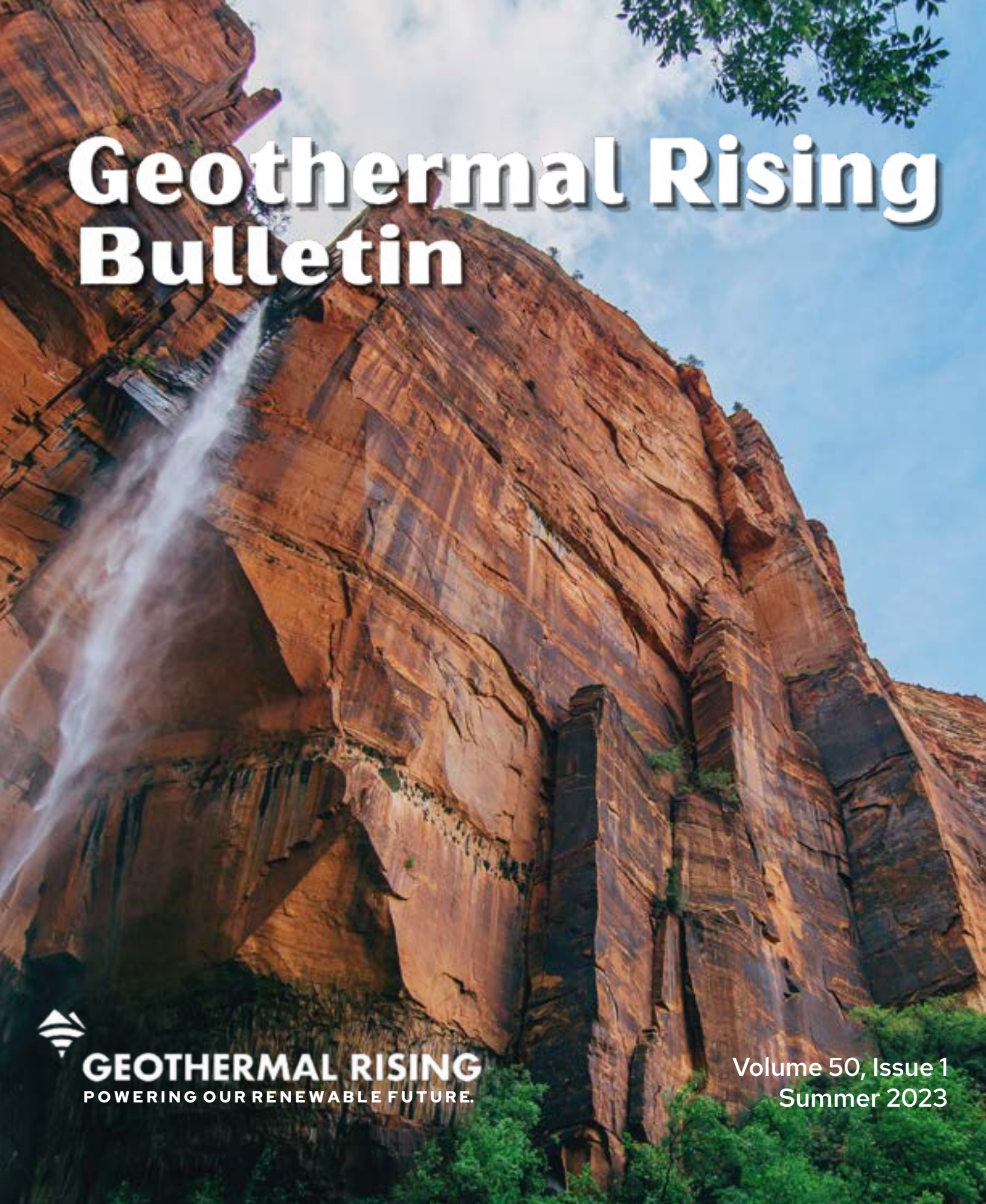

Geothermal Rising Bulletin

GEOTHERMAL RISING
POWERING OUR RENEWABLE FUTURE.

Volume 50, Issue 1
Summer 2023

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The Geothermal Rising (GR) Bulletin (ISSN 01607782) is published as a service to its membership and the public. Geothermal Rising is a 501(c)(3) and 501(c)(4) non-profit organization that empowers the advancement of human understanding and practical use of geothermal energy through collaboration and communication of robust research, knowledge, advocacy, outreach, and guidance in the United States and around the globe. The GR Bulletin provides a forum for information transfer to the public and among professionals in many fields related to geothermal resources, including geology, exploration, development, electric-power production, and direct-use technologies. The views and opinions expressed by authors in this publication do not necessarily reflect those of the GR or its members. For change of address or membership information, please contact us at info@mygeoenergy.org.

Volume 50, Issue 1

July 2023

Geothermal Rising

President Report Summer 2023

Steam of Fumaroles in Lahendong Geothermal Field: A Sign of Hope. Photo by Darrell Cornett.

We are so excited to provide a Geothermal Rising Bulletin to the membership again! This effort was kicked off with our previous President of the Board, Jon Trujillo, whose day job is with BHE Renewables. He really wanted to see the Bulletin back in print and distributed to our members once again. We'd like to thank BHE Renewables for their generous support for this issue and Jon for his vision!

For those who do not know me, I am Kelly Blake and am currently serving in my second year as Geothermal Rising President of the Board of Directors. I am also the Division Director for the Navy Geothermal Program Office (Why does the Navy have a geothermal program office you may ask? Because the Department of Defense is the largest consumer of power in the United States! Check out the article in this issue from Dr. Andrew Sabin) and I am just about to roll out of a leadership role for Women in Geothermal, an organization to promote the education, professional development and advancement for women in the geothermal community that proudly asks for men members and advocacy. All three of these leadership roles have been very rewarding, have provided me great opportunities for growth, and I've been happy to serve the geothermal community in all three capacities.

The printed version of the Geothermal Rising Bulletin was a mainstay for this organization until around 2018; we have been without a bulletin publication in roughly 5 years and 3 years since an online version. What we would love from the Geothermal Rising community is feedback on this issue as well as feedback on the Geothermal Rising Bulletin in general. Find a board member at the upcoming Geothermal Rising Conference in Reno, NV in early October and let them know what you think or send us an email at info@geothermal.org. We would love to hear from you all and would love to continue the Geothermal Rising Bulletin if the membership receives it well!

In my tenure as on the board and as President, Geothermal Rising has gone through significant change and I do believe that the organization is currently set up to be very successful during the ongoing geothermal decade within the larger global energy transition. With a brand new executive director, the most diverse board ever and an enthusiastic membership, we are ready to increase the profile of all geothermal technology applications in the United States.

In my time volunteering for this organization and being on the board of directors what has been the most amazing aspect is the hard work and drive of those employed within the association, as well as everyone who volunteers their time for the association. Without the geothermal community stepping up in the last few years, there are numerous initiatives, programs and changes within Geothermal Rising that would have never come to fruition or been achievable. For that, we can only say a huge THANK YOU!

A few ways for the geothermal community to continue to support Geothermal Rising are to nominate your colleagues or those you admire in the community for awards (all of the opportunities I am going to discuss can be found on our website www.geothermal.org by the way). You could run for the board of directors if you'd like to help steer the association. Many of the large changes you have seen in the organization over the last 5 years have been decisions by the board of directors; make your voice within the community heard. If that does not sound appealing, join one of our task forces (the Geothermal Rising Bulletin task force being one of them) to volunteer for the association. Lastly, we cannot do much of anything without the support of our sponsors; please check out the opportunities to become a sponsor of Geothermal Rising and help fund the great initiatives that you will read more about in this issue of the Geothermal Rising Bulletin.

Lastly, this is such an exciting time to be in the geothermal industry and community. As someone who has been around for over a decade now, to hear from those who have been in the industry for multiple decades that this time does feel quite different is encouraging and motivational to say the least. As one of the very powerful tools in our climate change toolbox, the future is nothing but bright for geothermal and for Geothermal Rising.

GEOTHERMAL RISING
POWERING OUR RENEWABLE FUTURE.

Executive Director

A geothermal area in Gunnuhver, Iceland. Southwest Iceland. Photo by Danyil Kovalov.

Introduction

I joined Geothermal Rising in February to usher the next chapter for the geothermal community, which will play a significant role if the transition to a clean energy economy is successful. The opportunity to serve as Executive Director of Geothermal Rising (GR) continues my career of public service.

I have over 20 years of experience working on public policy at federal, state, and local levels. My professional career has taken me to Capitol Hill, the White House, and the U.S. Department of State. Additionally, for the past six years, while I completed my PhD, I researched and explored social, policy, organizational structure, and collective action reasons that energy technologies remain stagnant and how the hurdles that prevent technological adoption can be reduced and eliminated. Geothermal was one of the case studies in my academic research.

I am excited to build this community and empower the geothermal industry in North America and around the globe by aligning all geothermal technologies and applications. As a nonprofit educational association, community organizer, and research organization GR sits in a unique place to support and facilitate the clean energy transformation. Our geothermal community is itself in transition, and GR's role through this change is critical. The next chapter of GR and the geothermal community will be pivotal and impactful. Some of these changes and accomplishments have already begun.

Geothermal Rising Accomplishments

GR has accomplished so much already this year. GR hired a new Executive Director, was awarded the GEODE grant with a consortium of two other nonprofits, hosted an inaugural Geothermal Day on Capitol Hill, created a Tribal and Indigenous Geothermal Working Group, started the monthly Full Steam Ahead Webcast series, launched the weekly Geo Community at the Core communication, initiated a fundraising campaign for traveling geothermal museum exhibits, and launched the Regional Interest Group (RIG) initiative, which has grown to ten RIGs from Hawaii to Texas to Vermont.

The next several months will be equally active as GR plans to onboard new staff and hosts the annual GR Conference (GRC) in Reno, Nevada between September 30 and October 5. The 2023 GRC is packed with workshops, field trips, presentations, networking, and panels. Additionally, GR will bolster our outreach and advocacy activities for external communications and policy work. GR will hire staff to oversee policy operations for the Geothermal Rising Policy Committee as well as bring on staff to implement tasks detailed in the GEODE grant. Other upcoming initiatives aim to build and align partnerships.

Building Bridges

Geothermal offers the American economy benefits and applications that everyone desires, just not enough people know about geothermal–yet. One mission of Geothermal Rising is to raise the profile of technologies and applications. To accomplish this, our goal is to align the geothermal industry and develop partnerships that build bridges, to underscore the theme of the upcoming 2023 PIVOT conference.

There are three overarching segments of the geothermal industry: geothermal ground source heat pumps, geothermal direct use, and geothermal power. These segments represent our industry's version of the hydrogen rainbow. Within each of these industry segments there are numerous subsegments, technologies, systems, and applications. This wide variety of technologies allows geothermal to be an everywhere technology but also creates division and the want to segregate the industry. To realize the full potential of geothermal, we need to align the voices across the industry and tear down these divisions.

The vision of Geothermal Rising is to align the voices of all these geother A geothermal area in Gunnuhver, Iceland. Southwest Iceland mal segments and subsegments, so our industry delivers a consistent and stable message to external audiences. These external audiences include educators, public utilities, investors, textbook publishers, policymakers, the media, students, environment and climate nonprofits, government staff, research institutions, and the public, among others.

Our message is two-fold. First, geothermal is everywhere. And second, geothermal is now!

We need to make room for innovators who are advancing engineering and physical boundaries as well as respect the mature and proven technologies of geothermal heat pumps and conventional hydrothermal power generation.

Geothermal is geothermal. Geothermal is earth energy no matter what depth or what type of geothermal system is used to harness this renewable and clean energy resource. Together we are using the Earth to save the Earth.

Geothermal Spans Political Boundaries

States from Texas and Idaho to New York and California are hot on geothermal. Significant geothermal legislation has been passed by state legislatures in Massachusetts, New York, Texas, Colorado, and Minnesota.

Geothermal leverages and respects the existing knowledge and skills of the oil and gas workforce and can utilize oil and gas technologies. Geothermal is renewable, clean, and provides solutions to decarbonize the built environment. Geothermal has the smallest physical footprint and lowest environmental impact of all energy technologies. Geothermal is stable and dispatchable while offering communities local, American-made heating, cooling, and electricity.

We all know and appreciate the benefits of clean and firm power, heat for manufacturing, or climate control (HVAC) that geothermal offers us. Geothermal energy creates more jobs per megawatt hour than all other renewable energy technologies, according to research from the National Renewable Energy Laboratory. And because the geothermal industry is not reliant on imported fuels or scarce critical minerals, the energy provides us with national and energy security unique to no other energy resource because geothermal is local and American.

Geothermal transcends political boundaries. As a community and industry, we need to embrace this unique characteristic.

Next Steps

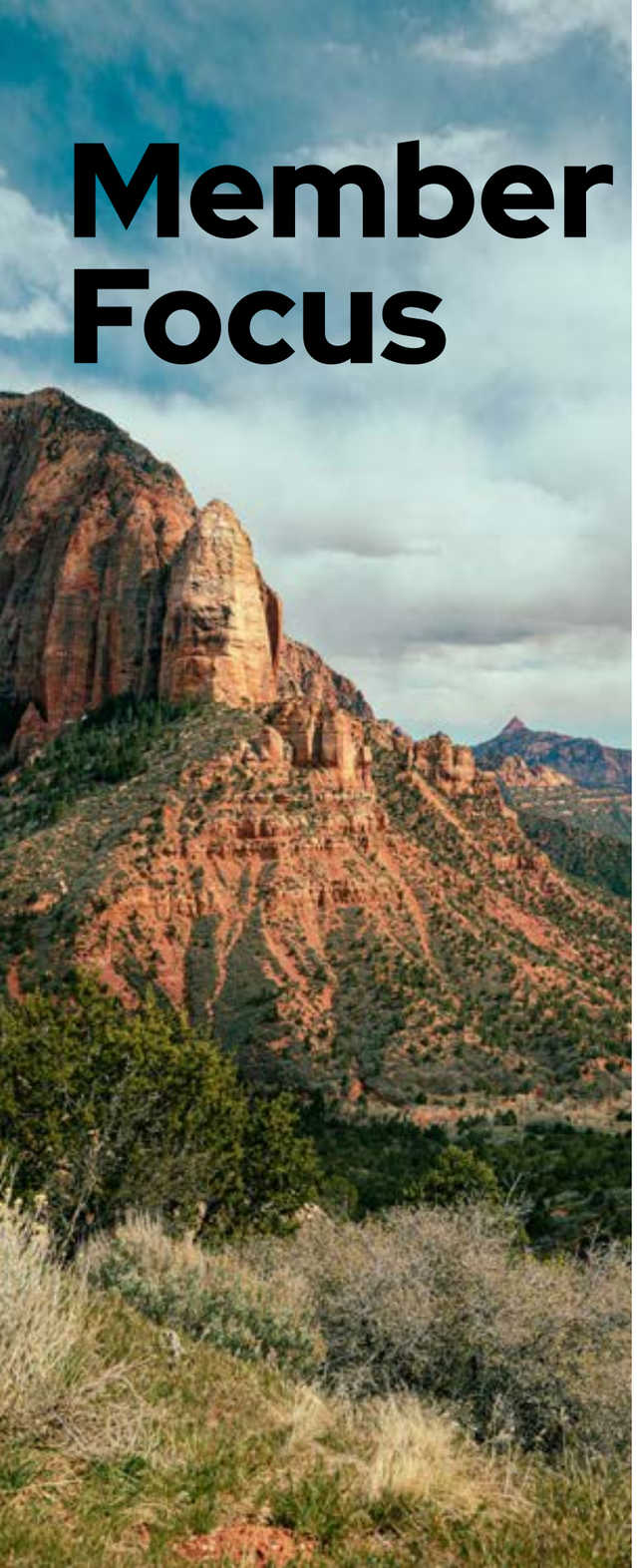
Alignment, encouragement, and mutually supportive messaging will help sustain and grow the investment in the geothermal industry from private equity, venture capital, governments, and traditional capital. It is critical that representatives from each geothermal segment allow their peers to be innovative, take risks, and offer grace when there are failures.

