds more than 175 geothermal energy projects nationwide that leverage more than $400 million in research, development, demonstration, and analysis.



Power grid at sunset, when American energy demand can spike. *Source: Thomas Schultheis*

The Akutan project in Alaska could offset five million gallons of diesel every year with clean, renewable geothermal energy.

Old Faithful Geyser, Yellowstone. *Source: Laura Garchar*

Play fairway analysis probes through resource uncertainties to plot the most promising sites for geothermal exploration.

$4 Million Awarded to Adapt Play Fairway Technique from Oil and Gas

In 2014, GTO issued a funding opportunity focused on adapting play fairway analysis (PFA), a technique successfully employed in the oil and gas sector, to reduce uncertainty for drilling targets by defining the most promising areas for geothermal exploration by utilizing data and software tools.

Conducted on a regional (basin) scale, the resulting maps can cover smaller areas or multistate regions up to several thousand square miles. For geothermal, the PFA approach defines levels of uncertainty among geothermal system elements of heat, permeability, and fluid, and translates them into maps that pinpoint highly probable "play fairways" for geothermal exploration.

By adapting this practice, GTO addresses an industry need to quantify and reduce uncertainty, which will subsequently reduce cost and risk of geothermal exploration.The following 11 awards were competitively selected from a strong pool of applicants:

Atlas Geosciences Inc. will explore the geothermal potential of the Cascade Mountains and Aleutian Island chain. These areas have significant heat flow and untapped potential for geothermal power generation due to recent volcanism. The project will focus on understanding the occurrence and distribution of these resources to help identify the most promising targets for electrical power generation.

Cornell University will determine the most favorable locations for geothermal heat within the Appalachian Basin in New York, Pennsylvania, and West Virginia. This project aims to narrow the focus to the most favorable locations near population centers.

Los Alamos National Laboratory will apply the play fairway framework to the Rio Grande Rift and the Southern Basin and Range of New Mexico and develop a proof-of-concept framework to identify gravity-driven geothermal systems.

The research team at ***Nevada Bureau of Mines and Geology*** at the ***University of Nevada, Reno*** will perform an integrated geologic and geophysical study of three critical areas in the Great Basin. The Great Basin was chosen for study because it is one of the largest geothermally active areas on Earth, and clearer mapping of subsurface indicators may lead to increased development in this region.

Ruby Mountain Inc. will identify geothermal resources in new areas using geothermal play fairway modeling in the Tularosa Basin study area of southwestern New Mexico to discover geothermal resources. The military has a large presence in this area and would benefit from regional geothermal development.

Scientists from ***University of California, Davis*** and ***LBNL*** will employ geothermal play fairway analysis to assess geothermal potential in the geologically complex and understudied regions of Northeast California, Northwest Nevada, and Southern Oregon. In the process, they will develop tools for risk assessment

Dr. Brian Anderson, left, chemical engineering professor at West Virginia University, shares the scope of a collaborative play fairway analysis project underway in the Appalachian Basin during a poster session at the GRC/GEA Annual Meeting in Portland, Oregon in September. *Source: GRC*

that can be used by industry to enhance opportunities for geothermal energy development.

Researchers at the ***University of Hawaii*** are developing a play fairway analysis of geologic, geophysical, and geochemical datasets for geothermal resources in Hawaii, which will be integrated into statewide maps showing geothermal resource probabilities.

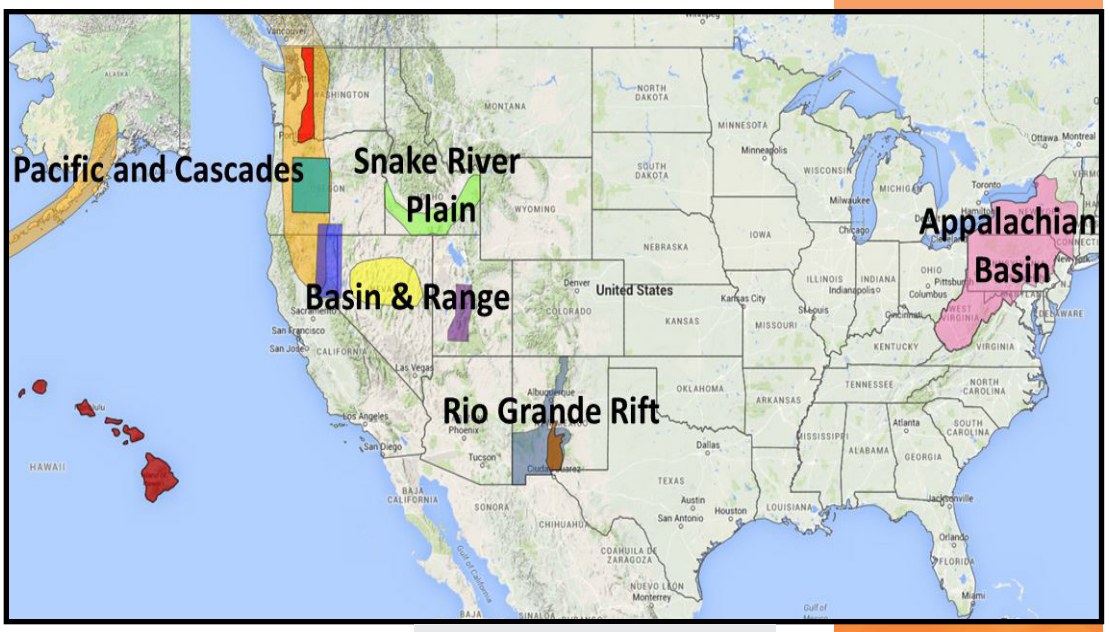
The ***University of Utah Energy & Geosciences Institute (EGI)*** will combine a range of mapping techniques, including play fairway analysis, to evaluate geothermal systems in the eastern Great Basin. The analysis will exploit new, fluid-sensitive imaging technology.

Another ***University of Utah EGI*** project combines mapping techniques, including LIDAR and play fairway analysis, to evaluate geothermal systems in the Central Cascade Range area. The project seeks to locate high-temperature resources in the Central Cascades.

Utah State is adapting play fairway methodology to search for geothermal resources in the Snake River Plain, Idaho. The team is assembling relevant data from publicly available and private sources to build a geothermal play fairway model that identifies the most promising locations for geothermal energy development there.

The ***Washington Division of Natural Resources*** will apply geothermal play fairway modeling to build upon their recently developed Washington geothermal resource potential model. The resulting maps will estimate uncertainties within three target areas in Washington State.

All of the PFA projects were initiated in October and kicked off their efforts with poster presentations at the Geothermal Resources Council's annual technical conference and Geothermal Energy Association Expo. The 11 mapping efforts will be completed in 12 months, and a limited number may be selected for additional exploration activities and drilling of temperature-gradient wells in FY 2016 to test the conclusions of the analyses.



Eleven play fairway projects were awarded in diverse regions of the country to study the potential for geothermal energy development. *Source: Laura Garchar*

Mount Hood, part of the Oregon Cascades, is one of many volcanic centers being examined for geothermal potential. *Source: Laura Garchar*

Night drilling at Pilgrim Hot Springs, Alaska. *Source: C Pike / ACEP*

Geothermal development at Pilgrim Hot Springs could spawn new industries and allow the native populations to return there.

Pilgrim's Progress

As a project partner with GTO, the Alaska Center for Energy and Power (ACEP) led an extensive geothermal exploration effort at Pilgrim Hot Springs, Alaska.

ACEP found a sufficient geothermal resource to tap geothermal energy for a spectrum of uses, including on-site power generation. In fact, experts consider the resource at Pilgrim—50 miles northeast of Nome—to be the largest identified geothermal resource on the Seward Peninsula.

Mike Weathers is the DOE project lead for Pilgrim Hot Springs. "This tremendous resource has the potential to bring clean, low-cost, domestic power to the citizens and industries of Alaska while providing a reproducible model for other rural communities," he said.

While developers have long known that a geothermal resource exists at Pilgrim, breakthroughs in technology have only recently enabled researchers to utilize geothermal waters below the boiling point for power production.

Pilgrim Hot Springs percolates with rich geothermal energy. *Source: C Pike/ ACEP*

In 2007, research at Chena Hot Springs yielded a new technology that produces electricity with lower-temperature geothermal resources below 168°F, increasing the feasibility of development at other geothermal sites like Pilgrim.

Between 2010 and 2014, a variety of geophysical surveys were conducted, which culminated in fall 2013 with the drilling of a large diameter well capable of high flow rates.

In September 2014, for the first time, flow testing of this well sustained rates greater than the naturally occurring artesian wells. The well was successfully airlifted for over seven hours at an average rate of 300 gallons per minute, with a temperature of 80°C. Temperatures up to 91°C have been reported in the past. Repeated productivity measurements with flow rate changes of 60 to 240 gallons per minute (gpm) all gave values of 20.4 to 27.5 gpm/psi, which indicates a productive well.

The accumulation of positive flow data, in fact, has encouraged the landowners to initiate discussions on development opportunities that may allow native communities to return to Pilgrim Hot Springs with the potential to host a spa destination, agricultural applications, or residential direct heating.

Galena power plant, part of the Ormat Steamboat geothermal complex in Nevada. *Source: GRC*

Exploration in Nevada

U.S. Geothermal Inc. (USG) is currently executing a geothermal exploration and development program at the San Emidio geothermal resource in Washoe County, Nevada. The program—a cost-share between USG and Recovery Act (ARRA) funding from DOE—revealed a complex structural environment yielding numerous production drilling targets. To test several of the identified targets, USG drilled six slimholes in the southern exploration area and one in the northern area from 2011 through 2014. Five of the wells encountered temperatures above the commercial target of 280°F, and three of the

Drilling at Glass Buttes

A GTO project in south central Oregon is merging a range of geophysical and geochemical datasets to reduce risk in geothermal exploration.

GTO's project partner Ormat Technologies completed a range of surveys over the area of interest, analyzed data to identify drilling targets, and conducted geologic field work to verify and map identified features. Some of the techniques applied in that stage were deemed so successful that they have now become a standard part of Ormat exploration work. With the successful completion of Phase 1 in 2013, drilling began in October on the first of two slimholes with the goal of providing enough data to site a potential production well. In October, Ormat began coring the well with an expected target depth of 3,000 feet. Pending results from the first well, a second well could be drilled in 2015.

five achieved commercial-scale permeability as well. Two wells encountered temperatures that were 10-15°F higher than the maximum previously observed in the San Emidio resource. At the close of the drilling period, USG observed higher temperatures in a new exploration area of the operating field, covering about one square mile. Analysis and evaluation are ongoing.