Support one another. Innovations from one energy transition to another all begin. as nascent technologies. When mature technologies empower nascent ones, funding opportunities increase for all. Human ingenuity is powerful. If we support innovators, our human ingenuity will help us overcome engineering, chemical, subsurface, and physical hurdles. It is social acceptance and policy alignment (also socially constructed) that hold back the geothermal renaissance.

I am excited about where the geothermal industry is going. Through alignment and a supportive community across geothermal industry segments, we will see geothermal become a mainstream and widely familiar energy resource in North America. Together, aligned and united, we can use the Earth to save the Earth!

Executive Director Bryant Jones, Ph.D..

Member Focus



Karen Rae Christopherson

Ms. Christopherson is a professional geophysicist who has been working with Magnetotellurics (MT) and electromagnetics (EM) for over 40 years. She has taken part in dozens of MT/EM surveys worldwide, exploring for geothermal, hydrocarbon, water, and mineral resources.

At the age of 7, she fell in love with rocks and decided to be a geologist when she grew up. She stayed true to this course through college, majoring in geology and starting work at the USGS upon graduation. In her first assignment found her in Reno and then Susanville, California where she was tasked with hauling gear and pulling wires for geophysics studies into geothermal energy. She'd found her niche and refocused her career on geophysics, specializing in geothermal.

Her love of geothermal had also started at a young age, while traveling with her parents and sister to ski and enjoy hot springs around Colorado. This was further encouraged by her job with the USGS, doing geophysics on KGRAs throughout the western US and spending inordinate amounts of time in places like Gerlach. With the support of the USGS, she did her MS thesis on Steamboat Springs, Colorado, ending many workdays with a beer in Strawberry Park Hot Springs (which at the time were uncrowded, free, and clothing-optional).

She has had many amazing experiences, here's one out of her most memorable: "In 1981, one year after Mt. St. Helens erupted, I participated in a helicopter airborne EM survey over the volcano. After work, the pilot and I decided we should land in the crater. This took some convincing of air traffic control, I think we said we needed ground-truthing. We landed, walked around, it was like being in Hell. We lifted off; there was one other USGS helicopter with geologists still in the crater. Within minutes of lifting off, the volcano vented. We only felt a mild shock wave. But the other USGS helicopter was blown over. Luckily only minor injuries were sustained by the people in that helicopter, but it certainly gave me an eerie feeling about the power of Mother Nature."

She received an MS degree in geophysics and a BS degree in geology, attending the University of Colorado and the Colorado School of Mines. She worked for the US Geological Survey for 15 years acquiring geophysical data on more than 20 KGRAs. She then joined BP America Technology Center, applying electromagnetic geophysics to frontier O&G exploration. In 1988 Ms. Christopherson founded her own firm, Chinook Geoconsulting based in Evergreen CO, focusing primarily on the acquisition and interpretation of electromagnetic geophysical data.

She is a member of SEG, GR, AAPG, WING, DGS, and Geothermal Canada. She served as 2nd Vice-President of SEG, and has been on numerous committees for SEG, GR, and WING. Karen is also the instructor for SEG's Continuing Education course on MT. She has authored over 40 papers about the use of MT and EM for exploration. In 2022, Karen received Geothermal Rising's Geothermal Pioneer Award.

Karen has traveled throughout the world for exploration, always making time to enjoy the local cultures and bring smiles to faces. When not working, she enjoys fly fishing, mountain biking, camping, and almost all things outdoors with her husband Jim and their cat, Y-Lee.

As Technical Chair of GRC 2022 and 2023, she is greatly inspired by the participation of so many diverse and varied segments within the geothermal industry as well as the quality of the student contributions. Karen is looking forward to GRC 2023 which she feels will be bigger and better than last year and provide a great opportunity to learn about the exciting new activities in geothermal, see old friends, and make new ones.

Leland C. Davis

Leland is the Chief Operations Officer and a Senior Project Manager and Geoscientist at Geologica Geothermal Group, Inc with over 15 years of experience in the geothermal resource consulting industry. Leland first joined Geologica, Inc as a Staff Geoscientist in early 2008. In late 2014, he joined Jill Haizlip in forming Geologica Geothermal Group, first as Operations Manager, eventually elevating to Vice President of Operations, before joining the ownership group in early 2022. Since joining the Geologica team he has focused his professional time working on the exploration and development of geothermal resources. His primary expertise is in well test planning, implementation, and evaluation. He specializes in reservoir data collection and resource analysis including computer-based GIS mapping and conceptual modelling. His broad work experience across multiple disciplines in 15+ years with Geologica provides a practical understanding of all facets of geothermal development including geology, geophysics, geochemistry, conceptual modeling, well targeting and design, reservoir engineering, and power plant selection.

Leland is a current board member of Geothermal Rising and served as the General Chair for the 2022 Geothermal Rising Conference (GRC), a role that he will be reprising in 2023.

Speaking of his experience with the conference, he had this to say:

"Geothermal Rising is at an exciting crossroads as an organization and industry influencer. In 2022, we finally had the opportunity to come together in person and celebrate a new era after several years of physical, emotional, and social impact of COVID-19. The 2022 GRC in Reno was, by all accounts a triumphant success, with attendance not seen in over a decade, even in the face of lingering COVID impacts, a shortened window to prepare from an earlier than normal conference date, and the abrupt departure of our previous ED in the final stretch of conference preparations. In 2023, we are back to our more traditional fall schedule, finally coming to terms with the lasting impacts of a global pandemic (though the memory of those we lost will live on), and an expanding geothermal industry newly invigorated by innovation and a global push for moving the energy transition forward toward a sustainable and reliable future. We are led into this new era by an exciting and enthusiastic new ED who promises to further reshape and transform an organization that has been a champion of geothermal for over 75 years and hopes to lead the way for decades to come. GRC 2023 promises to continue and expand upon the exciting themes of 2022 and venture into new exploration and development initiatives for the future. Can't wait to see everyone there!"

Investigating

Using Earth Source Heat at Cornell University, New York

Authors: Olaf Gustafson, Wayne Bezner Kerr, and Jeff Tester, Cornell University

Why is Cornell University Pursuing Earth Source Heat (ESH)?

Cornell University has adopted a Climate Action Plan (https://sustainablecampus.cornell.edu/our-leadership/cap) that aspires to achieve carbon-neutral operations at Cornell's Ithaca, NY campus by 2035. There are three principal components of energy use to be addressed: electricity, transportation, and space heating/cooling. Cornell is pursuing parallel initiatives to reduce carbon emissions in all three areas; here we provide an overview of our efforts to address perhaps the biggest of these challenges: renewable heat. **Figure A** shows Cornell's annual energy demand for electricity, heating, and cooling for the past 20 years.

Due to decades of investment in energy conservation and strict energy standards for new buildings, Cornell's energy needs have declined slightly since 2000 despite continued campus growth (shown in purple). Heating (shown in red) is responsible for over 40% of campus energy use, which places decarbonization of heat sources as a central challenge.

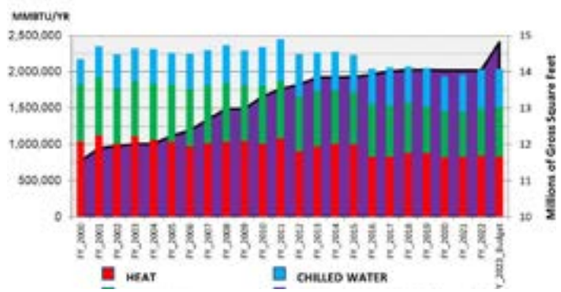


Figure A: Cornell campus annual energy demand for electricity, heating, and cooling from FY 2000 to FY 2023. Because of adopting aggressive energy efficiency standards for new and retrofitted buildings, Cornell's total demand for energy has remained relatively constant despite the addition of over 3 million square ft of new building space from 2000 to 2023

Given the large size of the Cornell campus (~16.5M gsf) and its cold-climate location (~6800 heating degree days annually), substantial carbon-neutral heat resources will be needed. Currently the primary candidates are deep direct-use geothermal (ESH), a ground-source heat exchange (GSHE) system powered by renewable electricity, and bioenergy generated from campus agriculture and food wastes. These are being evaluated to meet both base load and peak heating requirements. A preliminary assessment of these options has found that GSHE systems would require a substantial increase in both average and peak campus electricity consumption, which would exacerbate an already challenging situation regarding limited potential renewable electricity resources. In addition, peak consumption would occur during winter months when regional renewable electricity generation is at its lowest, contributing to the zero-carbon generation deficit illustrated in **Figure B**. Local, sustainably produced bioenergy could potentially be stored for use during winter months, but cannot be produced at the scale needed to meet Cornell's heating needs; this is considered a potential resource for supplemental peak heating only. Therefore, ESH has emerged as the most suitable potential renewable heat resource for the Cornell campus (**Figure C**).

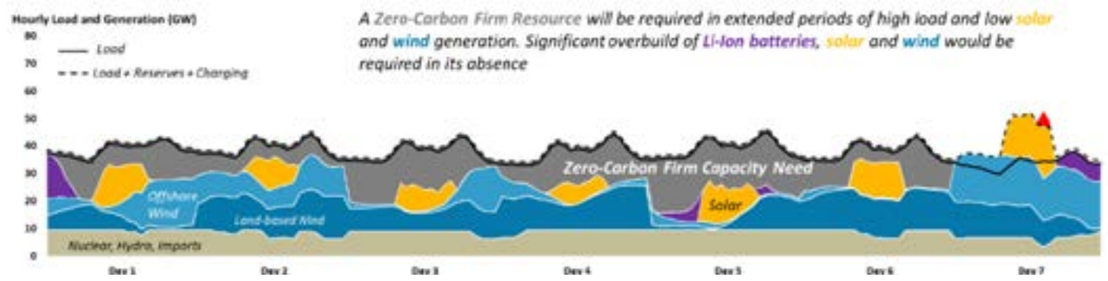


Figure B: Zero Carbon Firm Capacity Need Over a Challenging Week Appendix G: Integration Analysis Technical Supplement New York State Climate Action Council Scoping Plan)

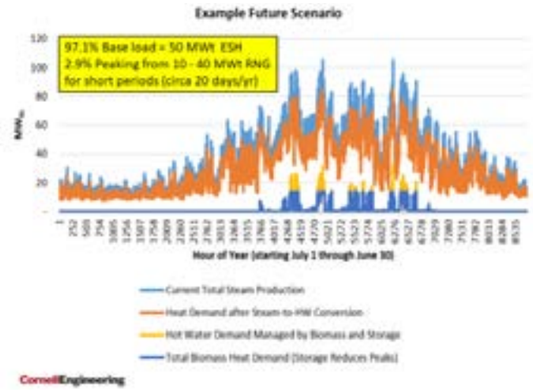


Figure C: A representative future scenario simulation of carbon-neutral heating at Cornell. In this simulation, the campus heating load (up to 80+ MWth) is accommodated using four geothermal well pairs to supply approximately 50 MWth of base load heat to the campus distribution system. The modeled system includes a provision for using centralized heat pumps to increase geothermal reservoir output if needed as well as 16 M liters of hot water storage and 14 MWth of peaking heating for coldest days using bioenergy generated by campus agricultural and food wastes. Peaking heat demand can be further reduced by adding seasonal thermal storage or if buildings are modified to extract more heat (return cooler water to the reservoirs). (See Beyers and Racle 2020, Tester et al. 2021 and Kassem, et al 2020 a,b,c)

Cornell University Borehole Observatory (CUBO)

Background and objectives

To evaluate the potential for ESH, Cornell initiated a phased research and development program. The initial phase was the Preparation Phase (ESH Phase 0). The main objective of this phase was to evaluate available background geological data and perform additional data collection to support an assessment of the feasibility and risks associated with drilling the CUBO Exploration Well. Background data obtained and analyzed included historical local and regional seismicity, regional crustal stresses, stratigraphic data from offset wells, geologic maps of faults and other structures, 2D hydrocarbon-industry seismic reflection profiles, and commercial aeromagnetic data (Tester et al., 2020). Cornell also collected additional data, including installation of a local 15-node seismometer network, completion of a multichannel seismic reflection survey, high-resolution gravity

measurements, and installation/sampling of five groundwater monitoring wells near the proposed drill site. These background studies supported an initial characterization of potential geothermal reservoir targets (Tester et al., 2020) and the potential risk of induced seismicity, as well as establishing baseline levels of microseismicity and groundwater quality to use as a reference during drilling or geothermal development.

The ESH Phase 1 exploration well program (CUBO) had the following key objectives:

- Confirm bedrock stratigraphy and rock types through the sedimentary section into the upper portion of crystalline basement
- Measure pore pressure and fracture gradients, in-situ bedrock stress conditions
- Refine the drilling and casing program needed to ensure well control and wellbore stability
- Collect temperature measurements
- Confirm and evaluate potential geothermal reservoir depths and thicknesses and measure key properties via geophysical logging and imaging
- Perform hydrogeologic testing
- Collect bedrock cuttings and core samples for petrologic, geochemical, geomechanical, and thermal property tests
- Construct a well capable of supporting subsequent in-situ monitoring and measurements

Scope of CUBO project

In 2021, Cornell began work on CUBO, with initial funding from the U.S. DOE Geothermal Technologies Office. The required stratigraphic well drilling permit was secured from the NY Department of Environmental Conservation. Drilling with a 1500 HP triple drill rig commenced on June 21, 2022, and TD was achieved at a depth of 9,790 feet on August 13, 2022. As shown in **Figure D**, the well was completed in five sections: a 36-inch conductor section with 30-inch casing to 110 feet; a 26-inch surface section with 20-inch casing to 789 feet; a 17.5-inch first intermediate section with 13.375-inch casing to 4,256 feet; a 12.5-inch second intermediate section with 9.625-inch hung liner to 7,809 feet; and an 8.5-inch open hole section to 9,790 feet. Each section of casing and liner was fully cemented. The number of well sections and casing set points were chosen to ensure well control and wellbore stability while drilling through potential hazards such as the Syracuse salt (water soluble), Vernon shale (a hydrophilic swelling shale), and several known gas-producing shale and carbonate units. Water-based mud was

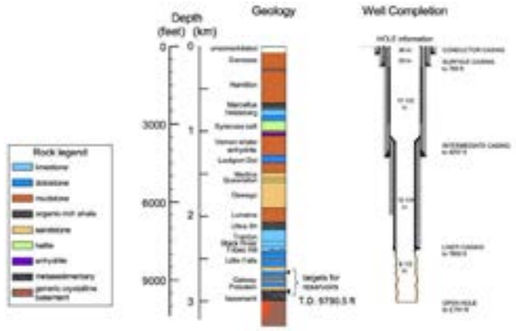


Figure D: CUBO Lithology and well design. The depth region for potential heat reservoirs was completed as an open hole from 2,380 m (7,809 ft) to 2,984 m (9,790 ft). Within that depth range, target zones were identified that have a higher density of fractures and favorable signals of hydrologic transmission.

utilized, in part due to issues of community acceptance with oil-based muds. Drill cuttings, excess cement, and waste drilling fluids were containerized on site and trucked off-site for disposal at licensed facilities.

Continuous mud logging, generally at 10-foot intervals, was performed for all sections below the conductor casing. A team of Cornell students was trained as sample catchers to assist the professional mud logging crew. Continuous gas monitoring by gas chromatography (GC) was performed for C1-C6 hydrocarbons entrained in the drilling fluid. In the 8.5-inch open hole section, a DQ-1000 mass spectrometer was also utilized to identify additional gas species such as noble gases, CO2, aromatics, and sulfur compounds.
In the cased intervals of the well, wireline logging consisted primarily of natural gamma ray logs to assist with stratigraphic mapping and correlation, caliper logs to monitor wellbore stability and assist with cement volume calculations, and ultrasonic cement bond logs. Within the open hole section that spanned the potential geothermal reservoir zones of interest, a more extensive suite of wireline geophysical logs was collected, including gamma, resistivity, neutron porosity, density, spectral gamma, sonic velocity, ultrasonic imaging, and micro-resistivity imaging (FMI). Additional open-hole wireline testing included several mini-frac (MDT) test stations, collection of 25 XL sidewall cores, and collection of pressure-temperature logs during flow testing. Flow testing was the last testing phase performed while the drill rig was on site. Air-lift equipment was used to lower the water level in the well to measure inflow; this was followed by reinjection (bull-heading) to measure the ability of the open hole section to accept water.

Preliminary Findings

Subsurface logging, testing, and sampling were conducted within CUBO during and soon after drilling with the primary objectives of characterizing the lithostratigraphy, temperature, hydrogeology, and stress conditions within the subsurface.

Stratigraphy, rock types

Through cuttings analysis and borehole logging/imaging, CUBO enabled confirmation and refinement of the lithologic column and rock types at the site (**Figure D**). In the upper sections of the borehole, this information will be used to inform future drilling operations in terms of drilling methods and hazards, as well as to refine seismic velocity models and calculations of vertical stresses. In the bottom section of the borehole below 7800 feet, the depth, thickness, and detailed lithology of potential reservoir units was documented. This included exploration of the poorly characterized crystalline basement rocks from 9400 feet to TD at 9790 feet. Preliminary analysis of the basement units suggests that the upper portion consists of low-grade metasediments, while the lower portion appears to be mafic metavolcanics – neither of which were previously documented in limited offset well data.

Fracture distribution and in-situ stresses

Fracture characterization based on borehole image logs revealed abundant fractures that are largely focused within discrete stratigraphic intervals (**Figure E**; Fulcher et al., 2023). In general, these fractures strike NE and dip NW, although within the basement orientations are more varied. The depth distribution of fractures largely agrees with downhole logs. However, 3D far-field sonic logs reveal a secondary orthogonal set of fractures away from the borehole with a NW trending orientation. These data, along with analysis of fractures present within 25 sidewall cores from the open-hole section, are being used to characterize existing subsurface fracture networks and their potential to transmit water.

The susceptibility of fractures to respond to hydraulic stimulation or to slip in general is related to their stress state within the 3D stress field. Understanding the state of stress is therefore important to guide stimulation strategies, establish the direction of potential future well bores, and assess induced seismicity hazards.

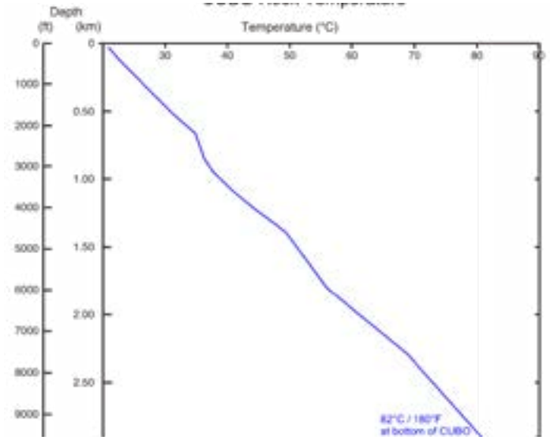


Figure E: Estimated equilibrium temperature profile based on measurements in the lower, open-hole section of CUBO obtained immediately after drilling and casing operations and before, during, and after a hydrologic airlift drawdown test and subsequent re-injection of displaced borehole fluid (see Purwamaska, I. and P. M. Fulton, 2023 for details).

A variety of observations and techniques have been used to characterize the stress state at depth within CUBO (Pinilla et al., 2023). Dual-packer mini-frac tests along with integration of density logs at multiple depths within the open hole section constrained stress magnitudes. Interpretation of borehole breakouts observed in both 4-arm caliper and borehole image data informed stress orientation as a function of depth. In general, maximum principal stress orientation is roughly NE-trending with little variation with depth. Stress magnitudes reveal a principal strike-slip / transpressional setting at depths of 8,000 ft or more with the overburden stress being σ2.

Temperature, permeability

To meet campus heating needs, hot fluids must be supplied to surface heat exchange equipment at a rate and temperature adequate to supply campus district energy infrastructure. The first technical uncertainty is the subsurface temperature. Because borehole circulation during drilling temporarily cooled the near wellbore region, borehole temperature measurements taken immediately afterwards underestimated true formation temperatures as seen in **Figure F**. However, analysis of several bottom hole temperature measurements (Purwamaska and Fulton, 2023) reveal a re-equilibration trend suggesting an equilibrium formation temperature at 9710 feet depth of ~81°C.

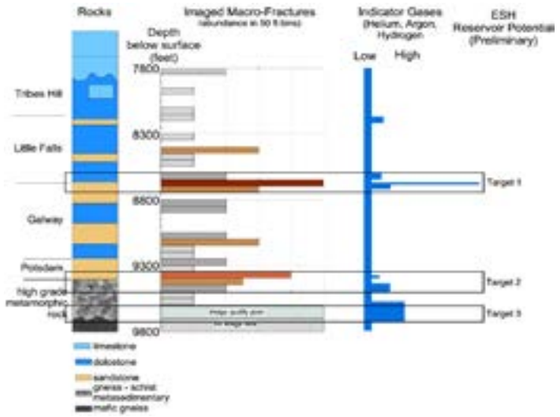


Figure F: Summary of relative abundance of fractures identified in borehole image logs and spikes in inorganic gases observed in online gas monitoring during drilling. Intervals with gas spikes correlate with areas with higher fracture density providing an indication of permeability and connectivity. The noted targets for ESH reservoirs are preliminary and may be adjusted as analysis continues (Fulcher et al., 2023).

Higher resolution temperature logs before, during, and after subsequent disturbances during hydrologic testing showed temperatures of at least 77°C at 9,500 ft immediately after drilling (**Figure F**). In addition to providing constraints on formation and potential fluid production temperatures, analysis of the high-resolution temperature surveys associated with hydrologic testing provided insights into the hydrogeology – a key technical uncertainty prior to CUBO drilling. High-volume fluid flow in contact with sufficient bedrock surface area between injection and production wells is needed to effectively supply heat. These factors are controlled by permeability and hydrogeologic structure. Analysis of the time-varying thermal response by depth can reveal permeable intervals where drilling fluid or formation fluid infiltration occurred during drilling. The CUBO temperature data revealed several permeable zones which seemed to both take and produce fluid. Most notably, there is a zone with a large negative temperature anomaly associated with fluid infiltration during drilling within the upper basement and its interface with Paleozoic strata – a known geologic unconformity (**Figure F**; Purwamaska and Fulton, 2023).

Next steps

Preliminary CUBO data analysis indicates that, while reservoir temperatures appear adequate and extensive natural fractures were observed, the existing fractures are not capable of transmitting sufficient water flow to achieve the 25-50 kg/s production rate needed (Clairmont et al., 2023). Therefore the next project phase (ESH Phase 2) will be focused on fracture stimulation testing within CUBO to determine if later reservoir-scale stimulation is likely to achieve target flow rates. Should the stimulation testing yield promising results, Cornell will move forward to ESH Phase 3: installation, stimulation, and production testing of a two-well doublet system to demonstrate sustainable heat production in the range of 5-15 MWth (10-20% of Cornell's average heating demand). The drilling experience and subsurface knowledge obtained from CUBO will inform the design of both the Phase 2 stimulation testing program and the Phase 3 two-well demonstration system.

In Phase 3, we expect to first choose the target depth and trajectory for an initial pumping well. After drilling and stimulating the first well, reservoir modeling of thermal/hydraulic/mechanical performance will be used to specify the trajectory of a second well. Then the second well will be drilled, tested, and stimulated if needed to establish connectivity with the first well. An extensive period of performance testing and modeling would then be carried out to validate the doublet's energy extraction performance and establish its capacity to sustain production in the 5-15 MWth range. Finally, should the demonstration well pair meet its objectives, Cornell would move into ESH Phase 4: installation of additional well pairs to create a full-scale system capable of providing ~50 MWth of baseload heating.

McGraw Hall of Cornell University.

The 144' tall derrick is shown fully raised on the CUBO drill rig. (June 17, 2022). Photos courtesy of Cornell University.

Acknowledgment

The Cornell Earth Source Heat project team contributed in major ways to information reported in this article. The team includes a large group of committed Cornell's staff, students, and faculty along with many other experts involved with drilling and logging operations, analysis and modeling. This article covers work financially supported by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Geothermal Technologies Office Award Number DE-EE0009255 and by Cornell University.

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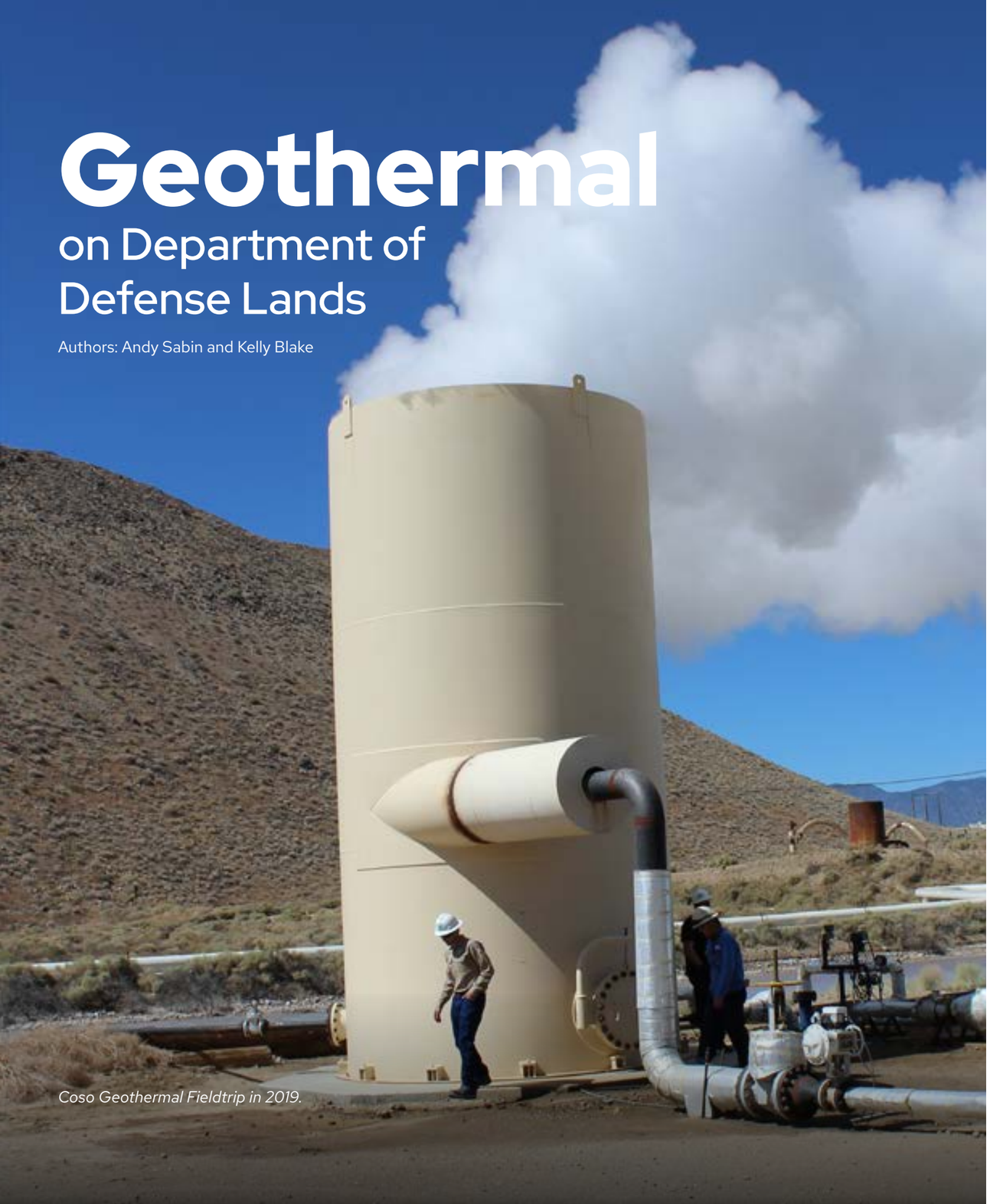
Geothermal on Department of Defense Lands

Authors: Andy Sabin and Kelly Blake



Coso Geothermal Fieldtrip in 2019.

Geothermal development opportunities on the almost 30 million acres of Department of Defense (DOD) managed lands in the United State are numerous. A large amount of this land is in the western U.S. where the geology is favorable for hydrothermal systems. If you consider heat flow as a first, albeit broad indication of geothermal power potential, then elevated high heat flow suggests that there is a good chance for geothermal power or direct-use opportunities to exist on DOD land (**Figures 1 and 2**). Until some of the evolving technologies like engineered geothermal systems (EGS), superhot/supercritical or even advanced geothermal systems (AGS or closed-loop geothermal) become commercially viable, hydrothermal systems or deep, hot water systems (e.g., sedimentary basins especially if economic incentives like feed-in tariffs exist) are the only targets currently applicable for geothermal power production.

There are also over 300,000 buildings on DOD land. Buildings account for 76% of electricity use in the United States and 40% of all primary energy use and associated greenhouse gas (GHG) emissions (OSD, 2023; USEIA, 2023). Geothermal heat pumps (GSP) use the constant temperature of the earth as a heat exchanger and can help warm buildings in the winter and cool them in the summer. A new or retrofitted GSP can cut building energy consumption by 20 to 50% and reduce maintenance costs over a building's life (IGSHPA, 2023). So the installation of geothermal heat pumps (GSP) or some hybrid variation of this technology represents another excellent geothermal opportunity for DOD as it would dramatically decrease power consumption and decrease DOD's carbon footprint.

Figure 1: Generalized heat flow map of continental United States. Large regions of the western United States have heat flow values 2-3 times that of most of the central and eastern United States. Figure from Sabin and others (2004).

Figure 2: Select military bases of the continental United States and tectonic settings. Note the correlation of tectonic setting, elevated heat flow (from figure 1) and military bases. From Sabin and others, (2004).