A patented laser technology is performing at commercial strength in the laboratory. The tool has been adapted for harsher geothermal downhole settings and will be field tested next year. *Source: Foro Energy*

Laser Innovations

Through a 50/50 costshare award, Foro Energy LLC is pioneering a laser technology that could decrease hard-rock drilling costs. The project passed a Go/No Go threshold in May and has successfully demonstrated well completion at lab-scale with its high powered laser tool.

This year, the company finalized the building and testing of the tool's core optical and power components. In 2015, Foro is tasked with commercializing the laser completion tool and preparing for a Phase II Stage Gate review—slated for May 2015—before moving into the final downhole field test.

A New Collaboration

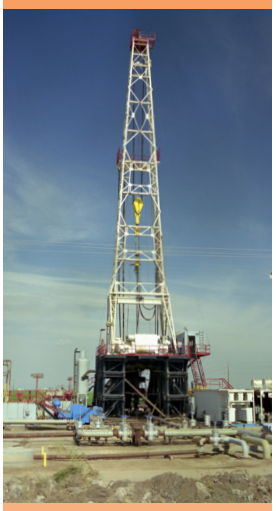
In the fall of 2013, GTO and the National Renewable Energy Laboratory (NREL) joined CSM to launch the Subsurface Research in Geothermal Energy (SURGE) collaboration, aimed at isolating opportunities for DOE to accelerate technology transfer and support adoption of petroleum best practices.

Together, NREL's experience in geothermal research and analysis and CSM's well-established expertise in petroleum engineering and oil and gas drilling are combining their research capabilities to advance geothermal R&D.

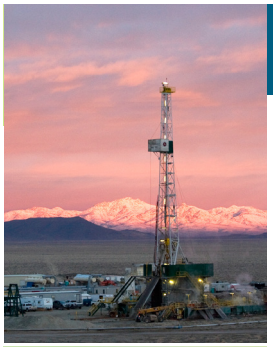
While the geothermal and petroleum industries share similar drilling and completion challenges, the petroleum industry holds a significant advantage in the scale of investment and wells drilled.

During the first year of this effort, SURGE addressed three projects: evaluating geothermal energy potential in sedimentary basins through numerical reservoir modeling; assessing oil and gas completion technologies used to create multi-zone hydraulic fractures in horizontal wells for their ability to adapt to geothermal settings; and conducting "perfect well analysis" on a set of real geothermal well construction records to help identify where petroleum technologies can make the most significant performance increases and/or cost savings for geothermal.

The second year of this effort will also include greater collaboration with SNL and its expertise in drilling systems. Detailed analysis will be published in 2015.



Geothermal production well in the Imperial Valley. *Source: NREL*



Geothermal drilling at Blue Mountain. *Source: GRC*

"The results will...provide a local, low-cost, sustainable energy source...and establish a reproducible pilot project adaptable to other volcanic island environments worldwide."

Mark Ziegenbein, GTO project officer, Akutan Exploration Project

Mark Ziegenbein, GTO project lead (far right), meets the Akutan exploration team during the environmental field assessment in the fall. Pictured from left are Mary Ohren, Geothermal Resource Group; Chris Hoffman, biologist and president of High Tide Environmental; Jeff Shively, environmental scientist with HDR Inc.; Sarah Meitl, archeologist, Cultural Resource Consultants; Haley Huff, masters student, Environmental Geology and Geochemistry at the University of Alaska, Anchorage; and Ziegenbein.

Clean Geothermal Could Displace Costly Diesel Power

As an isolated community along the Aleutian arc off southern Alaska, the City of Akutan comprises a modest population base and the largest commercial seafood processing plant in North America, with nearly 1,200 workers. Together, they rely on up to 4.5 million gallons of costly, imported diesel fuel to survive.

Exploration for geothermal energy on Akutan dates back to 2007 and includes field and geophysical surveys and temperature gradient well drilling. Despite earlier predictions, a new report issued by the USGS estimates 29 MW potential from geothermal resources beneath the Mt. Akutan Volcano.

In addition to historical investments in Alaska, DOE kicked off a project there in October with a site visit from GTO's Project Lead Mark Ziegenbein.

The project, slated for completion in 2016, will entail finding a drilling target and production well site in Hot Springs Bay Valley, drilling a resource confirmation well, flow-testing the geothermal resource, and assessing the probability of commercial production.

The team will then construct a comprehensive business strategy to attract investors.

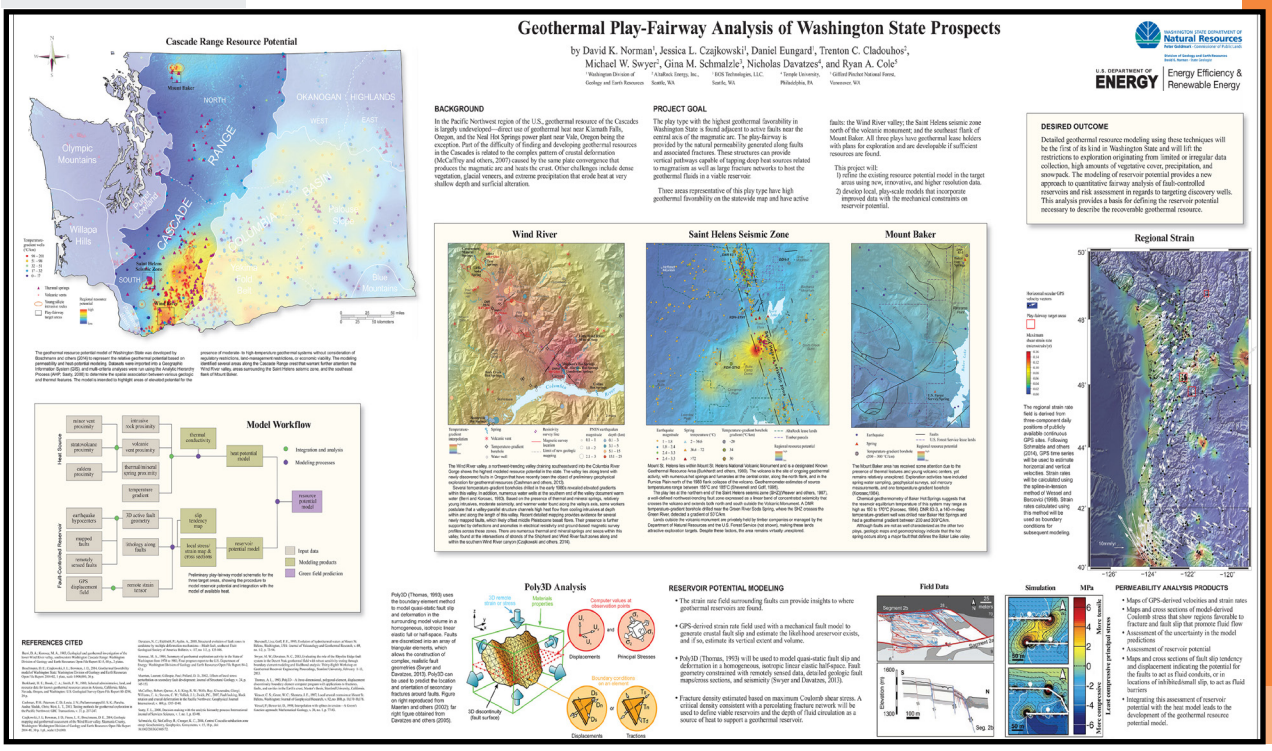
"This is just an excellent opportunity for GTO to leverage DOE project funds by partnering with the Alaska Energy Authority and the City of Akutan," Ziegenbein said. "The results will hopefully provide a local, low-cost, sustainable energy source for Akutan and establish a reproducible pilot project adaptable to other volcanic island environments worldwide."

Project Successes

Well testing at a geothermal development site (above) taps abundant, natural steam from the earth. *Source: GRC*

Natural geothermal steam generates electricity at The Geysers in California, the largest operating geothermal field in the world. *Source: Calpine Corporation*

See more innovations in the Hydrothermal portfolio on our website: http://energy.gov/eere/geothermal/hydrothermal



Check out the play fairway technical posters from each of our awardees online: http://energy.gov/eere/geothermal/downloads/play-fairway-analysis-poster-session

Fish cultivation is one application of natural geothermal heat, at work here at Klamath Falls, Oregon, where a cascade of uses for geo energy are underway. *Source: Laura Garchar*

The GTO team stopped for a tour of the Raft River Geothermal Plant in SE Idaho as part of the trip to Idaho National Laboratory. *Source: Laura Garchar*

Hydrothermal Team Visits Project Sites and National Laboratories

The Hydrothermal team traveled to three national laboratories in the fall of 2014. These laboratories are among a group of Federally Funded Research and Development Centers (FFRDCs) across the United States that have critical core capabilities.

Funded by GTO through Annual Operating Plan (AOP) funds, these projects assess technical and economic barriers currently facing geothermal development. Hydrothermal team members met with experts and toured facilities at Los Alamos, Sandia, and Idaho National Laboratories.

At ***Los Alamos National Laboratory (LANL),*** located in northwest New Mexico just below the rim of Valles Caldera, the team witnessed demonstrations of linear and non-linear acoustics. Motivated by the oil and gas industry, these acoustic improvements will facilitate better borehole communication, monitoring of fracture density and crack orientation, and manipulation of microseismic events.

Using ultrasonic pulses and low-frequency 3D imaging, this research at LANL can assist developers in locating subsurface geothermal reservoirs.

LANL's core mission is largely centered on U.S. national security and currently includes component and systems modeling, energy studies, and climate research.

GTO funds at the lab primarily support the geophysics group working on simulating complex hydrological, thermo-dynamic, mechanical, and chemical (THMC) modeling of interactions in fractured rock. The Hydrothermal program currently funds three projects at LANL. Under a 2011 competitively awarded R&D funding opportunity, LANL was funded to develop a novel 3-D elastic reverse-time migration-imaging technique aimed at improving fault zone imaging for geothermal exploration.

"Stimulation in our New Mexico labs has the potential to improve future geothermal drilling, We are eager to see the findings on these energetic materials."

Eric Hass, manager, DOE Geothermal Technologies Office Hydrothermal program

This project is nearing completion and will apply the technique to seismic data to verify improvements in imaging fault zones for its final task. LANL also received funding in late 2014 under two new program initiatives: play fairway analysis (PFA) and SubTER.

Sandia National Laboratories in Albuquerque, New Mexico houses a strong team of scientists and engineers on the cutting edge of drilling applications and downhole tool development for geothermal. During the site visit, Sandia demonstrated current work on downhole explosives and stimulation techniques, high-temperature and pressure tool development, lab-scale hydro-shearing tests, vibration suppression on drilling rigs, and percussive hammers.

Idaho National Lab (INL) in Idaho Falls, Idaho is located on the edge of the Snake River Plain in the basalt-covered southeast part of Idaho. In recent years, GTO funding has supported a collaborative effort between INL and LBNL to develop an understanding of spring geochemistry and identify geochemical indicators of resource potential. INL also works closely with a consortium of universities under the Center for Advanced Energy Studies where students, faculty, and researchers work together to study energy-related topics, including geothermal systems.

While in Idaho, the team also met with University of Utah researchers, who are undertaking a play fairway analysis of the Snake River Plain. In southeast Idaho, the team also toured Raft River, a geothermal power plant generating 10 MW and an active EGS demonstration site. GTO is currently contributing funding for well stimulation efforts there.

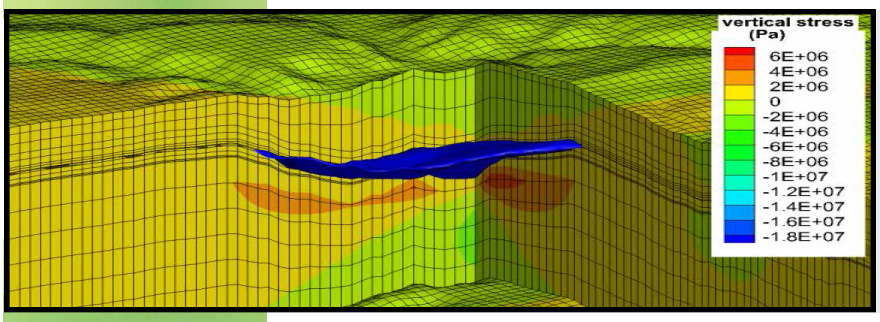
Hydrothermal team members Alexandra Prisjatschew and Laura Garchar (right) take in the view of Mt. Saint Helens in Washington state. *Source: Laura Garchar*

Klamath Falls Nursery (left), is heated by low temperature geothermal resources. *Source: Laura Garchar*

Hydrothermal Projects Underway in our National Laboratories

The Hydrothermal program currently oversees 22 R&D projects across our national laboratories, leveraging approximately $4.7 million in DOE investments.

Industry, academia, and our national laboratories undertake geothermal research, both in the laboratory and at field sites. At left, students collected transient electromagnetic survey data near Santa Fe, New Mexico during a summer study called the Applied Geophysical Experience (SAGE). *Source: Laura Garchar*



A GTO project designed to couple 3D waveform inversions and poro-elastic modeling capabilities is helping to minimize seismic risks in EGS stimulations while improving performance. *Source: Fugro Consultants*

> "With the subsurface crosscutting initiative, DOE is bringing together its Science, Fossil Energy, Environmental Management, Energy Efficiency and Renewable Energy, and Nuclear Energy programs into a coherent, coordinated approach to common challenges ..."
>
> Ernest Moniz, Secretary, United States Department of Energy

DOE Pursues Subsurface Research

Subsurface energy sources satisfy over 80% of total U.S. energy needs. DOE has convened a new crosscut team to address shared challenges in the subsurface, and GTO is playing a central role.

The Subsurface Technology and Engineering Research, Development, Demonstration and Deployment crosscutting technology team (SubTER) works collaboratively among different subsurface energy technologies to find and effectively exploit these resources and mitigate impacts of their use.

SubTER encompasses all the energy technologies that use the subsurface—for clean energy deployment (geothermal) and environmentally responsible management and disposal of hazardous materials and other energy waste streams (like CO_2 storage).

These priorities are critical components of the President's Climate Action Plan, necessary to meet the 2050 greenhouse gas (GHG) emissions reduction target. Increasing domestic energy supply from greater hydrocarbon resource recovery in a sustainable and environmentally sound manner is also an Administration goal that enhances national security and fuels economic growth. In fact, opportunities in subsurface technology and engineering have immediate connection to many societal needs.

The SubTER Crosscut identifies common research, development, and demonstration (RD&D) and policy challenges across DOE and enables energy technology programs to work together toward solutions.

The SubTER Crosscut reports to the Under Secretary for Science and Energy and leverages program budget priorities to better plan for investment and assistance.

SubTER partners include DOE programs and national labs, academia, industry, and other federal agencies.

DOE program and staff offices involved in the crosscut include: Fossil Energy, Energy Efficiency & Renewable Energy, Nuclear Energy, Environmental Management, Science, ARPA-E, Electricity Delivery & Energy Reliability, Energy Policy & Systems Analysis, Congressional & Intergovernmental Affairs, and the Energy Information Administration.

Mastering the subsurface for energy production and storage and for the management of energy waste streams constitutes an energy "grand challenge." To meet this challenge, DOE is implementing a new collaborative model

Current Activities

National Laboratory Early-Phase Research

Approximately $1.6M has been awarded to national laboratory teams by the GTO and the Office of Fossil Energy to begin work on crosscutting topics. These projects are envisioned to feed into broader program efforts in upcoming years:

Lawrence Berkeley National Laboratory (LBNL) will undertake an intermediate-scale hydraulic fracture and stimulation field laboratory in a deep mine to investigate induced seismicity and fracture flow.

Los Alamos National Laboratory is developing a novel 3D acoustic borehole integrity monitoring system.

Los Alamos National Laboratory will evaluate the state of stress away from the borehole.

National Energy Technology Laboratory is researching big data and analytics for induced seismicity.

Oak Ridge National Laboratory will work on a photo-stimulated luminescence spectroscopy stress sensor for in-situ stress measurement.

Pacific Northwest National Laboratory is developing a borehole muon detector for 4D density tomography of subsurface reservoirs, geophysics, hydrology, geochemistry, and biochemistry.

Experts Call for DOE Leadership

to address the following common subsurface challenges.

Discovering, Characterizing, and Predicting: using integrated geophysical and geochemical technologies to find viable, low-risk resources by quantitatively inferring subsurface evolution under current and future engineered conditions

Accessing: safe, cost-effective reservoir integrity

Engineering: creating/constructing desired subsurface conditions in challenging high-pressure/high-temperature environments

Sustaining: maintaining optimal subsurface conditions over multi-decadal or longer time frames through complex system evolution

Monitoring: improving observational methods to advance the understanding of multi-scale complexities through system lifetimes

In response to these challenges, SubTER is planning and implementing jointly funded targeted research, development, and field demonstrations (RD&D) in four pillars:

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

Visit the SubTER Tech Team website or download the SubTER fact sheet: http://energy.gov/subsurface-tech-team

A new report by an independent panel recommends that the DOE take a leading role in understanding sub-surface systems to better address the nation's energy and security issues.

JASON—a group of scientific thought leaders that has provided consultation to the U.S. government for over 50 years—undertook the study on behalf of SubTER during a summer study period that began with a day-long briefing series in La Jolla, California.

Members of the subsurface research community were invited to present state-of-the-art to JASON study members, who also visited the La Jolla cliffs to study the Eocene marine sedimentary rocks, stress-induced geologic structures, and heterogeneity in the field. These interactions provided the background that the JASON group built on during a month of analysis and writing that culminated in a finished report.

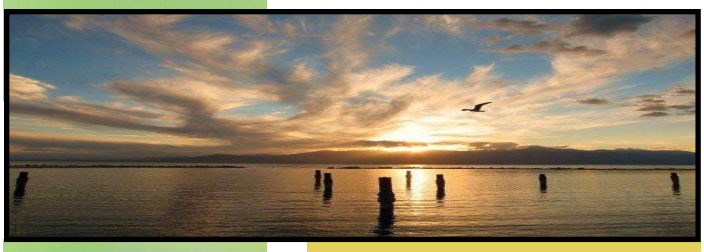
In the new 2014 study, JASON recommends that "DOE take a leadership role in the science and technology for improved measurement, characterization, and understanding of the state of stress of engineered subsurface systems in order to address major energy and security challenges of the nation." Successful utilization of the vast majority of U.S. energy resources fundamentally hinges on understanding and control of the state of stress and mechanical deformation of rocks in the upper crust. Examples include creating and sustaining fracture networks in EGS and unconventional oil and gas reservoirs; predicting and controlling geomechanical stability of reservoir rocks and seals in CO_2 storage reservoirs; and predicting geomechanical evolution at the interface between geologic media and engineered materials in nuclear waste storage and disposal settings.

New insights into characterizing the state of stress at key scales are needed to understand, predict, simulate, and monitor the dynamic response of the subsurface to changing stresses—fracture initiation and propagation and induced seismicity, for example.

The report considers existing methods and new opportunities for resolving the subsurface stress field. JASON recommends coordinated research and technology development at dedicated field sites to connect insights from laboratory scales and models to operational environments.

The group proposes "dense arrays of micro-boreholes… and sensor networks" and implies "a focus on rapid/inexpensive drilling as well as development of small, inexpensive sensors" deployed at existing field sites, abandoned boreholes, mines, or newly developed sites. Complementary laboratory analyses and advanced theory modeling and simulation will leverage DOE expertise and national lab facilities.

JASON study members stand on a basaltic dike exposure below the La Jolla cliffs while Professor Yuri Fialko of the Scripps Institution of Oceanography describes how its orientation is controlled by the stress field at the time of emplacement. *Source: Benjamin Phillips*



The Salton Sea, California is a fertile region for geothermal, and potentially mineral extraction. *Source: NREL*

"Investments in leading-edge geothermal technologies are diversifying our nation's energy portfolio today and could help power our low-carbon future tomorrow."

Douglas Hollett, Deputy Assistant Secretary, Renewable Power EERE, US DOE

Overview

Low temperature and coproduced resources represent a growing sector in the geothermal industry. Considered nonconventional geothermal resources below 150°C (300°F), these applications are bringing valuable returns on investment in the near-term, using unique power production and resource optimization methods. These resources—once chiefly used for direct use applications such as heating, fisheries, and industrial processes—can now also be used for power generation in the right conditions.