Coso: DOD's Geothermal Power Producer

The only geothermal power production today on DOD land is at the Coso geothermal field, Naval Air Weapons Station, China Lake, CA. Coso was the result of determination, timing and some pretty solid government-led science. Discovering and then developing the Coso field was driven by a single-minded and influential Navy scientist at China Lake, Dr. Carl Austin. From the mid-1960s until a CalEnergy team was awarded a development contract in 1979, Carl and a hand-picked group of other Navy scientists (the nascent Geothermal Program Office) begged, borrowed and stole money to conduct studies at Coso all the while trying to convince other government offices, Navy leadership and private industry that Coso was not just a developable geothermal resource but was probably a world-class geothermal field. In the meantime, they were also able to convince the Navy and the Department of Interior to allow a geothermal lease sale to take place inside the China Lake fence. This had never been done before and has not occurred since. Finally, this group had the presence of mind to be doing all of this at a time when the country, including its elected officials, agreed that never-ending gas lines of the 1970s driven by Organization of Petroleum Exporting Countries (OPEC) oil embargoes needed to end. The best way to stop this was to rid ourselves of foreign fossil fuels by replacing them with indigenous sources, especially and including renewable en-

Figure 3: View to WNW of Navy I power block gathering array of wells, separators, mufflers and low- and high-pressure steam pipelines. Young rhyolite domes (background) and hydrothermally altered rhyolite and pyroclastic flows (white rocks in foreground) bound this infrastructure.

ergy like geothermal. The Public Utilities Regulatory Policies Act (PURPA) was passed in 1978 and opened the door for small power producers to sell power to utilities at attractive prices. From 1978 to 1988, geothermal capacity production in the United States quintupled from a nameplate capacity of 300 megawatts electricity (MWe) to almost 2,500 MWe (Robbins and others, 2021) during what could arguably be called the first geothermal boom in this country. Needless to say, Coso was a product of these factors and started selling power to the California grid in 1987.

While production has declined since the high-water mark of just over 300 MWe power generated, and our understanding of the geologic setting at Coso has evolved beyond what some early practitioners argued, the fact is that this driven group of Navy scientists played and continues to play a pivotal role in a remarkable accomplishment (**Figure 3**). Over $550 million in revenue has been received by the Navy from the production of this Navy resource. Plus, thirty-six years of continuous power production from inside a highly secure Navy base has occurred. This is a very high bar but can still serve as a guide for geothermal development on other DOD bases. The timing is again ripe for geothermal development inside DOD installations.

Defense Innovation Unit

Among the many projects that DOD is currently pursuing is one spearheaded by the Defense Innovation Unit (DIU). DIU is a government organization created 7 years ago with a mission of accelerating innovative commercial technologies for DOD. DIU employs contracting mechanisms that can fast-track many of the required steps typical of the often time-consuming, federal acquisition regulations (FAR) that governs most federal government contracts. The Air Force, Army and Navy are working with DIU with the goal of awarding contracts by this summer to potential geothermal developers. Their objectives will be to develop geothermal power on a handful of select military bases.

In January, 2023 a DIU notice invited potential vendors to propose on how and where they would develop geothermal power. By May, a series of discussions between Army, Air Force and Navy personnel yielded a down-selected group of vendors from the 68 that responded. A subset of the these vendors is currently being identified by all 3 services with the objective of contracting one or two to begin addressing the steps needed to find and produce geothermal power using conventional geothermal (i.e., develop a hydrothermal system like Coso), EGS (engineered geothermal systems) or AGS (advanced geothermal systems; aka, closed-loop geothermal) technologies. The bases being considered for this work are Mountain Home Air Force Base, ID, Joint (Air Force) Base San Antonio, TX, Ft. Irwin, CA, and Ft. Wainwright, AK and Naval Air Station Fallon, NV.

Notwithstanding the costs and tremendous technical obstacles, above and below ground, required to explore, drill and ultimately prove out the existence of even a "conventional" geothermal system like Coso, the DIU program has several appealing aspects. First, it signals an interest in geothermal by DOD. This may seem like a nominal hurdle, but DOD created military bases to perform military missions. Base leadership is loath to engage in any activity that may encumber their mission, including geothermal exploration and development activities. Second, DOD installations have suffered setbacks owing to weather events, fires and grid stability in many regions in recent years. The likelihood of this trend doing anything but increasing is low. Consequently energy resiliency on all DOD installations has become a priority. Resiliency refers to the ability to perform a mission despite disruptions in the energy supply, whether unexpected disruptions due to weather or targeted disruptions from assaults on the grid by domestic or foreign terrorists. DOD understands the need to maintain secure and operational installations and is beginning to appreciate how indigenous and renewable sources like geothermal can meet their needs.

This DIU geothermal project is also occurring at a time when the momentum for geothermal development in the United States is very high. Recent legislation and Biden administration orders, including Executive Order 14008 that calls for the country to become net zero for carbon emissions by 2050 and the Inflation Reduction Act which will provide almost $11 billion in grants and loan opportunities to help rural energy providers bring reliable clean energy to their communities, are contributing to this surge. Investment funds like Breakthrough Energy and focused government programs like the DOE's Earthshot are catalyzing new and accelerated growth across the spectrum of geothermal opportunities. The number of vendors who responded to this DIU notice alone attests to this interest.

A limitation of this program is that the only commercial geothermal power to date is generated from hydrothermal systems. Great strides have been made in EGS technology in recent years especially, of course, at the DOE-funded Utah FORGE project. AGS is a relatively new newcomer to the innovative geothermal power producing space. A few companies have made progress in the myriad closed-loop approaches and have presented their results at the GR Annual Meeting, the Stanford Geothermal Workshop and other venues in the last few years. It remains to be seen if any of the companies that proposed non-conventional or even conventional geothermal solutions for the DIU program will achieve desired outcomes. Regardless, much will be learned along the way and DOD should move closer to achieving their resiliency goals.

Pipeline Fumarole.

Re-Boiler at the Coso Geothermal Field.

Other Programs

DOE's Geothermal Technology Office (DOE) is fully invested in supporting the development of geothermal (see DOE article in this publication) including on DOD installations. The Federal Geothermal Partnership program is a collaboration between DOE's GTO and the Federal Energy Management Program that is helping to demonstrate the potential for geothermal heating and cooling systems on federal sites. Oak Ridge National Laboratory is leading the effort to perform analysis and site specific work required to bring geothermal heat pump and/or a geothermal district-scale system solutions to two military installations in 2023, the U.S. Military Academy at West Point and the U.S. Army's Garrison Detroit Arsenal in Michigan.

The GTO-funded Hidden Systems project includes two groups that are currently developing and testing innovative approaches to the exploration for conventional geothermal systems (see INGENIOUS article in this publication). One of these teams, led by Sandia National Laboratories, employed a helicopter-borne, electromagnetic survey (HeliTEM) survey over a large swath of northern Nevada including two military bases, Hawthorne Army Depot and NAS Fallon. The objective of this survey is to integrate shallow HeliTEM resistivity data with existing data from this geothermal-rich region. Interpretations of these data are being augmented by additional data, as needed, including site-specific geologic mapping, focused geophysical surveys including magnetotelluric (MT), two-meter probe data and shallow drilling. A detailed description of all methods and results will be presented in the next Geothermal Rising Bulletin. So far it appears that new conventional geothermal targets exist on the DOD bases at Hawthorne and Fallon, in addition to those already described in the literature (e.g., Lowry and others, 2020; Blake and others, 2015).

The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) are DOD programs that support basic and applied research as well as demonstration programs to improve DOD's performance in a number of areas including installation energy. An ESTCP contract is anticipated in the coming weeks that will be focused on reducing energy consumption on DOD installations through a novel, thermal microgrid project that integrates borehole thermal energy storage and heat pumps.

Navy Geothermal Program Office

The Navy's Geothermal Program Office (GPO) was created in 1978 to oversee the exploration and development of the Coso geothermal field. Exploration for geothermal resources on other DOD installations, as budgets allow, and relevant R&D work are the other primary functions of the GPO.

During this recent surge in geothermal interest and project work, GPO has served as advisors to the DIU program and provided initial input to the FedGeo Partners project. GPO is also teaming with Sandia National Labs, Geologica and others on the abovementioned northern NV exploration program. The Navy and Army have been very supportive of this work so far as potential geothermal development opportunities on both Hawthorne Army Depot and NAS Fallon would help meet their respective energy resiliency needs. ESTCP is in the final stages of awarding a contract to GPO, RESPEC, Lawrence Livermore National Labs and their partners. The combined effort will generate a feasibility analysis for employing a novel borehole thermal energy/heat pump thermal microgrid on a joint service military base in the eastern U.S. GPO also recently performed a desktop analysis of the geothermal power producing potential on four Army bases in Tennessee, Iowa, North Dakota and Alaska. The Army wants to decommission coal-fired plants at all four sites and would ideally like to replace them with clean, local power and/or heating sources. Given the current understanding of available data and the geologic settings at each site, no obvious solutions applying commercial geothermal technologies are apparent. Perhaps one or more of the newer, evolving technologies will meet their needs.

GPO's main role throughout is maintaining all Navy interests in the Coso geothermal field. Among the more intriguing projects currently being pursued by GPO and the Coso Operating Company (COC) is the DOE-funded and Colorado School of Mines-led Machine Learning project. This work is using large GPO and COC data sets like surface temperature data, fault maps, and mineral maps, to test the probability of additional resources in or around the Coso field. Results could ultimately lead to renewed interest in expanding the field. Another Machine Learning project focused on Coso is being led by a team from the Expeditionary Warfighter Center (EXWC) in Port Hueneme, CA. EXWC's Artificial Intelligence group and GPO are investigating correlations between micro-seismicity (Meq) and production within the field. GPO has been acquiring, post-processing and cataloging Meq data from their Coso seismic array since the 1990s. As water management within a geothermal field is of primary importance, and it has been observed that micro-seismic events at Coso are spatially and temporally associated with production and injection, quantifying this relationship could assist our ability to more efficiently manage water at Coso.

Obstacles for Geothermal on DOD Land

Against this backdrop of renewed interest and enthusiasm, this next geothermal boom, what if anything might hold DOD back from finding and exploiting more geothermal on their installations today? There are a few practical matters that may hinder development.

The first is mission. Each military base was established to conduct a mission. Land was withdrawn from the public domain and placed in the care of DOD in order to perform this mission. Exploration and development of geothermal requires the use of much of this land to perform a function (e.g., geothermal power production) that was not contemplated during the land withdrawal process. So multiple government agencies in addition to DOD may need to negotiate procedures that authorize this land to be used for other or at least additional purposes. While the footprint of geo-

thermal as opposed to solar and wind is quite small, a well field, gathering lines, roads and the construction of a centralized facility, whether for power production or direct-use purposes, still requires land and DOD's time to pursue permits, NEPA and other matters associated with development and construction.

A second reason why no further geothermal power or direct-use has been developed on DOD land since Coso is funding. Other than the initial exploration at Coso and subsequent exploration by the Navy GPO, DOD has rarely dedicated money to pursue something like geothermal on their installations. As DOD installations are not open to the public and therefore not easily explored, much less available for lease nominations, most of the ground remains unknown from a resource perspective. No third party will agree to build a power plant or even a direct-use heating and cooling system unless data exists that demonstrates the existence of a resource. And unless DOD has agreed up front to purchase this power or fluids to augment heating/cooling on a base, any developer will want a Power Purchase Agreement or the opportunity for a PPA with an off-taker outside of the base. As alluded to earlier, GPO and its contractors have been filling that exploration void on DOD installations; however, absent a budget to conduct exploration, military bases will remain largely unknown and untested.

The last reason that has hindered geothermal development on DOD installations is markets. Geothermal power production on a base requires a market, either the base itself or an outside buyer such as a utility. In the few instances when exploration work was conducted on a base and there was alignment among DOD decision-makers and base leadership to develop a resource, the power sales markets were poor. Consequently, the interest of potential third-party developers was nonexistent. An Ormat-Navy geothermal development contract for NAS Fallon signed in 2005 was mutually dissolved a few years later because of poor markets among other reasons.

The Future

Geothermal is much more than power production as many other articles in this publication attest to. As DOD fully embraces the need for their installations to be energy resilient and accept the notion that the entire geothermal spectrum, from power production to hybrid ground source heat pump/thermal microgrid solutions, can assist with their needs, many of the obstacles previously described are being mitigated.

The DIU program signals DOD's desire to work with 3rd parties to find and exploit power on DOD bases. Current DOE-funded efforts to explore and/or exploit geothermal is helping to drive geothermal opportunities on all lands including DOD managed ground. In concert with attractive markets and the collective desire of stakeholders at all levels, we appreciate the triple bottom line that geothermal can meet (profit, people and planet) and are optimistic about the future of the geothermal industry. Stay tuned to this publication and the GR website for updates on geothermal development and opportunities on DOD installations.

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Figure 1: GBCGE and Philippines' Team who worked together on the Northwestern Luzon Play Fairway Analysis.

Opportunity

to Deep Dive into the Great Basin

Author: Maria Richards, Interim Director of GBCGE

The Great Basin Center for Geothermal Energy (GBCGE) is an organization recognized by the geothermal community for approximately 25 years. For some of you, the GBCGE is fundamental to research in geothermal resources exploration; for others its importance is leading the National Geothermal Academy. Some know it from the people – past Director Bridget Ayling or Jim Faulds, who is current Director of the Nevada Bureau of Mines and Geology (NBMG), within which the GBCE resides. For the present, it is my pleasure to be the Interim Director for GBCGE. This position offers me the privilege to get to know, in detail, this world-renowned group of people and share with you the current activities.

Job Opening

The GBCGE Director[1] position announcement is posted. The best way to attract the right person is often word of mouth, therefore please discuss the position with those who would be an excellent leader and mentor. The position is within NBMG as a tenure-track Associate Professor in the College of Sciences. The primary responsibilities will be to develop broad programs in research and education in the field of geothermal energy while serving as Director of the GBCGE. For more details, see the full listing on the UNR.edu/HR/jobs website or contact Beth Jacobsen at jacobsenb@unr.edu.

GBCGE Research

The two biggest projects within the GBCGE are the U.S. Department of State (DOS) International Capacity Building and the U.S. Department of Energy (DOE) INGENIOUS (INnovative Geothermal Exploration through Novel Investigations Of Undiscovered Systems).

International Capacity Building

The International Capacity Building project is within the DOS Bureau of Energy Resources Geothermal Development Initiative with a goal of overcoming barriers to geothermal resource development. The GBCGE five-year grant was extended to March of 2024. Our team, consisting of Dr. Emmanuel Olvera Garcia (Postdoctoral researcher), Maxwell Wilmarth (Research Geoscientist) and myself, initiate meetings with a country's geological survey and/or university faculty to determine if they can use our geothermal knowledge. We assist the country in applying the Play Fairway Analysis (PFA) process to local areas with potential geothermal resources not yet known. Together we analyze available data such as Quaternary faults, hot springs, strain, geological formations, well data, etc. – providing guidance about how each parameter can be incorporated into models to categorize specific areas with higher to lower potential for productive resources. Working alongside the country team on their evaluation process aids them in prioritizing their employee time and data collection budget.

For the past five years the focus was on South America in Argentina, Peru, and Colombia. A paper about our work in northwestern Argentina is already published (Lindsay et al., 2021). The southern Peru project includes parts of Tacna, Moquegua, and Arequipa regions. A Peruvian delegation attended the GRC in Reno last year and while here completed the PFA process with our GBCGE team. The related paper is expected to be completed later this year. The Colombian PFA results for the Azufral volcano area are being submitted to Geothermics.

This year the focus is on Asian-Pacific countries. Manny, Max and I just returned from Manila, Philippines where we worked with the Philippine Geothermal Energy Management Division within the Department of Energy, Renewable Energy Management Bureau (**Figure 1**). Although the Philippines is a leader in geothermal power production, they asked for assistance in teaching their team the PFA process to search for resources beyond the high-temperature, high-pressure zones. We used the Northwestern Luzon region to teach the PFA process as it has few visible surface manifestations. They also plan to use the PFA process to explore where more data collection, near the high temperature known geothermal areas, will be most beneficial in expanding those resources. Our work with the Philippines continues this summer with a final product being a combined paper and their PFA map of NW Luzon. A poster will be presented at the GRC meeting in Reno.