Simbol Materials, one of DOE's awardees, patented technology in collaboration with LBNL that has been successfully demonstrated at California's mineral-rich Salton Sea. *Source: Simbol*

Geothermal Brines Prove Valuable for Mineral Harvesting

In addition to supplying new applications for geothermal power, some geothermal brines are turning up relatively high concentrations of rare earth elements (REEs) and other valuable materials. To explore this potential, in August GTO Director Doug Hollett announced a new $4 million targeted initiative to discover viable, commercial pathways for combining geothermal power with mineral recovery from low-to-moderate temperature geothermal resources. Nine awards ranging from $250,000 to $500,000 were awarded under a 2014 funding opportunity announcement (FOA).

"Investments in leading-edge geothermal technologies are diversifying our nation's energy portfolio today and could help power our low-carbon future tomorrow," said Hollett. "These projects will spur the development of cost-competitive geothermal energy and help provide U.S. manufacturers with the critical materials they need to build clean energy technologies right here in the United States."

GTO selected projects that address extraction technologies and process economics; assess the current critical materials resource base; and research and develop innovative extraction methods. As project partners assess the potential to carve out viable, commercial pathways for this new industry, the result could optimize the value stream of producing energy from low-to-moderate temperature geothermal resources.

Southern Research Institute (SRI) will be working to develop an innovative geothermal thermoelectric generation system specially designed to extract high-value lithium from low-temperature geothermal brines while generating electricity. The proposed system will endeavor to provide large quantities of previously inaccessible baseload renewable electricity to the grid and a lithium recovery system that could decrease costs by 20%-50% over current state of the art.

SRI International will prepare advanced ion-exchange resins chemically designed to bind lithium and manganese ions. The objective of this project is to develop a new generation of highly selective, low-cost, ion-exchange resins that will separate metals from geothermal fluids more efficiently than current processes.

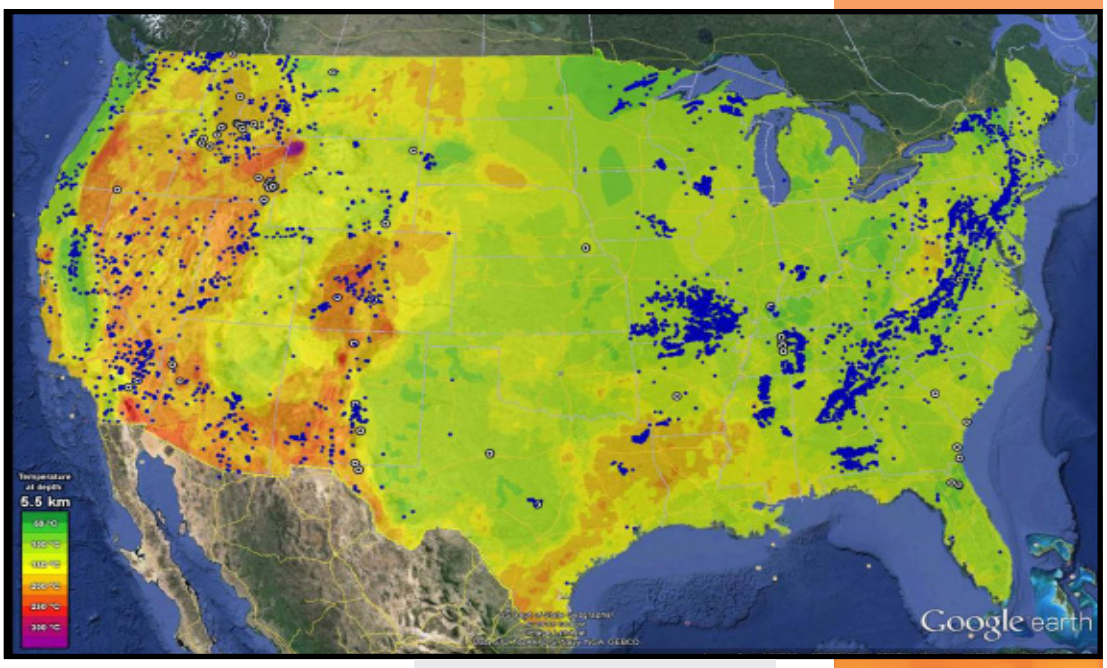
Lawrence Berkeley National Laboratory is working on an innovative technology that uses microorganisms to selectively bind valuable metals in geothermal brines. This novel process could help remediate

contaminated sites while extracting critical materials from operating fields.

The University of California seeks to provide high-quality data characterizing the content of geothermal brines from a range of U.S. geothermal fields. Research will focus on sampling sites across a range of geothermal systems to identify the factors influencing concentrations of valuable rare earth elements in geothermal fluids to allow industry to better target geothermal systems for pilot plant development. In turn, reducing uncertainty will boost investor confidence and stimulate investment by quantifying reward.

Pacific Northwest National Laboratory (PNNL) is developing a new class of nanofluid called metal-organic heat carriers to improve efficiency of low temperature geothermal power systems. This project will demonstrate a new nanofluid application that is a simple and cost-effective method for extracting rare earth metals from geothermal brines.

PNNL will also evaluate and utilize novel materials to collect rare earths, precious metals, and other critical materials from geothermal brines by performing an engineering and economic feasibility analysis on the viability of solid phase sorbent materials as a value-added proposition for geothermal systems.



DOE plotted concentrations of rare earths and other minerals, like lithium, zinc, and manganese used in electric vehicle batteries (in blue) on this geothermal heatflow map. *Source: Google Earth and Southern Methodist University*

Carnegie Mellon University will develop and test low-cost reusable resins for highly selective separation and recovery of rare earth elements from low temperature geothermal resources. The project aims to design and synthesize chemical binding agents for separation and recovery of critical materials from complex fluids. The lab testing will set the stage for potential follow-on, larger-scale testing with the highest performing resins.

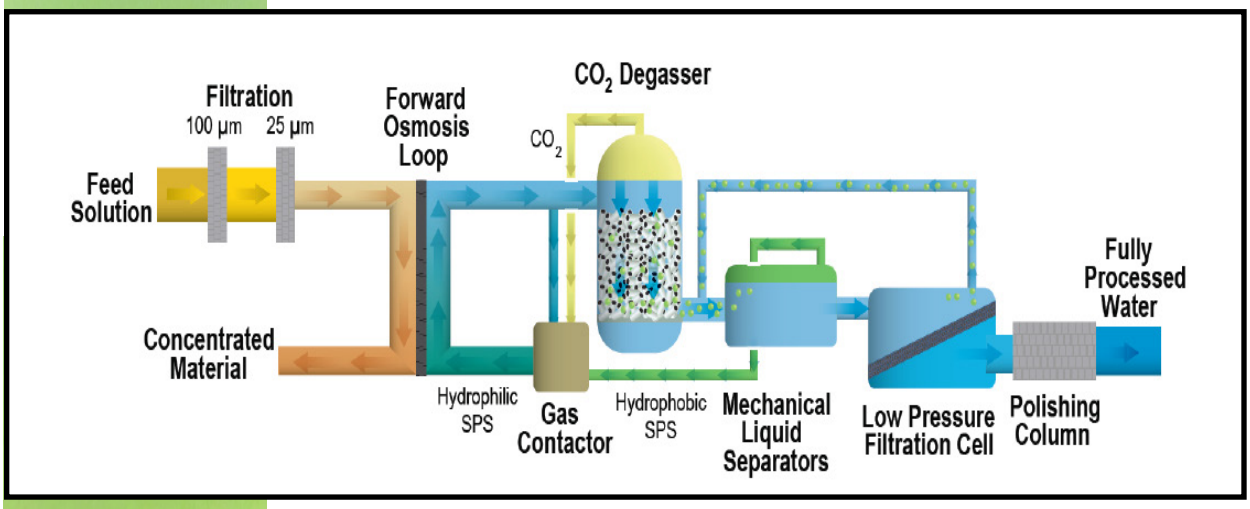
Simbol Materials will develop a database of rare earth element concentrations in U.S. geothermal waters and conduct research on extraction methods. A preliminary economic model of rare earth element production will also be completed.

Tusaar Corporation will use existing surveys and studies to identify suitable geothermal brines that contain viable concentrations of target metals and minerals, and will develop similar synthetic fluids in the laboratory. Tusaar's proprietary recovery agent will be tested to evaluate its metal sequestration capability.

A detailed techno-analysis will also be conducted to justify the use of this technology to support geothermal mineral recovery in conjunction with power generation.

"With political and environmental forces worldwide making it increasingly difficult to carry out conventional mining, this may well be how primary metal is produced in the future."

Jim Engsdahl president and CEO, Star Minerals, industry partner in the rare earths evaluation project at PNNL



Idaho National Laboratories is developing a novel technology to purify water, which could have dramatic effects on both drinking water availability and water access for industrial use. *Source: INL*

Novel Technology Purifies Water

The Idaho National Laboratories (INL) continued their efforts to evaluate the feasibility of switchable polarity solvent forward osmosis (SPS-FO) technology to purify the produced waters from oil and gas operations, and more specifically, the hotter produced waters that are considered lower temperature geothermal resources. Significant potential also exists for more traditional geothermal applications. Plant water consumption, for instance, could be reduced by recycling the blowdown from evaporative cooling. It could also be used to produce the makeup water for cooling systems. An intriguing probability exists that there could be sufficient energy in geothermal fluids to provide the required energy for these purification processes. INL is currently validating the potential to generate the required process energy from geothermal fluids, as illustrated above.

SPS-FO technology is promising. INL has already demonstrated the ability to extract purified water from a NaCl solution with a concentration 10 times that of seawater. By developing a model to simulate performance of the system, the lab can better assess the energy requirements of the process and provide initial estimates of costs and throughputs for consideration of future commercial viability of the technology.

The value of potable water varies across the nation. Findings this year indicate that costs would be about $0.57 per barrel (bbl) of product water. To put this in perspective, residential use currently ranges from $0.10 to $0.65 per bbl, while the cost for industrial usage is likely lower. This new technology would also reduce the amount of water requiring disposal. With produced water disposal costs varying between $0.30 and $105 per barrel, and disposal by injection reaching $10/bbl, the avoidance of disposing of the produced waters will likely drive the economics of using this technology in the near term.

Future work will refine the model and evaluate potential applications at conventional geothermal facilities that use evaporative cooling systems. SPS-FO technology could also enable evaporative cooling at plants that would otherwise rely on less efficient air-cooling because of the scarcity of water.