Thailand is the next country requesting our assistance with their Geological Survey and Chulalongkorn University. In September, we are also planning a workshop on the PFA process for the Indonesian government as part of the Indonesia International Geothermal Convention and Exhibition (IIGE).

INGENIOUS

The INGENIOUS project started as an extension of the Nevada PFA (Faulds et al., 2021), using it as a foundation of geological knowledge, research methods and tools. This project explores the Great Basin Region (GBR) – including

Figure 2: Basin and Range's western side looking towards Sierra's to the west in the Reno area.

the portions in California, Oregon, Idaho and Utah (**Figure 3**). It is a momentous U.S. DOE Geothermal Technologies Office award focused on assessing geothermal resources in the GBR. The project goal is to reduce the exploration risk for hidden geothermal systems in the GBR by depicting improved methods to determine resource potential, improved uncertainty of the PFA parameters, and at a few 'local' sites provide specifics of their geothermal prospects, using them as our test sites for methods. For the geothermal community, the project minimizes development risk through creating new geothermal favorability maps, data products, software tools, and a geothermal developers' playbook that integrates all the GBR findings with easy access for external stakeholders. These products will be useful beyond the GBR.

As we achieve the half-way point in the grant, we strive to be agile by finding solutions when setbacks occur and using varied approaches to define success. One example is working closely with the BLM Field office for our permits this year, as last year, BLM provided no permits for us to collect data (2-meter temperatures, gravity, magnetic, magnetotellurics (MT), paleomagnetic and rock property, and drone flown aeromagnetic) or for us to drill temperature-gradient (TG) wells in Granite Springs Valley.

Our summer plan is to combine fieldwork for our third local site in Buffalo Valley (**Figure 4**) (near Battle Mountain, NV), which is Quentin Burgess's MS thesis area at the University of Nevada (UNR), with the data collection of the U. S. Geological Survey (USGS) geophysical team (J. Glen, T. Earney, W. Schermerhorn, and G. Rea-Downing). The USGS team works with GBCGE to develop the local site 3D models processing of the geophysical data (data collection mentioned above plus 2D seismic lines). The 3D model is then sent to Jeff Witter of Innovate Geothermal Ltd., who improves the accuracy of matching all datasets by using the SimPEG program. The final 3D model is used for choosing drilling sites for temperature-gradient (TG) wells. With the additional well data, the review of the model is repeated. In this manner the team shows the benefits of specific data and tools for reducing exploration costs.

Our UNR graduate student, Mary Hannah Giddens, is using the Favorable Structures Setting (FSS) analyses to dig deeper into the geological settings most likely to produce a geothermal reservoir. These FSS analyses are based on fault type and placement (step-over, fault termination, fault intersection, accommodation zone, displacement transfer zone, etc.), first highlighted by the NBMG team in 2011 (Faulds et al.). As part of the INGENIOUS project over 1000

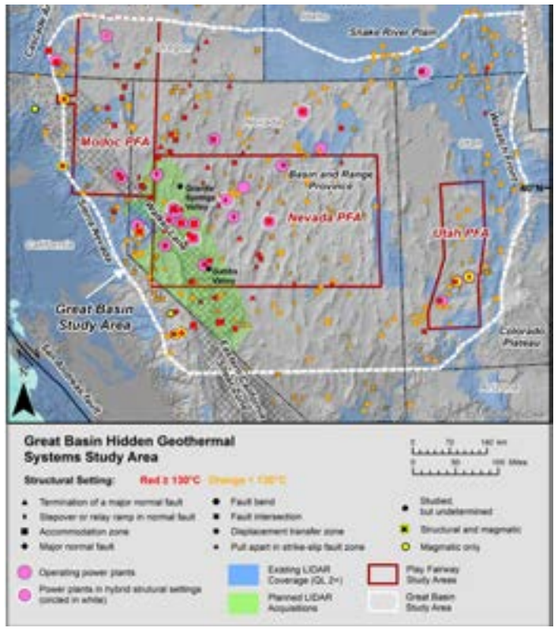

Figure 3: INGENIOUS map of the Great Basin region.

FSS were picked this spring by the Idaho Geological Survey (IGS) (C. Berti, Z. Lifton, R. Anderson, and R. Di Fiori), Utah Geological Survey (UGS) (S. Kirby, E. Szymanski, C. Hardwick, E. Kleber, A. Hiscock), Jim Faulds, Quentin Burgess, and Mary Hannah. It is a new dataset for the project.

Our fourth and last local site is being determined this summer with UGS as the lead. They are working with the PFA team, which is led by our PhD candidate, Nicole Wagoner, working with Mark Coolbaugh on the improved analytics for the PFA processing, including a review of value for each parameter. Another contributor is Steve Brown, Aprovechar Lab L3C, who mixes datasets with neural networks to determine ways to 'see' further into the Earth. Steve and the GBCGE team are incorporating the newly completed heat flow and machine learning efforts of the USGS team (J. DeAngelo, E. Burns, S. Mordensky, C. Lindsay) and Petrolern LLC (now Teverra, J. Batir and E. Gentry).

An example of a tool already used is the VOI (Value of Information) method of taking a large multi-aspect dataset and determining the specific value for each site (cell in models). This is being applied to drilling of TG wells at Granite Springs

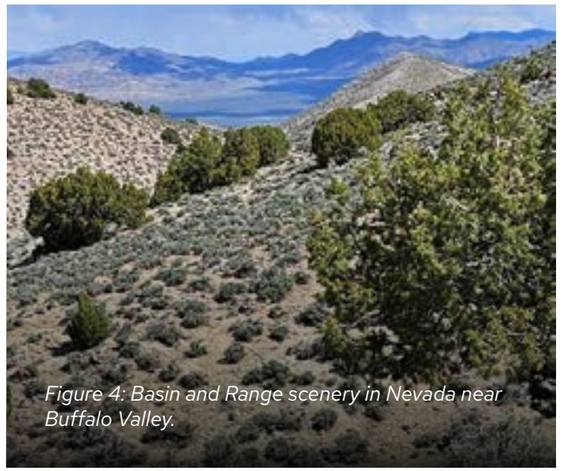

Figure 4: Basin and Range scenery in Nevada near Buffalo Valley.

Valley. VOI specialist Whitney Trainor-Guitton of the National Renewable Energy Lab (NREL) worked with Cyrq Energy as they narrowed the suggested drill sites enough to prove the resource and stay within budget. The drilling of TG or slim holes is the top expense for the project. We are working with Geothermal Resources Group (B. Rickard, M. Mann, and E. Rivas) to get new bids for drilling in early 2024. Based on cost and funding, the other TG well drilling will be at Argenta Rise and/or Buffalo Valley, in Nevada.

Other plans this summer are to install one or two passive seismic arrays in Nevada with the team from Lawrence Berkeley National Lab (C. Hopp, M. Robertson, and E. Majer) possibly in southeastern Gabbs Valley and/or Granite Springs Valley both in Nevada. With the multi-month data collection of passive seismic data, we will determine if it is possible to use this as a Great Basin tool for finding blind reservoirs with no surface expression. The deep sediments in some basins are a concern because the sediments may muffle beyond use the low-magnitude microseismic signals.

As the data gets completed for this project, it is uploaded into multiple platforms for users at every skill and interest level. The NBMG – GBCGE Subsurface Explorer dataset (http://gbcge.org/subsurface) was improved this spring for ease of access by GBCGE Data Manager, Eli Mlawsky. For those with limited ArcGIS skills, the Subsurface platform comes with explanations and built-in tools for you to manipulate the data. If you prefer to download data, then the NREL Geothermal Data Repository (GDR) is the place to find what you're looking for: https://gdr.openei.org/submissions/1391.

At GRC there will be a GBCGE – NBMG Expo booth, INGENIOUS session and posters. Please plan on discussing your ideas, use of the data, and potential collaboration. We look forward to socializing with you as we celebrate another year.

Since some of you know me from the Southern Methodist University Geothermal Lab, I'll be returning in January 2024 to Dallas full of new ideas after this fantastic opportunity this year at the University of Nevada-Reno. Congratulations Geothermal Rising on this first printed version of the Geothermal Rising Bulletin!

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Footnote

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Senator Heinrich picture: L to R: Emily Tucker (Clean Air Task Force), Jenna Hill (Clean Air Task Force), Terra Rogers (Clean Air Task Force), Dr. Will Pettitt (Baker Hughes), Lucy Darago (XGS Energy), Senator Martin Heinrich, John Redfern (Eavor Technologies), Katerhine Hamilton (38 North Solutions), Dr. Bryant Jones (Geothermal Rising), and Neil Etheir (Eavor Technologies).

Geothermal DC

Fly-in Summary

The Inaugural Geothermal Day on Capitol Hill was a smashing success. The geothermal event in Washington, DC brought together 130 people from over five dozen companies and organizations representing the three overarching segments of the geothermal industry (i.e., geothermal heat pumps, geothermal direct use, and geothermal power). The geothermal industry hosted over 60 meetings with congressional offices from across the country (e.g., Colorado, New Hampshire, Idaho, Massachusetts, South Carolina, Ohio, Hawaii, West Virginia, Minnesota, Arizona, Louisiana, etc.). We were thrilled to have Senators and Representatives join their staff to learn about geothermal technologies including Senators Lisa Murkowski (Alaska), Martin Heinrich (New Mexico), Ted Cruz (Texas), Jacky Rosen (Nevada), Bernie Sanders (Vermont), Catherine Cortez Masto (Nevada), Jon Tester (Montana) and Representatives Mark Amodei (Nevada), Wesley Hunt (Texas), Roger Williams (Texas), and John Carter (Texas), among others.

Geothermal Rising was excited to see the geothermal industry align and empower robust partnerships among so many non-profit partners such as the Building Decarbonization Coalition, the Conservative Coalition for Climate Solutions, Clean Air Task Force, ClearPath, HEET, Project InnerSpace, the Texas Geothermal Energy Alliance, Third Way, and the Vermont Community Geothermal Alliance, among others. Geothermal Rising looks forward to building on these and other partnerships.

Staff from the Senate Energy and Natural Resources Committee commented, “there were so many geothermal people in the building today meeting with their members.” Staff from Senator Schatz’s (Hawaii) office made a decision to organize a congressional delegation to visit geothermal and CCUS innovations in Iceland.

Left to right: Isaac Aviles (SLB), Congressman Wesley Hunt, Nathaniel Hartwig (SLB), and Edward Cazier (Suyapa Consulting)

Additionally, geothermal companies were able to fit in a meeting with the DOE Loan Program Office director, Jigar Shaw, and meet the new Under Secretary for Infrastructure, David Crane, who now oversees the Office of Clean Energy Demonstrations, a critical office for possible geothermal demonstration funding.

Impact from the geothermal industry fly-in is already demonstrating success. Geothermal Rising was invited to join a bipartisan U.S. congressional delegation to Iceland where GR Executive Director Dr. Bryant Jones will join Senators Brian Schatz (D-Hawaii), Lisa Murkowski (R-Alaska), Mike Bennet (D-Colorado), Cindy Hyde-Smith (R-Mississippi), and Peter Welch (D-Vermont) as well as Representative Scott Peters (D-California).

The congressional delegation will visit Iceland to explore and learn about the deployment of geothermal heat pumps, geothermal direct use (e.g., industrial and residential heating and cooling applications), and geothermal power generation. The delegation will meet with government leaders in Iceland as well as geothermal developers.

Other outcomes from the geothermal industry DC fly-in include follow up meetings with Democrat and Republican policymakers around geothermal-specific permitting reform, risk mitigation programs, and geothermal-specific funding through the DOE’s Office of Clean Energy Demonstrations.

GR plans additional DC fly-ins including making this event annual and hosting targeted thematic fly-ins with smaller groups of geothermal organizations. Reach out to Dana Groves (dana@geothermal.org) to sponsor next year’s Geothermal Day on Capitol Hill or Dr. Bryant Jones (bryant@geothermal.org) if your organization would like to arrange a thematic DC fly-in.

The Geothermal Technologies Office:

Setting the Course for the Future of Geothermal Energy

By: U.S. Department of Energy Geothermal Technologies Office

Imagine this: It's 2050.

Across the United States, geothermal power plants dot the land, small but powerful facilities feeding clean, dispatchable, baseload electricity to the nation's grid. In communities nationwide, people live and work in buildings that are kept warm in winter and cool in summer with geothermal heat pumps. College campuses, cities, and remote towns hum along above a system of geothermal district system piping, keeping buildings comfortable, melting snow off sidewalks and streets, and saving money for users. Industrial sites are tapping geothermal resources, too, directly using Earth's heat to dry paper and lumber, grow fresh produce, even brew beer. All the while, geothermal energy is contributing to new technologies aimed at saving the planet from climate change—from providing lithium for electric-vehicle batteries to supporting hydrogen production and direct-air capture. It's a world where geothermal is a central part of America's energy landscape.

As far as the U.S. Department of Energy's (DOE) Geothermal Technologies Office[1] (GTO) is concerned, this isn't just a set of imagined scenarios: It is the future of geothermal energy. We are targeting this future, where geothermal is an essential, cost-effective, and well-known clean energy resource. To get there, GTO is working across the resource spectrum to reduce costs and risks associated with geothermal development. We're doing this work in numerous ways, including research, development, and demonstration (RD&D) of innovative technologies and techniques that address key exploration and operational challenges, and modeling and analyses to support that technical work.

In partnership with industry, academia, and DOE's national laboratories, GTO works on RD&D in four program areas: Enhanced geothermal systems[2] (EGS), hydrothermal resources[3], low-temperature and coproduced resources[4], and data, modeling, and analysis[5]. Our activities across these program areas are holistic and complementary, with a focus on making advancements that can support all geothermal development. GTO's portfolio is broad and too much to cover in one article, but we'll share some key activities that are set to move the needle—or the drill bit—for geothermal energy.

The most notable recent update in GTO's portfolio is, of course, the launch of the Enhanced Geothermal Shot™[6]—a DOE-wide effort to reduce the cost of EGS electricity generation by 90%, to $45 per megawatt-hour by 2035[7]. While the Enhanced Geothermal Shot™ is not a specific activity itself, it is now the driving force behind GTO's EGS research. However, achieving this aggressive target will require overcoming both technical and nontechnical challenges. EGS requires engineering the subsurface environment miles below our feet, which is often hot, harsh, and corrosive. In addition, EGS and hydrothermal development both face barriers related to development timelines, permitting, and high capital investment.

In fact, GTO understands that improving existing technologies or inventing new technologies to advance EGS can benefit all the other forms of geothermal as well. Our 2019 *GeoVision* analysis[8] confirmed that EGS technology improvements can support vast potential to expand geothermal heating and cooling, as well as direct use. So even though the initiative is called the Enhanced Geothermal Shot™, it's really a geothermal moonshot that can help expand the use of the heat beneath our feet across the resource spectrum.

So what is GTO doing to get to our Enhanced Geothermal Shot™ goal and support geothermal development? The first and largest of GTO's initiatives is the Frontier Observatory for Research in Geothermal Energy[9], or FORGE, in Milford, Utah. Led by the University of Utah, FORGE is a dedicated field site where scientists and engineers develop, test, and accelerate breakthroughs in EGS technologies and techniques. FORGE RD&D focuses on strengthening understanding of the key mechanisms controlling EGS success—specifically, how to initiate and sustain fracture networks in basement rock formations. The objective is to de-risk EGS technologies and techniques for industry and create replicable pathways to commercial-scale EGS deployment.

In May 2023, the FORGE team started drilling its new producer well, known as 16B. The 16B well will intersect the fractures from the previous stimulation of the site's 16A injector well, allowing the team to create an EGS injector-producer well pair. The FORGE team will also do interference tests to evaluate the subsurface connections between these two wells and additional stimulations of both wells to improve subsurface flow pathways. This will allow flow testing between the two wells to measure heat extraction and power production potentials. These activities will add substantially to the understanding of EGS wells and reservoirs and GTO is excited to see the outcomes. FORGE is also preparing to announce selections in its second solicitation[10], which offered up to $44 million for projects in topics like induced seismicity monitoring, stimulation, and high-temperature proppants.

Meanwhile, GTO is anxiously awaiting applications for the EGS pilot demonstrations[11] authorized in the Bipartisan In-

frastructure Law. This $74 million funding opportunity will help us prove out the efficacy and scalability of EGS by funding projects using various well orientations, locations, and geologic conditions. This work will dramatically increase our ability to understand how EGS reservoirs behave nationwide, which is critical to advancing the technology.

GTO is also excited to see its Drilling Demonstrations initiative[12] ready to kick off. This initiative aims to reduce the cost of developing geothermal energy by improving drilling rates by at least 25%. Because drilling can represent more than half the cost of a geothermal project, improving rates is on the critical path to make geothermal competitive with other energy sources and spur more geothermal deployment. In December, we selected two projects[13] for this initiative: One in the Denver-Julesberg (CO) Basin that will drill twin high-temperature geothermal wells using existing and novel drilling technologies, and one in The Geysers (CA) that will use innovative drilling technology and varying methods in a range of temperatures and conditions. GTO also recently selected a team to lead the Geothermal Energy from Oil and gas Demonstrated Engineering initiative[14], or GEODE, which will help us apply techniques and lessons from the oil and gas industry to geothermal. GTO is excited to see these projects get underway and we're confident they will help the geothermal industry reduce costs, train the workforce, optimize drilling, and expand deployment.

GTO's portfolio also includes several projects making strides to accelerate discoveries of new, commercially viable hidden geothermal systems in numerous locations. For instance, GeoFlight[15], a collaboration with the U.S. Geological Survey where we are collecting data on hidden geothermal systems in California's Imperial Valley using specially equipped, low-flying aircraft, as well as the INnovative Geothermal Exploration through Novel Investigations Of Undiscovered Systems[16] (INGENIOUS) and Basin & Range Investigations for Developing Geothermal Energy[17] (BRIDGE). In addition, GTO is continuing work to assess opportunities for lithium extraction from geothermal brines, particularly in the Salton Sea. All of this work expands opportunities for geothermal energy.

Recently selected projects in our Community Geothermal Heating and Cooling Design and Deployment[18] represent a giant leap forward in GTO's efforts to expand the use of low-temperature (< 300°F [150°C]) geothermal resources for geothermal heating and cooling. This first-of-its-kind initiative will support 11 projects in 10 states to design and eventually deploy innovative community-scale district heating and cooling systems that help reduce energy costs and carbon emissions, train a skilled workforce, and provide benefits to local communities and underserved populations. Projects will also provide case studies and data that can help other communities nationwide understand how to design and implement such systems. These projects are also part of Justice40, President Biden's initiative to ensure that 40% of the overall benefits of certain federal investments flow to disadvantaged communities that are marginalized, underserved, and overburdened by pollution.

In addition to technical RD&D, GTO is working hard to address the nontechnical barriers that can hinder geothermal deployment. Our data, modeling, and analysis efforts include a range of projects in this area, including work to ensure better representation of geothermal and its costs in energy models and analyses to understand the benefits and impacts of geothermal deployment. We also recently supported and participated in an interagency task force[19] to assess opportunities to optimize geothermal permitting[20]on federal lands and funded several national-laboratory-led projects to evaluate other nontechnical barriers like valuation of geothermal in power purchase agreements[21] and barriers to geothermal in California and Nevada[22]. These efforts help GTO prioritize its RD&D efforts and provide policymakers and industry with valuable data and information to optimize decisions that impact geothermal deployment.

Speaking of barriers, we know that one of the concerns for geothermal energy is a lack of public knowledge or understanding—geothermal isn't the sun in the sky or the wind in your face, and people do not always realize there is energy right beneath our feet. To help address that, GTO continues to develop and use numerous tools for outreach and engagement. For instance, we launched a lithium storymap[23] last year—a web-based tool that will walk users through the importance of lithium and how geothermal energy can help the United States meet its need for this critical material. We are also redesigning our website[24] to provide updated and easier-to-access information about geothermal, and adding new ways to engage with GTO funding opportunities like stakeholder toolkits, infographics, and a quick guide to help interested parties navigate funding opportunity documents[25]. We are always looking for creative ways to educate, boost awareness, and ensure that outreach supports GTO's focus on engaging and supporting underserved and disadvantaged communities.

GTO knows that geothermal energy provides amazing opportunity for the nation's clean energy future: zero-carbon, renewable baseload power[26]; efficient, low-carbon heating and cooling[27]; clean energy jobs; and a more equitable energy system. Hopefully this snapshot of the amazing work going on at GTO and through our research partners gets you as excited about the future of geothermal energy as we are! GTO is laser focused on that future, but we're not the only ones critical to moving the needle. Everyone with an interest in geothermal has an important role to play if we are going to bring this clean, renewable technology to the forefront in America's energy picture.

GTO looks forward to the challenges and opportunities each new day brings in geothermal. We know that together, we will realize that vision of an energy future with geothermal at its core.

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Geothermal
at the Discovery Museum

The Terry Lee Wells Nevada Discovery Museum, generally referred to simply as the Discovery Museum, is a 67,000 square foot, interactive science museum in Reno, NV. As a proud sponsor to The Discovery's local educational efforts, Geothermal Rising's mission is to connect the geothermal community and champion geothermal energy not only in the United States, but also around the world. As such, Geothermal Rising is working to develop a geothermal exhibit for the Discovery Museum to be unveiled at the 2023 GRC.

Working with the Geothermal Rising Communication Committee, a local Reno, Leland Davis, who also happens to be on the board at The Discovery, started working on the idea for a museum exhibit in 2022. The idea grew from just that, an idea, to a fundraiser and now is morphing into an exhibit in The Discovery, as well as working on an exhibit that can move around the country to grow outreach in a tremendous way.

"The geothermal exhibit project is an amazing opportunity for the geothermal industry, and specifically Geothermal Rising, to raise the profile of this renewable energy resource that is literally in the backyard of the residents of Reno," said Kelly Blake, Board President of Geothermal Rising.. "This project enthusiastically furthers the objectives and goals of Geothermal Rising, specifically by raising and broadening public awareness of geothermal. We could not be more proud of this partnership with The Discovery Museum and for future opportunities to rotate a geothermal exhibit around the country."

Education for a sustainable future

Some of Geothermal Rising's objectives are to elevate innovation in geothermal technologies, and build an enabling environment that will allow expansion of the industry. Geothermal energy is also a crucial component of our transition to a sustainable future, and it's important to teach the next generation about this nearly unlimited resource so they can continue the great Geothermal revolution. This new exhibit aims to put geothermal energy into the spotlight, and educate the public about how this essentially unlimited source of energy can help ensure that future generations inherit a healthy and habitable planet.

The exhibit caters to visitors of all ages, from young children to adults. One of the aims is to provide adult visitors with knowledge on what geothermal resources can offer, as well as address misinformation that some may have about the resource. The goal is to provide everyone a well-rounded understanding of geothermal's potential to enrich lives, and encourage more people to become geothermal supporters. Hopefully this will inspire younger generations to pursue careers in the geothermal field, ones they may not have otherwise known. Spreading awareness of geothermal's success across the globe can play an integral part in enrolling newer generations into fields where they can innovate and make a difference in the world.

The value that this exhibit brings to the geothermal community is immense, and it's an exciting opportunity for the public to gain an understanding of this renewable resource. Not only does it raise awareness of its growing potential and accessibility, but it will also spark interest and enthusiasm to participate in the industry that's gaining global traction. The open source design component aims to help propel that objective by reaching museums and visitors around the world.

The geothermal exhibit is made possible by help from generous sponsors and volunteers, including BHE Renewables, Geothermal Rising, Ormat, Geologica, Eavor, Business on Camera, Cyrq, Toshiba, and SteveIOR.

Through donations, you'll be supporting the exhibit's initiative to teach children and parents fundamental knowledge of geothermal resources, give older students insights into the industry they may want to pursue as a career, and encourage everyone to learn more about this reliable, sustainable, green energy that has the potential to change our world.

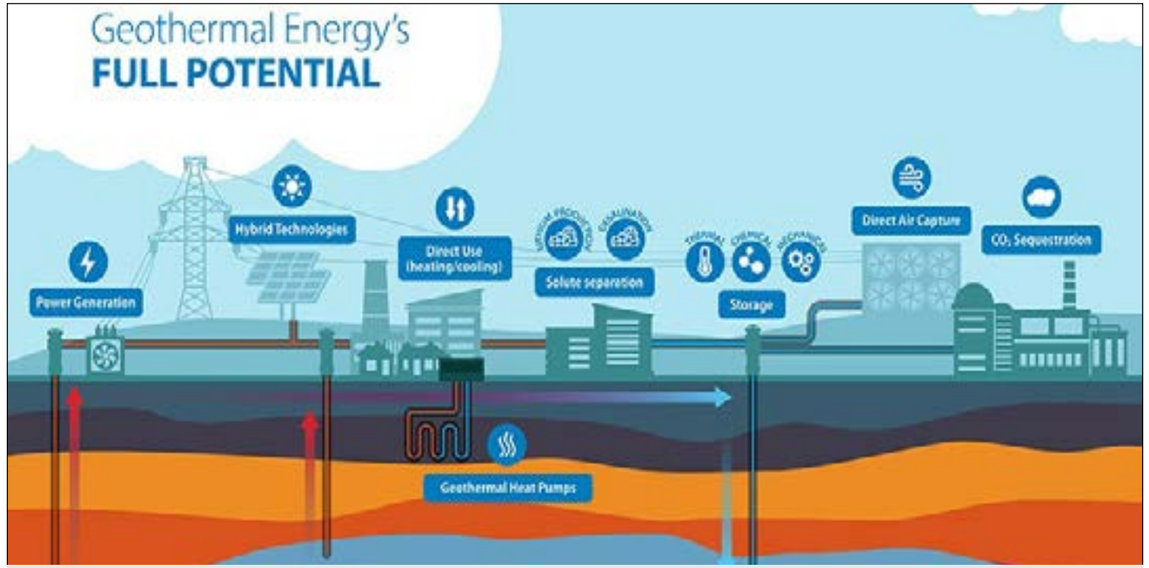
To learn more about supporting this initiative, please visit www.geothermal.org.

Full Steam Ahead:

Unearthing the Power of Geothermal

Lesser known than some of its renewable energy cousins, geothermal energy is now on the rise thanks to its ability to provide 24/7 power, heat, cooling, critical minerals, and more.

By Kelly MacGregor, NREL



Geothermal energy has the potential to assist with many aspects of the transition to a clean energy economy, including energy storage, mineral extraction, and more. All photos and graphics courtesy of NREL

While geothermal power plants have delivered renewable power for more than 100 years, recent research and advancements have shown that geothermal is more than a 24/7 clean power source.

"Geothermal is a triple resource: an energy source for heating, cooling, and power; a storage resource; and a mineral resource," said Amanda Kolker, geothermal laboratory program manager at the National Renewable Energy Laboratory (NREL). "The Earth itself has the potential to address a variety of hurdles in the transition to a clean energy future." With the ability to provide electricity, heating, cooling, and storage—plus the potential to access critical minerals, capture and sequester carbon, produce green hydrogen, and more—the natural heat of the Earth is a powerhouse ready to be tapped.

And investors and leaders across both the public and private sectors are moving full steam ahead with geothermal. Colorado Gov. Jared Polis recently launched "The Heat Beneath Our Feet"[1] initiative to encourage renewable geothermal energy generation in Colorado and other western states. As part of the project he toured the lab to learn about NREL's geothermal research portfolio[2].

From improving geothermal resource identification[3] to advancing drilling techniques[4] to expanding emerging technologies[5], read on to see how researchers at NREL are discovering how geothermal can use the planet to save the planet.

Emerging Geothermal Technologies

New technologies can bring missing components to areas that do not have them naturally and can enable geothermal on a community or household scale, opening the door for geothermal everywhere[6].

One emerging technology, enhanced geothermal systems (EGS), can bring the missing pieces (water or pathways through the rock), allowing for geothermal power generation in areas where it was previously unavailable.

"The U.S. Department of Energy is putting a great deal of investment into EGS with the recent Enhanced Geothermal Shot[7] as part of the Energy Earthshot[8] initiatives, funding for new EGS demonstration sites[9], and the current Utah

FORGE[10] demonstration site," Koenraad Beckers, an NREL researcher, said.

NREL participated in the EGS Collab Project[11], which ran experiments one mile underground at the Sanford Underground Research Facility[12], a former gold mine in South Dakota. EGS Collab provides a stepping-stone between laboratory tests and full-scale EGS deployment through cooperation between nine U.S. Department of Energy national laboratories[13], seven universities, and two industry members.

Closed-loop geothermal, also known as advanced geothermal systems, are another emerging technology for areas where traditional hydrothermal is not present. With these systems, water or another heat transfer fluid flows through pipe systems engineered for the specific area instead of through the subterranean rocks.

"With closed-loop systems, you keep the fluid within your well and pipes, and the pipes are exposed to the hot rock," Beckers said. "NREL can simulate both EGS and closed-loop systems for industry and government partners, providing important pre-validation that is required before major investments are made deploying new technologies."

Another frontier for geothermal energy is being explored in the DEEPEN project[14], a multinational project that aims to discover how a new type of resource—supercritical or superhot geothermal—can be harnessed using emerging technologies. Tapping geothermal resources that exceed the critical point of water (where liquid water and vapor are indistinguishable) has the potential to power millions of homes. NREL is working to develop new methods for exploring and characterizing these extra-hot systems, and the project, a collaboration between international universities, institutes, and energy companies, hopes to tap into the tremendous potential.

"The energy from a single superhot geothermal well could produce 5–10 times what a commercial geothermal well produces today," Kolker said. "If we can find and produce these systems, this could be a game-changer."

Tapping the Untapped

While emerging technologies are key to scaling geothermal energy, there are still abundant resources that could be tapped using conventional approaches. The United States currently leads the world in geothermal electricity production due to the natural, ideal geothermal conditions in the western states —evidenced through hot springs and geysers right on the surface. But how can we find the areas naturally best suited for the large-scale geothermal power plants that power thousands of homes?

"NREL is developing new modeling methods to allow us to statistically find the best places to put geothermal wells to have the most success," Whitney Trainor-Guitton, an NREL geothermal researcher, said. "When you are talking about drilling a very expensive $10 million well, we need sophisticated methods to understand the likelihood of the resource being there."

The oil and gas industry has developed similar modeling techniques for their exploration over the past several decades, but the conditions needed for oil and gas are different than those needed for geothermal.

"These models have been well developed for oil and gas because the value proposition was more obvious; brilliant minds went to developing these techniques," Trainor-Guitton said. "Geothermal is on the precipice of this happening, and NREL is at the forefront."

Data science can also help improve our assessment of large, untapped geothermal resources by consolidating data sets from around the world and using machine learning algorithms to recognize what responses in those data sets are favorable.

"Broadly speaking, there are a lot of tasks that are too time-consuming or challenging for humans to do on their own," said Nicole Taverna, a geothermal data scientist at NREL. "Data science lets us take the next step beyond what the human brain is capable of and recognize patterns we might miss."