The Mammoth-Pacific geothermal power plants, in the Imperial Valley of southern California, draw on the natural geothermal resource close to the surface. Early DOE investments helped to harness this energy. *Source: GRC*

For more information about low temperature and coproduced Geothermal Resources, visit our website: http://energy.gov/eere/geothermal/low-temperature-and-coproduced.

Public-Private Collaboration Sparks Innovative Design

In April, DOE recognized Johnson Controls Inc. (JCI) for achieving a major milestone at the Oregon Institute of Technology (OIT), Klamath Falls. As the first campus in America to be heated by geothermal energy, OIT announced that it is boosting its use of clean energy this year, through JCI and Energy Department support. The Klamath Falls campus will utilize 1.75 MW of installed geothermal capacity combined with a 2 MW solar array, making OIT the first university in North America to generate most if not all of its electrical power from renewable sources.

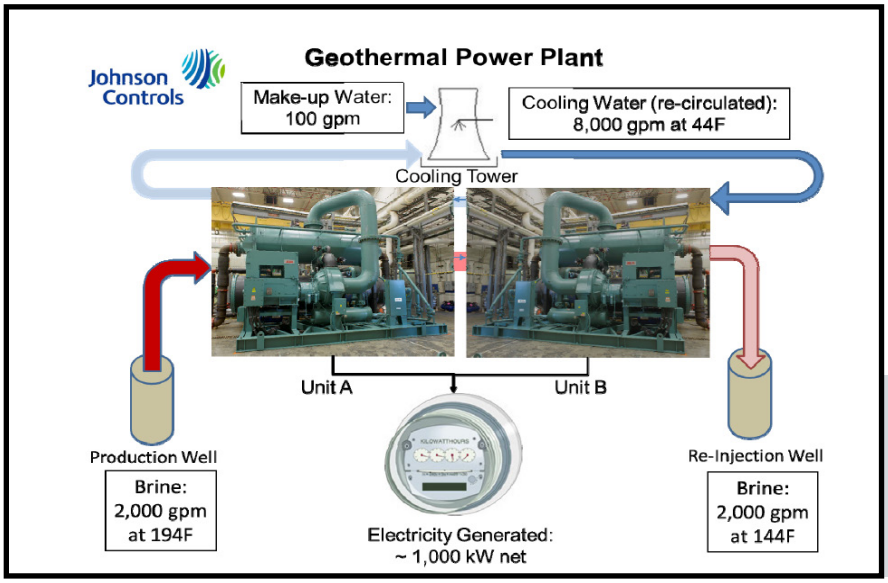
Energy Secretary Ernest Moniz applauded the effort. "The Department's investments at the Oregon Institute of Technology are another example of how partnerships with academia, industry, and the private sector can help cut energy waste and pollution while reducing energy bills," he said. "OIT's use of cutting-edge technology and its commitment to a clean energy future help diversify our energy supply while bringing us closer to the Administration's goal of doubling renewable energy for a second time by 2020."

A $1 million investment from Recovery Act funds, matched with a substantial $4 million costshare from JCI, enabled OIT to generate electricity at an estimated 20% cost savings over conventional binary systems. By developing an innovative technology, JCI leveraged previous work on the OIT campus to effectively demonstrate this novel, nearly emission-free application at Klamath Falls,

JCI's new technology converts low temperature geothermal heat to electricity by optimizing equipment size and modifying mass-produced, flexible commercial chilling equipment. "We targeted the design of the prototype to maximize replicability in different regions," said one official. Lower input temperatures are more widely available than high temperature geofluids, but they also pose more technical challenges. By successfully operating at lower cost and improving performance using lower geofluid temperatures, OIT enables a much wider swath of the country to access geothermal energy in many locations.

The school's Geo-Heat Center has been tapping geothermal to heat campus buildings for nearly 50 years. Beginning in 2008, Energy Department investments helped further geothermal development and supported the purchase of an initial 280 kilowatt (kW) geothermal power system. By 2010, the small binary unit was producing power for the school's facilities, and the groundwork was laid to utilize additional geothermal energy through an Energy Department investment of $3.5 million, with a matching costshare by the university.

Energy Department industry partner Johnson Controls Inc. commissioned another 1.75 MW of geothermal energy at Oregon Institute of Technology in 2014. *Source: Bill Goloski*



This schematic indicates key innovations demonstrated in the system at OIT. *Source: Johnson Controls*

> "The Department's investments at the Oregon Institute of Technology are another example of how partnerships with academia, industry, and the private sector can help cut energy waste and pollution while reducing energy bills."
>
> Ernest Moniz, Secretary, United States Department of Energy

Geothermal drilling at Blue Mountain. *Source: GRC*

Another Surprising Geothermal Benefit: Repurposing Oil & Gas Wastewater

In hydrocarbon production, some high water content wells can yield 10 barrels of water for every barrel of oil or gas they produce, which presents a challenge for operators. In fact, the high cost of excess fluid disposal—which ranges from 50 cents to several dollars per barrel—is one of the reasons many wells shut down. Repurposing wastewater from these wells to coproduce geothermal electricity could transform this burden into an asset.

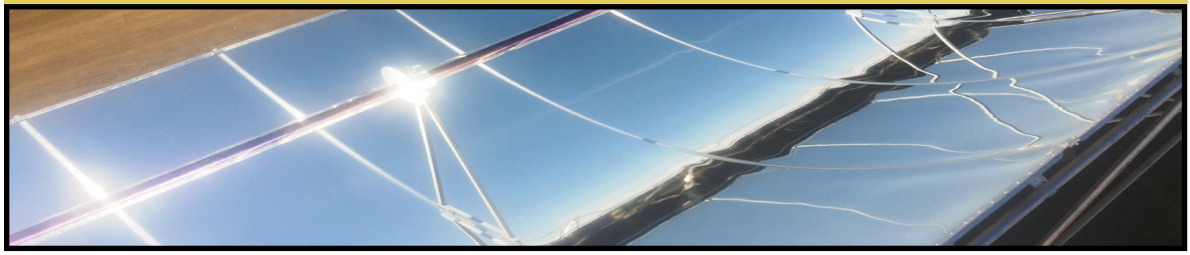
The costs of operating a geothermal plant vary widely based on the local circumstances. In favorable conditions, the total lifecycle cost of geothermal energy can be as low as $0.05/kWh, which is competitive with traditional power sources. The potential for this technology to offset some of the cost of produced water disposal could save the industry millions of dollars per year. When combined with the thermal water purification technology discussed on page 24, the results could be a game-changer for the oil and gas industry and beyond.

Optimizing Geothermal with Geo-Solar Hybrid Systems

DOE is exploring the potential of using hybrid applications to raise power plant outputs at low cost. During 2014, industry partner Enel Green Power—in collaboration with INL and NREL—began work to quantify the economic benefits of combining geothermal and solar thermal systems. Positive results could enhance deployment of these clean, renewable energy technologies in regions where the resources overlap. The research team is evaluating both the technical and economic aspects of hybrid power generation, by combining geothermal energy with concentrating solar technology. The work utilizes data from an operating hybrid plant at the Stillwater geothermal plant in Fallon, Nevada, where CSP was installed this year.

Modeled results achieved a 5% reduction in the levelized cost of energy (LCOE) by using a retrofit geothermal-solar hybrid plant. The magnitude of the results is highly dependent on resource productivity, power purchase agreement (PPA) penalties, solar collector array costs, and solar array installation parameters. The results also indicate that further savings are possible to the LCOE if reduced risk associated with the solar heat source translates to more favorable pre-operation project financing terms. Federal and state renewable energy incentives or tax credits could further decrease LCOE.

Hybrid systems are subject to any PPA penalties on the economics of the hybrid plant relative to the base CSP power plant. Additional work is planned to evaluate commercial opportunites and best alternatives for geothermal/solar hybrid systems.



The Stillwater geothermal plant is the first hybrid solar geo facility in the nation. In 2014 Enel Green Power added 2 MW of concentrating solar power to the existing geothermal plant and solar photovoltaic field, for a total installed capacity of 78 MW. *Source: Enel Green Power North America*

New Research Boosts Power Output

PNNL continues its development of innovative liquids called nanofluids—with the potential to boost power generation in thermal vapor-liquid compression cycles, such as those used in Organic Rankine Cycle plants. This technology uses nanostructured metal organic heat carriers (MOHCs) within the biphasic fluid to extract more heat from the geofluid in the heat exchanger, which can then be released in the turbo-expander, creating more power. A key advantage of this new type of material is that it does not require major modifications to existing operating equipment or conditions, cutting down on additional development and operating costs. Another benefit is that the process may boost efficiency in power output by up to 15%. Cost analysis for commercial-scale production of the MOHC nano-fluid prototype—applied in three different Organic Rankine Cycle systems—shows payback periods in as little as a few weeks. PNNL completed a preliminary commercialization plan for this technology in the fall and currently has a patent pending. Further collaborations with universities and industry are being pursued.

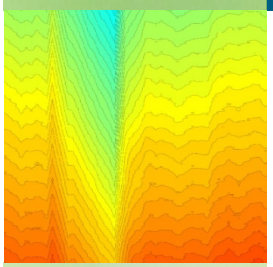
Exploration drilling at Newberry Volcano. *Source: AltaRock Energy*

Active Project Management

Arlene Anderson, technology manager for GTO's systems analysis and low temperature program, completed a project assessment site visit in November at the Carnegie Mellon University (CMU) for the new mineral recovery project, ***Chelating Resins for Selective Separation and Recovery of Rare Earth Elements from Low Temperature Geothermal Water***. The visit was conducted in accordance with *DOE Active Project Management* standard procedures and EERE guidance for the purpose of forming an opinion on the general performance of the project. At the CMU Campus in Pittsburgh, Pennsylvania, Ms. Anderson met with the prime CMU recipient Dr. Karamalidis and the co-principal investigators of the project research team. The team toured both the Civil and Environmental Engineering Laboratory facilities as well as the Chemistry Department Laboratory facilities, fostering cross-departmental coordination. From the discussion and presentations at the meeting, Arlene concluded that clear and significant progress has been made in a short time as positive preliminary results from a functionalized resin was a primary point of review. CMU completed synthesis of three functionalized resins ahead of schedule and has optimized a testing method. In addition, the visit included meetings with the Senior Contracts Officer Matt Bartman; Director of Finance and Administration Cathy Schaefer; and Sponsored Research Administrator Beth Ann Hockenberry to discuss project reporting requirements and payment processing.