Geothermal Everywhere

While finding the perfect location for a geothermal power plant can take time, harnessing the resource for heating and cooling can be as simple as digging out a basement, thanks to modern heat pump technologies.

"It doesn't have to be this amazing, dramatic volcano," said Trainor-Guitton. "We can use 55°F groundwater to heat and cool bus terminals, college campuses, and even whole towns."

While most geothermal heat pump installations in the United States are for individual buildings, they are used worldwide for heating and cooling large networks of interconnected buildings.

"International collaboration is increasing for direct-use technologies," Trainor-Guitton said. "A new project with Geothermica[15], called FLXenabler, is evaluating the flexibility provided for communities when geothermal heating and cooling is integrated with other renewable energy sources and thermal energy storage."

The FLXenabler consortium includes representatives from SINTEF (Norway), Equinor (Norway), TU Wein (Austria), the U.S. Geological Survey, and NREL's crosscutting research in subsurface characterization, power systems modeling, buildings research, and thermal energy storage.

"I am excited about the increased interest in direct use, because historically in the U.S. the focus has been on power production," Beckers said. "Direct-use heating and cooling was overlooked until now, even though we use a lot of heating in this country, and it can be used everywhere."

NREL's partnership with Con Edison[16] to study transitioning New York City's steam system, which powers the Empire State Building and is currently run on natural gas, to geothermal is evidence of the increased interest in direct use. NREL researchers are addressing geotechnical, economic, and logistical issues to understand the opportunities and challenges of using geothermal energy for generating steam in New York City. If converted to only 10% geothermal, this system would be the largest geothermal district heating system in the United States.

Reduce, Reuse, Recycle... and Repurpose

As NREL researchers work to refine models for geothermal exploration and expand direct-use applications, already drilled wells can be repurposed for geothermal in the meantime.

"Exploratory drilling is a huge upfront cost for geothermal development," Kolker said. "But there are thousands of oil and gas wells across the country that have already been drilled, some of which can be either repurposed for geothermal or used for coproduction of geothermal and hydrocarbons."
Two projects are currently underway, in Oklahoma and Ne-

vada, to generate 1 MW or more from oil and gas wells. One project aims to create a roadmap for "geothermal cogeneration"—generating geothermal energy at the same time as active oil and gas extraction—while the other aims to repurpose an abandoned well.

And when wells cannot be repurposed, the investment to drill new wells can be used to push the boundaries and create novel drilling techniques.

The Geothermal Limitless Approach to Drilling Efficiencies (GLADE) project aims to do just that. The project, funded by the U.S. Department of Energy Geothermal Technologies Office[17] in partnership with Occidental Petroleum, will drill twin high-temperature (572°F) geothermal wells deeper (up to 20,000 feet) and more quickly than most existing wells. This demonstration project seeks to reduce project timelines and costs for developing geothermal power plants by creating a 25% improvement in geothermal drilling rates.

Earth as a Battery?

Geothermal energy storage is attractive because not many other technologies currently have the capability for long-duration storage. And those that do also have high expenses or impacts, such as building giant storage tanks, sourcing rare-earth materials like lithium, and lacking recycling options.

"But the Earth itself is a storage tank," said Guangdong Zhu,

NREL group manager of thermal energy systems and executive director of the Heliostat Consortium for Concentrating Solar-Thermal Power[18].

Earth's subsurface can provide energy storage as thermal energy (heat), chemical storage (of carbon dioxide—better known as carbon sequestration—and of hydrogen and other gases), and mechanical storage (by repurposing infrastructure at depth, such as wells, for this purpose).

One NREL project, Repurposing Infrastructure for Gravity Storage using Underground Potential energy[19] (RIGS UP), is exploring the commercial viability of gravity-based mechanical storage systems using oil and gas wellbores. The ARPA-E-funded[20] project will store electrical energy as potential energy by lifting a multi-ton weight within a wellbore. Once proven, the technology could also be used inside of inactive geothermal wells for long-term mechanical storage.

NREL researchers are also partnering with legacy oil and gas companies to make geologic thermal energy storage a reality.

"Some rock systems are not great storage systems, but oil and gas fields are sedimentary and have good storage potential with sizeable pores—they could store gas, which means they can store water and thermal energy," said Dayo Akindipe, NREL subsurface energy systems research scientist.

Oil and gas sites that are no longer producing can be cleaned up and transitioned to mechanical or thermal energy storage—removing environmental contamination and transitioning jobs in those areas to the clean energy economy. NREL scientists are working with oil and gas companies to identify demonstration sites to accelerate this transition.

Mining Made Better—Lithium

Geothermal energy also has other battery-related applications. The salty, hot water that is heated underground and brought to a geothermal power plant can also contain rare minerals—like lithium[21]. The scarce mineral is essential for rechargeable batteries in electric vehicles, pacemakers, cell phones, and more. And recovering the mineral from water already being brought to the surface, rather than traditional mining operations, is better for the planet.

"As we transition to electric vehicles and battery storage for solar and wind power, the need for lithium is rising[22]," Kolker said. "Geothermal energy may be able to help in a sustainable way."

Only 1% of lithium used in the United States currently comes from domestic sources. An NREL analysis focused on lithium[23] found that it is economically feasible for geothermal brines to yield approximately 24,000 metric tons of lithium per year, enough to establish a secure, domestic supply of the scarce mineral.

One area in particular, California's Salton Sea[24], has immense potential for both geothermal energy and mineral capture through direct extraction technologies.

"Recent lab studies show that direct lithium extraction, a relatively new technique, can be more sustainable for the planet than current hardrock mining or evaporative pond techniques when we look at land use, water use, and carbon intensity of the operations," Kolker said.

Future lithium research[25] aims to advance the development of a domestic lithium supply chain through extraction from geothermal brines.

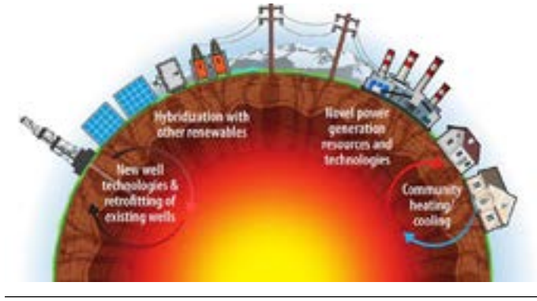
The Future Is Hybrid

In the sprint to transition off fossil fuels, geothermal is poised to help intermittent renewable technologies, like solar and wind, by providing a baseload fallback. And when you couple geothermal with other renewable technologies at the same site, the hybrid result is often better than either technology alone.

"By pairing solar and geothermal, we can design a system that naturally incorporates and takes advantage of the superior aspects of both technologies," Zhu said. "The solar can increase the heat for the geothermal system, leading to more electricity generation, and the geothermal system can store excess energy from the solar."

NREL researchers are experts in geo-solar integration optimization, maximizing power plant performance and storage capabilities for systems that house additional heat from concentrating solar power[26] systems in geothermal reservoirs.

Further, by using geothermal resources for power when adequate, and hybrid technologies when they are not, communities can even create their own microgrids for heating, cooling, and power. Such microgrids provide reliability and resilience against energy supply chain issues and extreme weather events. They also have the potential to create local jobs. NREL is helping communities by analyzing geothermal microgrid technologies as resources for isolated grids.



"At any scale, a decarbonized grid is going to be a mixture of renewable technologies, including geothermal," Kolker said. "That is the future."

1. https://westgov.org/initiatives/overview/the-heat-beneath-our-feet
2. https://www.nrel.gov/geothermal/technologies.html
3. https://www.nrel.gov/geothermal/2-point-0.html
4. https://www.nrel.gov/geothermal/advanced-wells.html
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Policy Committee Initiatives for 2023

Geothermal Rising's mission is to help the world "use the earth to save the earth" to leverage the extraordinary potential of our underground thermal resources to facilitate our nation's transition to a carbon-free economy. Geothermal Rising's Policy Committee (GRPC) supports this mission by advancing a comprehensive agenda of federal and state-level policies, regulatory work, and general actions to accelerate the deployment of:

- Electric power and heat production from conventional and unconventional geothermal reservoirs as well as from existing oil and gas wells,
- District heating from geothermal direct use resources,
- Residential heating and cooling from geothermal heat pumps,
- Critical mineral harvesting from geothermal brines, and
- Geothermal energy as an enabler of other green technologies like green hydrogen and direct air carbon capture (DAC).

The Policy Committee is currently chaired by Sarah Jewett, Vice President of Strategy at Fervo Energy, and it meets once monthly. Members interested in joining the committee should contact Dana Groves at dana@geothermal.org.

The GRPC currently represents 17 companies which embrace a range of technological approaches to geothermal development. The committee has two membership levels – Board and Corporate – and includes five subcommittees focused on appropriations, permitting, state and regulatory, innovation and tax. As topics are introduced, we generally assign them to a subcommittee, and further subcommittee organization may take place over time to reflect our strategic objectives.

Sub-Committee	Sub-Committee Chair
Appropriations	Sarah Jewett, Fervo Energy
Permitting	Caity Smith, Zanskar
Regulatory and State Policy	Jeanine Vany, Eavor Technologies
Innovation	Terra Rogers, Clean Air Task Force
Tax	Vacant – recruiting

Board Level members include Berkshire Hathaway Energy Renewables, Calpine, ClearPath, Eavor, Fervo Energy, Ormat Technologies, Clean Air Task Force, and Chevron. Corporate Level members include Cyrq Energy, SLB, Geothermal Resources Group, Halliburton, Zanskar, Transitional Energy, GreenFire Energy, XGS Energy, and Criterion Energy Partners. Clean Air Task Force (CATF) is a recent member of the Geothermal Rising coalition and takes no position on the opinions expressed in this article. We are actively looking to grow our corporate and board level memberships to increase the strength of our external outreach efforts.
This article provides a review of the major topics identified by the GRPC subcommittees for the 2023 calendar year. While we use these topics to establish advocacy priorities, the GRPC is also responsive to industry needs as these arise.

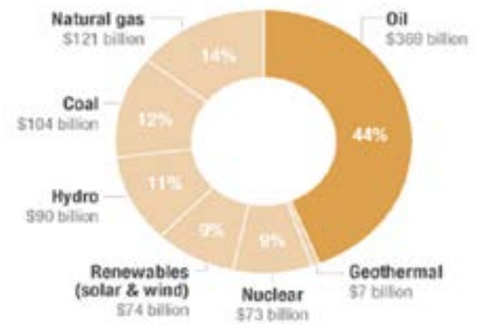
Appropriations

The Appropriations Subcommittee translates the geothermal industry's needs across a range of objectives into requests for federal budget appropriations. Some of these requests are general, whereas others are very specific. The subcommittee is primarily active during the budget cycles, whereas following final budgetary decisions, some of the topics are subsequently taken up in other subcommittees for further clarification and implementation. Other topics may remain within the Appropriations subcommittee. Subsequently, program evolution is monitored by all the subcommittees and channeled back into the next round of appropriations requests.

Our federal appropriations requests issued in March 2023 are summarized on the Geothermal Rising website under Bulletin Blog.

Technology RDD&D

During the appropriations process, we put a particular emphasis on research, development, demonstration and deployment (RDD&D) as the foundation for geothermal expansion. Geothermal is already enjoying a revived interest in research and demonstration funding, and one of our highest policy priorities is to amplify this trend and bring geothermal funding into the ranks of the competing resources. A 2021 Resources for the Future study, titled The Value of Advanced Energy Funding, analyzed the value of funding additional RD&D for advanced energy projects. While that study found that the benefits of funding geothermal energy projects would far exceed the costs, the federal budget for geothermal appropriations has historically lagged that of other renewables.



Federal Energy Incentives between 1950 and 2010.
Source: Energy Information Administration.

Figure 1

The study estimated for geothermal energy that the industry would experience a 30% cost reduction by 2035 due to ten-year RD&D funding and that the benefit-to-cost ratio from ten years of RD&D funding would be at least double that of advanced nuclear, natural gas with Carbon Capture & Storage (CCS), diurnal storage, or DAC.

Figure 2. Estimated Average Cost Reductions in 2035 Due to 10-Year RD&D Funding

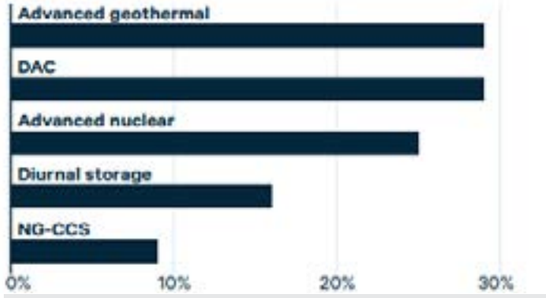


Figure 2: Funding; RFF Report.

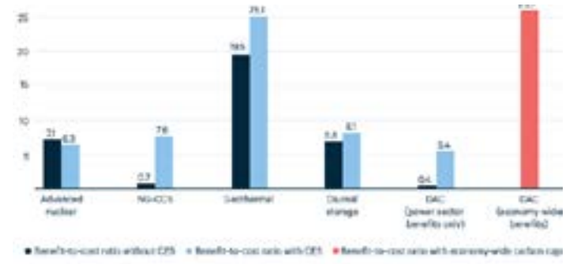


Figure 3: Estimated Benefit-to-Cost Ratios from 10 Years of RD&D Funding.

With this in mind, among other things, the appropriations subcommittee supports an:

- Increase of geothermal-specific federal appropriations to DOE offices such as the Geothermal Technologies Office (GTO), Building Technologies Office (BTO), Office of Manufacturing and Energy Supply Chains (MESC), and Office of Fossil Energy and Carbon Management (FECM) to encourage widespread innovation and necessary early-technology readiness level (TRL) technology deployment, increasing feasibility and competitiveness in the marketplace;
- Clarify through appropriations language that DOE shall specifically include funding opportunities for geothermal power, heat pump, and direct use demonstration projects through the Office of Clean Energy Demonstrations (OCED) using already appropriated Infrastructure Investment and Jobs Act (IIJA) funding. Geothermal was not listed in the 11 technologies that authorized the creation of OCED in 2021.
- Increase of geothermal-specific federal appropriations to support development and raise the profile outside DOE by specifically incorporating geothermal into existing grant programs at the Departments of Agriculture, Commerce, Defense, and the Interior.
- Write into FY2024 appropriations language that DOE and OCED specifically include geothermal in one of the 6 to 10 regional clean hydrogen hubs funded by the IIJA.
- Restart a financial risk mitigation program specifically for geothermal power, heat pump, and direct use technologies that will mitigate the cost of drilling and well exploration. A risk mitigation program, such as those previously authorized by the Congress in 1978, resulted in noticeable geothermal growth through the 1980s.

Several of these RDD&D initiatives will be advanced by the Innovation Subcommittee described below.

Financial Support

A second area of high priority in the appropriations requests was different types of financial support from the federal government. Our committees have been active in 2023 in addressing options for financing which involves federal and state government participation, including financial incentives, government grants, loan guarantees, insurance, and different types of public-private financing partnerships. Some of these topics will remain under the Appropriations Subcommittee, but the Regulatory Subcommittee has also weighed in with follow-on comments on program design (see discussion below).

Proposed loans for risk mitigation

For FY 2024, our largest single appropriations request has been for $500 million in loan authority for DOE to use for risk mitigation programs for district cooling/heating and electric power drilling, exploration, and deployment projects. Following a model used successfully in other countries, one objective would be to provide loans or insurance for exploration which are converted to grants in the event that the exploration is unsuccessful.

Public-private partnerships for venture capital

In our appropriations request and also in other comments, we have asked that DOE be allocated $36 million to form a geothermal Public Private Partnership Venture Capital fund in FY 2024, on the model of In-q-Tel. If this initiative moves forward, then we expect to be involved in the further design of such a fund.