A Strategic Materials project site visit to Carnegie Mellon University. From left: Dr. David Dzombak, CMU department head, *Civil and Environmental Engineering*; Arlene Anderson, DOE technology manager; Dr. Newell Washburn, CMU *Department of Chemistry*; and Dr. Athanasios Karamalidis, principal investigator and CMU assistant research professor, *Department Civil and Environmental Engineering.*

Data Mining is Uncovering Hidden Geothermal Potential



Data like this thermal gradient map are now available free online through the National Geothermal Data System. *Source: 2013 Peer Review*

In support of the Administration's Open Data Policy making data more accessible to entrepreneurs and the public, Energy Secretary Ernest Moniz announced the official deployment of the National Geothermal Data System (NGDS) in 2014.

This online geoscience tool serves as an open-source data platform for researchers, academia, and industry to increase exploration, development, and usage of geothermal energy by providing access to quantifiable, technical data in digital format. NGDS faces down one of industry's greatest barriers to development and deployment of this promising clean energy source.

This free digital tool encompasses thousands of databases, geologic maps, and reports, drawing from millions of digitized records that were previously unavailable electronically.

The NGDS can aid discovery of new data on geologic features, faults, seismicity, heat flow, geochemistry, drilling, and temperatures at various depths and in specific geographic areas. Already, industry is using the free, online tool to simulate geological features beneath the Earth's surface.

All DOE-funded geothermal projects submit cutting-edge research data to the network through a dedicated interface called the Geothermal Data Repository. The NGDS conforms to the U.S. Geosciences Information Network protocols, a joint undertaking of the United States Geological Survey and the Association of American State Geologists. The framework also uses the same free content management system as Data.gov, making geothermal data fully transparent to researchers and developers. Find out more at geothermaldata.org.

U.S. Department of Energy GDR Geothermal Data Repository

Secretary Ernest Moniz spoke at the White House Datapalooza in May, announcing deployment of the National Geothermal Data System. *Source: Energy.gov*

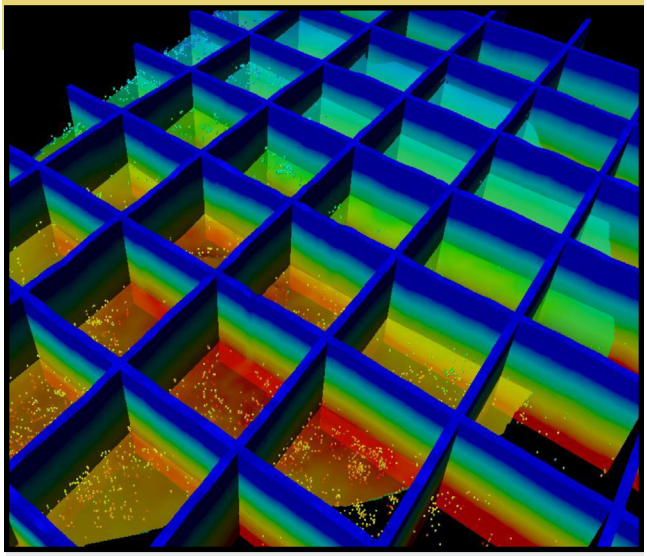
Network Sustainability

With the successful deployment of this data tool in 2014 and the establishing of a non-profit—USGIN Foundation, Inc. at usgin.org—the NGDS has sustainability going forward. GTO envisions that the data network and its growing library of geothermal knowledge will entice users to maintain the system. Like a data equivalent to the World Wide Web, this data network could become so useful to the geoscience community that it will be expected to be maintained by its clientele. This vision also opens the door for additional data providers external to geothermal development, increasing the value of the NGDS and its underlying data integration platform.

How the NGDS is Helping to Advance Industry

In response to industry demand for better scientific data about the subsurface, this mammoth resource of geoscience information—nine million datapoints and growing—represents critical subsurface information from all 50 state geological surveys and enough raw data to pinpoint elusive sweet spots of geothermal energy deep in the earth. This best-in-class data collection and usability effort supports DOE's intention to reduce cost and risks associated with widespread adoption of geothermal energy. A dedicated node on the system—the DOE Geothermal Data Repository—also collects data from all DOE-funded projects in the geothermal sector.

Already, NGDS data, free and publicly accessible, is providing tangible value to the subsurface community. Schlumberger, a global industry leader serving the oil and gas sectors, for example, was able to make better drilling decisions because of raw temperature data supplied to the NGDS.



In this data visualization, Schlumberger utilized bottom hole temperatures from the NGDS platform to supplement subscription data temperatures used to create basin-wide 3D temperature models in Petrel Exploration and Production software. *Source: Schlumberger*

Arlene Anderson, DOE project lead on the NGDS, receives the Geothermal Energy Association's *GEA Honors Special Recognition Award* for outstanding achievement in the geothermal industry from Executive Director Karl Gawell.

Winning Access to Earth Science Data

At the 2014 National Geothermal Summit, the Geothermal Energy Association recognized GTO Technology Manager Arlene Anderson for the overarching leadership she provided in managing the National Geothermal Data System.

Since 2009, the Energy Department's Recovery Act initiative has funded $33.7 million for multiple data digitization and aggregation projects focused on making vast amounts of geothermal-relevant data available to industry for advancing geothermal exploration and development.

These projects, led by Anderson, comprise the scope of the NGDS in an effort to lower the levelized cost of electricity (LCOE) by reducing risk in the subsurface.

"The goal over time is that the NGDS will reach a 'tipping point' at which it becomes self-sustaining because it is collectively viewed as filling a critical need."

Arlene Anderson, DOE Technology Manager, National Geothermal Data System

Elisabet Metcalfe (left), project lead on the National Geothermal Student Competition, smiles as GTO Director Doug Hollett presents University of Texas – Pan American with their plaque and awards. Student winners, from left, are Erica Balderas, Team Lead Jacob Garza, and Jose Cazares. *Source: Sharon Cosgrove*

Top Honors

Phil Ulibarri, this year's first-place winner in the National Geothermal Student Competition, is no ordinary student. His passion for geothermal and renewable energy have driven him back to school while sustaining a career in communications.

"I had to get good grades," Phil laughs. With his own kids in college, he couldn't afford to set a bad example.

To win top honors, Ulibarri created a colorful infographic and outreach campaign that resulted from

"If we're going to make any difference in society, we have to start with the earliest denominator, which is our children."

Phil Ulibarri, first place winner, 2014 National Geothermal Student Competition

Student Competitions Spark Interest in Geothermal Careers

GeoEnergy is Beautiful

DOE announced the 2014 winners of the National Geothermal Student Competition and the Geothermal Case Study Challenge in October, at an industry gathering in Portland, Oregon.

These competitions challenged college and university students to develop professional business solutions for public outreach as well as case studies that could help industry more accurately pinpoint geothermal resources in subsurface areas across the United States.

The winning student teams—from Truckee Meadows Community College in Reno, Nevada and Colorado School of Mines in Golden, Colorado—demonstrated exceptional rigor in their research and useful interpretation of technical geothermal concepts.

DOE's National Geothermal Student Competition (GSC) seeks students interested in building and showcasing scientific research, communication and leadership skills to convey the role of geothermal energy as an important contributor to the nation's clean energy future.

This year's event, *GeoEnergy Is Beautiful 2014*, focused on a non-technical barrier to geothermal development: public communications. Energy production can be a complex topic to explain to a broad public audience, and describing energy that comes from a subsurface environment—difficult to visualize for many—amplifies the challenge of explaining geothermal energy, how it works, and how it can benefit consumers. GeoEnergy Is Beautiful encouraged teams to focus on a non-technical deployment barrier: communicating the benefits of geothermal energy. The contest challenged students to create innovative infographics using publicly available data, scientific understanding, and graphics, and to develop an associated outreach strategy. Winners of the 2014 competition were announced in September.

1st Place	**Truckee Meadows Community College**
2nd Place	**University of Texas – Pan American**
3rd Place	**University of Mississippi**

interviews with the educational community and policy leaders. His slogan, "Geothermal energy is always renewing, never polluting," is accessible to all ages.

Initially Ulibarri targeted his graphics to kindergarten and first grade, creating an animated graphic of a dinosaur circling the globe with the message: "Mother Earth and geothermal energy were here before the dinosaurs, and they will give us heat forever."

He expanded a component to reach middle and high school students and feels strongly that passing on the significance of sustainable energy and a clean environment at an early age will empower kids to make clean energy choices in the future. It all begins in the classroom, he says. To view the graphics that won Ulibarri first place and a gallery of poster infographics, visit the GTO website: http://energy.gov/eere/geothermal/national-geothermal-student-competition.

Phil Ulibarri (center), from Truckee Meadows Community College, took home first place in the 2014 National Geothermal Student Competition. With him is Turguy Dogan, Pathway Specialist at the college. *Source: GRC*

Geothermal Case Study Challenge

GTO hosted a second student competition in 2014 in exploration research to engage students pursuing STEM careers and, ultimately, to aid in the next discoveries of geothermal energy development.

Over the course of the spring semester, student groups at participating universities produced a series of well-researched case studies detailing the exploration, development, and geologic history of selected U.S. known geothermal resource areas in tandem with college and university classes.

Case studies produced by each student group will be added to the existing collection of data currently available on NREL's Open Energy Information (OpenEI) platform. The new data collected will contribute to a set of exploration best practices for evaluating future geothermal prospects and delineating between resources with similar conceptual models.

NREL seeks professors interested in supporting the challenge by structuring their geothermal energy coursework and assessments around the case study project.

Student groups that produce the highest quality case studies are awarded paid travel to present their work in a poster session at the largest geothermal industry gathering in the nation. The top three student teams in the 2014 academic year were:

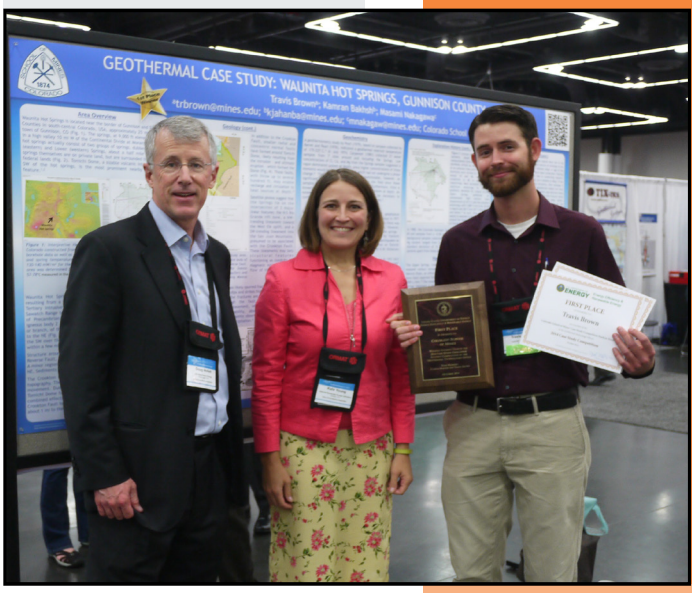
1st Place
Colorado School of Mines,
covering the Waunita Hot Springs Geothermal Area in Colorado

2nd Place
University of North Dakota,
covering the Mt. Princeton Geothermal Area in Colorado

3rd Place
University of North Dakota,
covering the Lightning Dock Geothermal Area in New Mexico

Visit the Geothermal Case Study Challenge online: http://en.openei.org/wiki/CSC/

Kate Young (center) at NREL managed this year's Case Study Challenge. Here, she and Director Doug Hollett congratulate First Place Winner Travis Brown, with the Colorado School of Mines. *Source: Sharon Cosgrove*



Benjamin Phillips, science advisor to the GTO team, taught geothermal science to middle and high school teachers in 2014. *Source: Sharon Cosgrove*

"I feel I now have sufficient background knowledge to comfortably explain and give relevant context on geothermal energy," shared one educator following training.

Teaching the Teacher about Geothermal Energy at the Smithsonian Center

The Smithsonian's Science Education program offers a weeklong energy academy for teachers each summer dedicated to responsible, alternative energy production. This year, middle and high school science teachers from around the United States engaged with professional scientists and engineers, where they learned and discussed renewable and clean energy options. In addition to inquiry-based learning sessions, teachers also enjoyed collections, exhibits, science research, and lectures.

Benjamin Phillips, science advisor to the GTO, devoted an afternoon to the program to present on the geothermal energy topic and provide educators with practical teaching tools they can take back to the classroom. Like the proverbial pebble in the pond, exposing science teachers to this level of understanding on energy technologies not only equips them to better teach on the topic, but also increases the caliber of engagement that their students will take away from this unit.

Phillips' presentation to this target audience made an impression. "I enjoyed the geothermal session," said one teacher, who said he will "work it into future lesson plans." "I'm excited to bring back the information on geothermal processes to enhance my energy unit in class," said another.

"I feel I now have sufficient background knowledge to comfortably explain and give relevant context on geothermal energy," shared a third.

Renewables for Future Generations

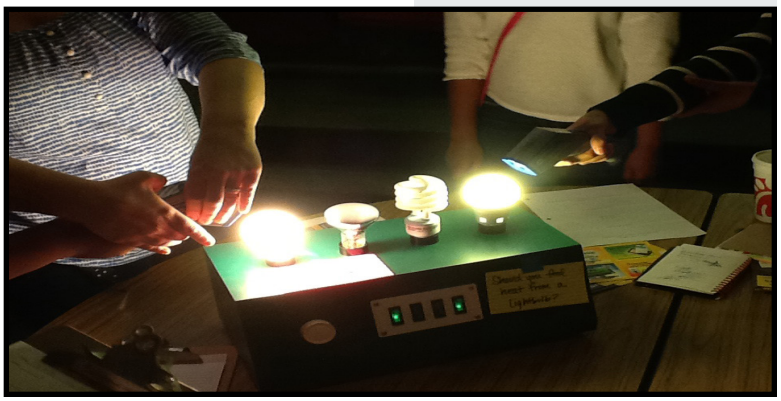
For a second straight year, GTO Communications Specialist Sharon Cosgrove shared a day with 300 sixth graders at Old Mill Middle School North in Pasadena, Maryland.

The Renewable Energy assembly featured mini-lab stations, where student teams experimented with renewable energy options and energy efficiency. Cosgrove and colleagues—Josh Sneidemann, a middle school science teacher on loan to DOE as EERE's esteemed Einstein fellow, and Erin Twamley, project and web manager for EERE's Education & Workforce Office—spoke briefly on geothermal, solar, wind, and water energy technologies. Then the students rotated between labs, and young scientists discovered for themselves the challenges and rewards of renewable energy.

Cosgrove led a hands-on, student-directed geothermal experiment on carbon reduction.

Learn more about education initiatives at http://energy.gov/eere/geothermal/education.

Sixth graders at Old Mill Middle School North measure efficiency in light bulbs during an assembly with Energy Department staff. *Source: Old Mill*



Student Scholarship Recipients Pursue Geothermal Studies

Roche, Recipient

In recognition of the University of Rochester's success in the 2013 National Geothermal Student Competition, GTO awarded a ***Geothermal Studies Scholarship***, administered by the Oak Ridge Institute for Science and Education, to ***Aurelie Roche***. Roche plans to use the award to conduct research in seismic activity related to geothermal energy production, at field sites and in the laboratory.

An online graduate course through Stanford University inspired Roche to pursue further geothermal research. The reservoir mechanics course helped her understand how industry addresses a number of the problems that transpire when exploiting oil and gas reserves.

Roche, who began her research this fall alongside her mentor, Cynthia Ebinger, Ph.D., determined to focus on reducing seismic activity in large-scale geothermic projects.

"When fluids are pumped into or out of the Earth, it can cause waves of seismic activity, which alarm many people and cause damage to buildings," she explained. To explore how to lower the risk of seismic activity, Roche will study the delicate balance between fluid injection and extraction at field sites.

Aurelie Roche, a rising junior in chemical engineering at the University of Rochester, was the undergraduate recipient of the 2014 U.S. Department of Energy Geothermal Studies Scholarship in 2014.

Brink-Roby, Recipient

David Brink-Roby applied for the Geothermal Studies Scholarship after he and his team won the 2013 DOE National Geothermal Student Competition for the University of Rochester. The team's submission subsequently took first place, earning the school two scholarship awards.

Brink-Roby received the DOE scholarship in early 2014, at a crucial point in his research. "To begin my project, I needed to collect preliminary data in the field. Specifically, without this scholarship, it would have been difficult or impossible for me to gather the data I needed to support any application for larger grants, such as the National Science Foundation grant."

Brink-Roby studies fluid flow through rock in relation to large-scale geologic structures, specifically within the foothills of Idaho, Wyoming, and Utah.

These foothills are the eroded remains of a much larger mountain belt, and contain rock outcroppings that expose structures formed 80 million years ago. Originally, these structures were tectonically buried to a depth of 2 to 12 kilometers and had super-heated fluids flowing within them.

Through his research, Brink-Roby attempts to answer questions about the origin of these fluids, where fluid flow occurred within the mountain belt, and how long fluid conduits persisted.

David Brink-Roby and his team won the National Geothermal Student Competition in 2013, earning his school the Geothermal Studies Scholarship for the following year.

> "Without this scholarship, it would have been difficult or impossible for me to gather the data I needed ... for larger grants."
>
> David Brink-Roby, 2013 NGSC winner and scholarship recipient

Surface manifestations like this mudpot are clues that a heated water chamber exists in the subsurface. Today, many of these resources have been identified. Geologists must find "blind" geothermal resources, where the thermal resource is hidden deep within the earth. *Source: GRC*

Regulatory and Permitting Toolkit

In the past, uncertainty regarding the duration and outcomes of the permitting process has been a deterrent for investment in renewable energy projects, contributing to delays in construction of geothermal power plants.

Reducing the permitting time, or reducing the number of required permits, can significantly lessen total project costs and investor risk while encouraging clean energy developments.

The Regulatory and Permitting Information Desktop (RAPID) Toolkit offers one location for agencies, developers, and industry stakeholders to collaborate in a wiki environment on renewable energy regulatory processes, including permit guidance and regulations.

With the success of the project in 2013, NREL expanded its Geothermal Regulatory Roadmap to encompass solar and bulk transmission regulatory environments as well. The RAPID Toolkit team has also identified a set of best practices for efficient permitting. The tool hosts a number of best practices including helpful resources in site descriptions, case studies, process templates, and how-to information.

Acronyms

ANL	Argonne National Laboratory
ARPA-E	Advanced Research Projects Agency - Energy
ARRA	American Recovery and Reinvestment Act of 2009 (Recovery Act)
BNL	Brookhaven National Laboratory
CO_2	Carbon dioxide
CSM	Colorado School of Mines
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOE-GDR	Geothermal Data Repository - DOE's node on the NGDS
EERE	Office of Energy Efficiency and Renewable Energy
EGS	Enhanced Geothermal Systems
FOA	Funding Opportunity Announcement
FORGE	Frontier Observatory for Research in Geothermal Energy
FY	Fiscal Year - October 1 through September 30
GEA	Geothermal Energy Association (industry associaiton)
GP/GT	Geopressured-geothermal
GRC	Geothermal Resources Council (industry association)
GRR	Geothermal Regulatory Roadmap (also known as RAPID)
GSC	National Geothermal Student Competition (also NGSC)
GSHP	Ground source heat pump
GTO	Geothermal Technologies Office
GWe	Gigawatt (electric)
IET	Innovative exploration technologies
INL	Idaho National Laboratory
JASON	A renowned group of scientists that perform independent analysis
kHz	Kilohertz
kWe	Kilowatt (electric)
kWh	Kilowatt-hour
LBNL	Lawrence Berkeley National Laboratory
LANL	Los Alamos National Laboratory
LLNL	Lawrence Livermore National Laboratory
LCOE	Levelized cost of electricity
MEQ	Micro-earthquake
MIT	Massachusetts Institute of Technology
MOHC	Metal Organic Heat Carriers
MWD	Measurement while drilling
MWe	Megawatt (electric)
NEPA	National Environmental Policy Act of 1969
NGDS	National Geothermal Data System
NREL	National Renewable Energy Laboratory
O&G	Oil and gas industry
ORISE	Oak Ridge Institute for Science and Education, a DOE institute
ORNL	Oak Ridge National Laboratory,
PNNL	Pacific Northwest National Lab
R&D	Research and development
RD&D	Research, development, and demonstration
RAPID	Regulatory and Permitting Information Desktop Toolkit
RSF	Research Support Facility (Colorado)
SBIR	Small Business Innovation Research program
$scCO_2$	Supercritical carbon dioxide
SiC	Standard industrial classification
SNL	Sandia National Laboratories
SPS-FO	Switchable polarity solvent forward osmosis, a technology under development to purify produced waters from oil and gas operations
SubTER	Subsurface Technology and Engineering Research, Development and Demonstration crosscutting initiative at DOE
SURGE	Colorado Subsurface Research for Geothermal Energy
USGIN	U.S. Geosciences Information Network (foundation governing NGDS)
USGS	U.S. Geological Survey
VSP	Vertical seismic profile

Tools & Resources

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

Reports

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

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

Low-Temperature, Coproduced, and Geopressured Geothermal Technologies—Strategic Action Plan—A strategic look at the growing low-temperature sector

Peer Review Presentations—Complete collection of technical presentations from GTO's 2013 Peer Review: http://energy.gov/eere/geothermal/annual-peer-review-meeting

Geothermal Technologies Market Trends Report—An updated snapshot of the geothermal market: http://www1.eere.energy.gov/geothermal/pdfs/market-report2013.pdf

GTO 2013 Peer Review Technical Report—Comprehensive final report summarizing GTO's 2013 Peer Review: http://www1.eere.energy.gov/geothermal/pdfs/2013-gto-peer-review-report-lowres.pdf

Latest GTO presentations—http://energy.gov/eere/geothermal/presentations

JASON Study on EGS—A report conducted by the JASON group on EGS

JASON Study on Subsurface Technologies—Findings from a study on subsurface technologies

Tools

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: nrel.gov/gt_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: http://en.openei.org/wiki/RAPID/Roadmap/Geo

GETEM Geothermal LCOE—The Geothermal Electricity Technology Evaluation Model (GETEM) is a detailed model of the estimated performance and costs of currently available U.S. geothermal power systems: geothermal.energy.gov/geothermal_tools.html

JEDI—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

National Geothermal Data System—Officially deployed in 2014, the NGDS has already collected millions of datasets from state geological surveys and other sources: geothermaldata.org

Find answers to the most frequently asked questions and more resources at http://energy.gov/eere/geothermal/geothermal-basics

DOE's EGS Demonstration at The Geysers in California was the first in the nation to prove a commercial scale 5 MW equivalent of steam. *Source: Calpine Corporation*

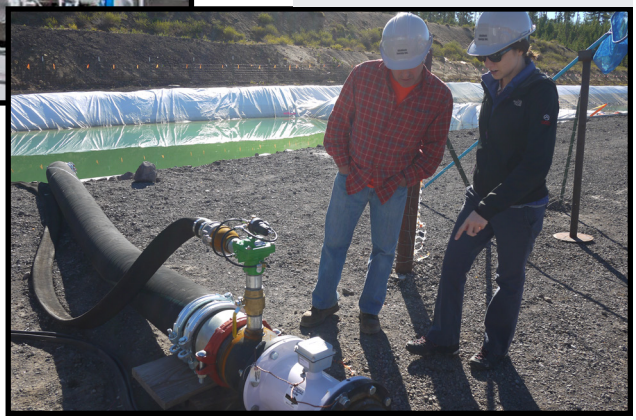
PEOPLE

Arlene Anderson stands before the Big Obsidian Flow at Paulina Peak, Newberry Crater, Oregon, with Juliet Newson, executive director of the International Geothermal Association. Anderson and others toured the site as part of a GRC field trip to the Energy Department's EGS demonstration project, a public-private partnership with AltaRock Energy at Newberry Volcano. *Source: Arlene Anderson*

Eric Hass, Hydrothermal program manager, pauses to capture geothermal surface expressions at Yellowstone with team members Laura Garchar and Holly Thomas during a field site visit this fall. *Source: Laura Garchar*

The Hydrothermal team takes a flowtest sampling at Crank Spring in the Raft River geothermal field, Idaho. *Source: Laura Garchar*

EGS Program Manager Lauren Boyd (right) meets with industry partner AltaRock Energy at the DOE EGS Demonstration at Newberry Volcano, Oregon. *Source: Elisabet Metcalfe*



During a recent trip to the Beowawe Geothermal Power Station in Nevada, Tim Reinhardt, program manager for the Low Temperature and Coproduced Resources Program, inspects a low-temperature geothermal plant that takes advantage of resources not traditionally considered commercially viable. DOE investments helped to enable development of this technology. *Source: TAS Energy*

A Fond Farewell ...

Doug Hollett was promoted to **Deputy Assistant Secretary for Renewable Power** in November to provide direction and leadership to the Solar, Wind and Water, Geothermal, and Grid program offices for DOE's **Office of Energy Efficiency and Renewable Energy (EERE).** In his role directing new technologies in the geothermal office, Hollett advanced geothermal's role in the U.S. energy portfolio, and most recently, secured unprecedented support and funding for the Office's FORGE initiative and new technical project portfolio in FY14. He draws on 30 years experience in oil and gas energy production, where he directed unconventional new ventures, including new global opportunities in shale gas and tight oil reservoirs.

Greg Stillman has taken on a joint degree at Stanford University in *Environment and Resources*/MBA. Stillman worked with the geothermal office for five years, overseeing projects in the EGS portfolio and representing geothermal interests in a CO_2 crosscutting initiative at DOE.

Benjamin Phillips has launched off to a new position as program manager for the Earth Surface and Interior focus area at NASA. This is the solid-Earth research program for NASA, which covers Earth science from crust to core, based on satellite and other remote sensing observations. While in the geothermal office, Phillips served as science advisor with SRA International, overseeing projects in the EGS portfolio and leading a new crosscutting initiative among energy technologies that use the subsurface.

Jodi Deprizio began a new job with Time Warner/Comcast Cable that involves sifting through big data with the goal of enhancing sustainability in the telecommunications sector. Deprizio applied her background with the USGS to establishing new resource maps for the geothermal office and supporting the systems analysis task as the data provision analyst with SRA International.

EGS Program Manager Lauren Boyd (left) and team member Elisabet Metcalfe take in the view atop Newberry Volcano, the site of a DOE EGS demonstration project. *Source: Elisabet Metcalfe*

Casa Diablo in the California Sierras holds an abundant geothermal resource that has been tapped for electricity production. *Source: Bob Sullivan/GRC*

… and Welcome, New Team Members!

Christine Bing brings extensive experience to GTO as a senior program analyst in the Solar Technologies Office. She has worked with 10 other EERE programs, including the Industrial Technology Program and the Office of Project Management. She gained management experience working with a portfolio of energy-related and international projects. Bing is acting operations supervisor for GTO, on detail.

Laura Garchar is a Science and Technology Policy Fellow through DOE's Institute for Science and Education at Oak Ridge, Tennessee (ORISE). She has a B.S. in Geological Engineering from the University of Nevada, Reno, and a MS in Geology from the Colorado School of Mines. Garchar conducted geothermal research and exploration in the western United States, gold exploration in Nevada, and environmental consulting in southwest Montana before joining GTO this summer. In 2014, she has been focusing on hydrothermal projects, particularly play fairway awards, but is also involved in other GTO efforts.

After supporting GTO on the Sentech/SRA team for multiple years as an integral part of the EGS Team, **Elisabet Metcalfe** transitioned to GTO's federal staff. Metcalfe and the EGS team worked tirelessly in 2014 on the FORGE funding solicitation. In addition, she manages projects in the EGS portfolio and served as the project lead on the Geothermal Student Competition in 2014. Congratulations to Metcalfe on this exciting new chapter in her career!

Alexandra Prisjatschew started with the Golden Field Office in January 2014, where she supports GTO as a senior project engineer with CNJV Contractors. Prisjatschew studied geological engineering at the South Dakota School of Mines and has a diverse background in oil and gas, mining, and geotechnical engineering. She looks forward to meeting and working with more of the project recipients in 2015!

Holly Thomas joined GTO in 2014 as a technical project officer managing hydrology and critical materials projects. She joined DOE in 2008 to manage R&D in solar energy, standards and codes, and system integration. Prior to DOE, she managed R&D efforts in distributed generation and solar energy at NREL and conducted project evaluation and economic analysis of prospective projects, both in geothermal energy and precious metals, for private industry.

GTO Leadership

JAY NATHWANI, ACTING DIRECTOR

JAY.NATHWANI@EE.DOE.GOV

Nathwani's diverse portfolio includes international and policy issues and levelized cost of electricity analysis, He has been with DOE since 1991, starting at the Idaho Operations Office and moving to the Golden Field Office before coming to headquarters in D.C., where he managed a $400 million Recovery Act portfolio for the geothermal office. In addition to acting as GTO's director, Nathwani has an M.S. in mechanical engineering from California State University at Fullerton and a B.S. in mechanical engineering.

ERIC HASS, HYDROTHERMAL PROGRAM MANAGER

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Hass supervises the hydrothermal portfolio for the Office, including innovative exploration technologies and low-temperature and coproduced resources. Prior to this, he managed the EGS program for two years and has worked with DOE EERE since 1993 and GTO since 2004. Eric brings over 30 years of experience in oil and gas, mineral exploration, and renewable energy project/program management to the team.

LAUREN BOYD, EGS PROGRAM MANAGER

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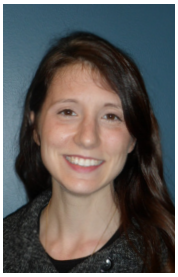

Boyd manages the EGS portfolio for the Geothermal Technologies Office, including both R&D and demonstration projects. Most recently, she championed the FORGE funding opportunity, which will drive the GTO portfolio over the next five years. She has an undergraduate degree in geology from Vassar College and a master's degree in geology from the University of North Carolina at Chapel Hill.

TIMOTHY REINHARDT, PROGRAM MANAGER, SYSTEMS ANALYSIS AND LOW TEMPERATURE & COPRODUCED RESOURCES

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Reinhardt supervises both the Systems Analysis (acting) and Low Temperature and Coproduced Resources portfolios for the Office, providing oversight and direction for crosscutting analysis as well as innovative technologies and projects, including the Mineral Recovery Program. He received a bachelor's degree in environmental sciences from Northwestern University and holds master's degrees from the University of Oklahoma and the University of Texas, Austin.

MARGARET SCHAUS, OPERATIONS SUPERVISOR

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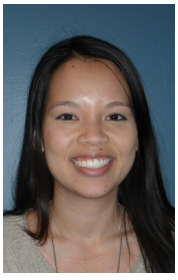

Schaus oversees GTO's day-to-day business functions, including strategic planning, budget execution, contracts, communications, and staffing. She has an undergraduate degree in science, technology and society and a graduate degree in management science and engineering, both from Stanford University.

Drilling at the AltaRock EGS Newberry demonsration project in Oregon, the Energy Department's largest investment in this next generation technology. *Source: GRC*