Market development

The government can take a role in market development through specific measures to facilitate supply chains and stimulate procurement of geothermal resources of any types for governmental and non-governmental customers. Another driver of market development which federal and state government policy influences is the infrastructure planning processes discussed in the Regulatory Subcommittee section below.

Our initial activities in this area have included some recommendations for major initiatives as well as many other smaller efforts which could gain traction over time.

Support for the oil and gas industry transition to geothermal

An area of market development which gets policy attention is the transition of oil and gas capabilities to geothermal applications. Geothermal Rising was selected as one of the consortium program administrators to administer the GTO's Geothermal Energy from Oil and Gas Demonstrated Engineering (GEODE) initiative, which aims to leverage best practices from the oil and gas industry for geothermal development. DOE is contributing $10 million for this consortium and to create a roadmap for up to $155 million in future investments. In our FY 2024 appropriations recommendations, we also suggested $12 million for DOE's Office of Fossil Energy and Carbon Management (FECM) to provide grants to repurpose oil and gas assets such as abandoned wells.

Supply chain development

Supply chains will be critical to the success of an expansion in geothermal technology, particularly if there are domestic content requirements to obtain government financing. In our FY 2024 appropriations recommendations, we have recommended that DOE's Office of Manufacturing and Energy Supply Chains (MESC) get $100 million to secure the domestic supply chain for Organic Rankine Cycle (ORC) or turbine manufacturing.

In addition to these major initiatives, we highlight the following:

- Government direct procurement – increased federal and state government engagement in the procurement of heat pumps for government buildings as well as to facilitate commercial development; DOE has recently announced funding for national labs to facilitate conversion of buildings at DOD installations.
- Social equity – support for social equity measures in economic development, including the siting of geothermal installations of various types to address the needs of disadvantaged groups and to address pollution in lower-income communities, with initial attention on support for tribal nations.
- Workforce development – DOE funding to address the aging work force and to scale the industry, with initial attention on technical and vocational programs in community colleges.
- Export markets – support for development of export markets for geothermal technologies, with initial attention on additional loan authority for the U.S. Export-Import Bank.

As we go forward in 2023-24, some of these topics will remain under the Appropriations Subcommittee, but the Regulatory Subcommittee has also weighed in with follow-on comments on program design (see discussion below) and the Innovation Subcommittee is expected to contribute.

Geothermal Rising Executive Director, Dr. Bryant Jones, presented to and joined a congressional delegation of U.S. Senators and their staff from Alaska, Colorado, Hawaii, Minnesota, and Vermont in Iceland to see geothermal technologies and applications. The delegation included U.S. Senators Lisa Murkowski, Michael Bennet, Brian Schatz, and Tina Smith as well as the staff of Senator Peter Welch and U.S. Ambassador to Iceland, Carrin Patman. The delegation visited geothermal power plants including ON Power and Baseload Power as well as learned about direct use geothermal greenhouses, geothermal heat pumps, thermal energy networks, direct air capture, and carbon capture technologies.

Innovation

With the Appropriations subcommittee kicking off our efforts in 2023-24 to advance RDD&D, the newly formed Innovation Subcommittee will take many of these topics forward into program development in order to advance innovative technologies that would catalyze the widespread deployment of geothermal energy. Identified priorities include:

- Building relationships between industry and national laboratories to support geothermal innovation,
- Categorizing budding innovations to incentivize organized, cross-industry collaboration,
- Identifying innovative commercial structures to incentivize geothermal development,
- Mapping the potential impacts of low TRL geothermal technologies,
- Identifying opportunities for international collaboration, and
- Standardizing a geothermal glossary to reduce public uncertainty and confusion.

The Innovation Subcommittee has already made progress advancing several initiatives, including the formation of a public-private Geothermal Center of Excellence to ensure effective development and deployment of geothermal projects.

Permitting

The federal permitting process presents a hurdle to building new geothermal energy projects on public lands. The process of analyzing and seeking multiple approvals required by the National Environmental Policy Act of 1969 (NEPA) to develop on public lands can take up to five years and is lengthier and more prone to delay for geothermal than for other renewables or for oil and gas industry projects.

The GRPC proposes the federal government take common-sense steps to streamline permitting for geothermal projects. Congress should address the disproportionate permitting burden on low-impact geothermal activities; surge resources to expedite geothermal permitting processes and allow for quicker NEPA processes when possible.

Renewable energy development on public lands should incorporate careful consideration of environmental impacts. However, the current permitting process is replete with duplicative assessments and opaque, prolonged processing, making it difficult for developers to effectively plan, finance, and build projects.

Across multiple critical phases of development, permitting and NEPA assessment timelines are consistent bottlenecks and are lacking in transparency, adding uncertainty to an already risk-laden and unduly time-consuming process.

In our appropriations requests, we proposed that the Department of the Interior (DOI) be allocated $15 million to speed up permitting by creating a National Center to Review Geothermal Permit Applications.

Related, the Bureau of Land Management (BLM) could equalize decision making across offices and states with a set of standard operating procedures for geothermal permitting that would greatly speed up development.

Additionally, the ability of BLM staff to work remotely rather than relocating to isolated locations such as Winnemucca or Battle Mountain, Nevada would attract more candidates to help alleviate staffing issues that the geothermal industry experiences at all BLM field and district offices. With the new language in the debt ceiling bill around Environmental Assessment (EA) / Environmental Impact Statement (EIS) timelines BLM is going to need to hire new staff to meet the condensed schedules.

To improve NEPA inefficiencies related specifically to geothermal and foster significant growth in geothermal energy development on public lands, the federal government should:

- Strive for parity between permitting for geothermal energy and oil and gas projects,
- Expand the application of Casual Use Reviews, Determinations of NEPA Adequacy, and Categorical Exclusions in place of full EAs and EISs where appropriate,
- Implement programmatic EAs and EISs to streamline the NEPA process,
- Increase transparency of permit tracking and agency delays,
- Allow for the combination of environmental analyses for multiple phases of geothermal development, and
- Allocate greater resources to the Bureau of Land Management to facilitate permitting and reduce backlogs.

GRPC only expresses its supports for these streamlined NEPA efficiencies when it comes to geothermal exploration and development.

In addition, we would like the BLM to ensure that the development of wind projects on BLM managed lands does not preclude the development of geothermal resources on those same lands. A wind project should never be provided an exclusive right-of-way that precludes geothermal development, given that both operations can co-exist without negatively impacting each other, given minor boundary conditions (e.g., established distances between geothermal wells, wind turbines, other renewable energy infrastructure, and pre-existing transmission facilities, etc.). Under an All-of-the-Above energy policy, it is imperative that all renewable energy resources are given equal access to land and development opportunities. As many of these technologies have different land requirements, it would make sense to co-locate technologies where possible to have the smallest overall land impact possible.

The GRPC will continue to engage policymakers in Washington, DC to take common-sense steps to streamline permitting for geothermal projects.

Regulatory

The Regulatory Subcommittee has a broad mandate to engage with both federal and state regulatory issues and other state policy topics, in coordination with the other GRPC subcommittees. The subcommittee has already been very active in 2023 and looks ahead to sustained efforts into 2024. Many of its topics will build on the initiatives identified by the Appropriations Subcommittee.

Major priorities for the Regulatory and State Policy Subcommittee include:

- Reforms to processes for leasing federal lands,
- Encourage the procurement and transmission of geothermal energy by highlighting successful resource planning models that incorporate geothermal resources into IRPs for utilities, illustrating the benefits of firm, clean dispatchable energy,
- Monitor and support regulatory reform on grid interconnection,
- Build market support for geothermal energy deployment through continued assessment of how geothermal is represented in resource planning tools and methods, ensuring accurate comparative valuation of clean energy resources, and supporting improved planning coordination on regional geothermal resources across the western US, and
- Identify and explore demand side support mechanisms.

Already in 2023, the Regulatory and State Policy Subcommittee has submitted comments in a number of state legislative and regulatory proceedings, as well as to DOE. In Hawaii, we commented on SB 458 related to the use of geothermal royalties. In Texas, we commented on SB 785 on the clarification of geothermal ownership rights, SB 786 on the consolidation of closed-loop permitting under the jurisdiction of the Texas Railroad Commission, and SB 1210 on repurposing orphaned oil and gas wells into geothermal wells. In California, we commented on the California ISO's (CAISO) Subscriber PTO RFI. Finally at the federal level, we submitted comments to DOE on market mechanisms and public-private financing which are discussed below. We also submitted comments and quotes in support of the geothermal-specific provisions included in the House Natural Resources Committee permitting reform bill (H.R. 1)

We turn now to some of these topics and additional items in more depth.

Leasing federal lands

We believe the federal government should return leasing processes to a prior framework that was utilized before the Energy Policy Act of 2005, whereby certain federal lands with known geothermal resources (Known Geothermal Resource Areas; KGRAs; defined by the USGS) were made available to lease under competitive lease auctions when nominated, while all other federal lands (outside of parks, designated wilderness areas, or other conservation easements) were available for non-competitive leasing. Several states now utilize a related non-competitive exploration structure (e.g., Alaska) by issuing exploration permits that give explorers exclusive rights for a several year period to explore for geothermal resources on that property, and if a discovery is made, to non-competitively lease the geothermal rights. Such a non-competitive structure incentivizes markets to fund geothermal exploration, akin to the mineral industry's junior mining and prospect generation ecosystem. This structure would allow the industry today to increase the rate of geothermal discovery across federal lands where a substantial portion of geothermal resources are blind (i.e., no hydrothermal surface expressions). Increasing the pipeline of prospects across federal lands is critical to the industry meeting today's, and the projected future market's, offtake demands.

We also advocate that federal lease sales are held more regularly than they currently are. In Nevada, they are held annually, while in other states, they are held ad hoc, or are greatly delayed (e.g., in Utah, the BLM lease sale has been delayed from 2023 to 2025). Without regular and frequent competitive lease sales, the industry is precluded from rapidly expanding the pipeline of projects.

The committee is actively seeking to partner with state level groups focused on regulatory reform and is pleased to provide letters of support for state initiatives. Please reach out to Jeanine Vany (jeanine.vany@eavor.com) if you have state legislation that could benefit from the GRPC support letter.

Infrastructure planning and resource procurement

Geothermal Rising and its member companies have collectively engaged with how state and power utilities have conducted resource and transmission planning and procurement for many years, mostly in the western U.S. on electric power projects. There are hundreds of such plans

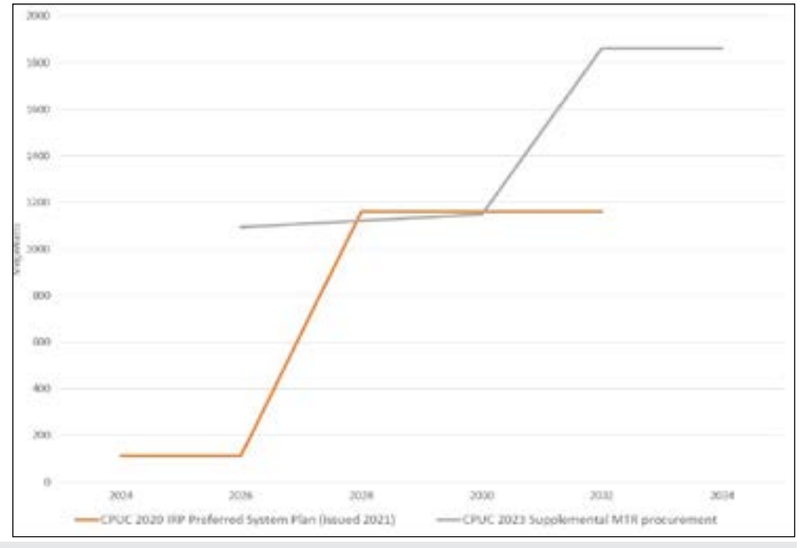


Figure 4: CPUC resource planning and procurement recommendations on geothermal, 2021 and 2023.

typically analyzed on 1 to 3-year timeframes in the region, with over 70 just in California. Most of our comments flow through the Policy Committee Regulatory and State Policy subcommittee, with the objective to ensure that geothermal resources are appropriately evaluated on an economic and reliability basis in these processes.

Resource planning

One of the geothermal industry's major successes in recent years was the California Public Utilities Commission (CPUC) Mid-Term Reliability procurement decision in 2021, and its subsequent final 2020 IRP decision, which created a target for jurisdictional load-serving entities to procure 1,000 MW of geothermal power by 2028. This procurement process is well underway, and the CPUC's recent Supplemental Mid-Term Reliability procurement decision issued in February 2023 went further and identified a resource planning need for up to 1,863 MW of new geothermal by 2033. Figure 4 below summarizes the results of these two CPUC decisions (with some alignment in the figure to line up dates in the original documents). In addition to these opportunities, the Los Angeles Department of Water and Power has identified between 500 MW and 1,600 MW of geothermal, depending on the scenario, in its most recent resource plan aimed at decarbonization (conducted with the National Renewable Energy Laboratory, NREL). It is up to the geothermal industry to mobilize to achieve these significant goals. With the recent success in California, the Regulatory and State Policy Subcommittee looks to apply similar models to other states as part of the 2023 objectives.

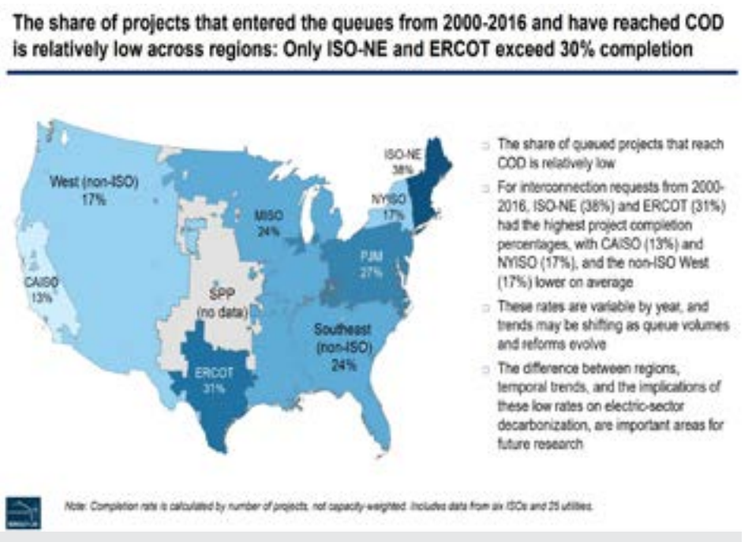


Figure 5: Estimated Benefit-to-Cost Ratios from 10 Years of RD&D Funding.

Geothermal Rising member companies have also periodically engaged in the resource planning processes at major western utilities outside California, often identifying specific issues where geothermal may be disadvantaged when compared to other planned resources. To the extent that these issues can be addressed on behalf of the geothermal industry by the Policy Committee, we encourage such communication.

Transmission planning, Interconnection and Queue Reform

Closely related to resource planning are transmission planning and the transmission interconnection queue process. Geothermal power projects need access to transmission, and any major expansion in such projects needs to be coordinated with transmission planning and expansion.

The GRPC and GR member companies have intervened into several aspects of this process over the years, including ensuring that transmission planners are using the right future resource portfolios which include geothermal, and addressing issues of access and scheduling on existing transmission lines. For example, historically, the Regulatory and State Policy Subcommittee has provided comments to the California Public Utility Commission (CPUC) when it provides long-term planning portfolios for use in the California ISO's annual transmission planning process.

In addition, transmission interconnection queues are greatly oversubscribed by many projects that will never be built. All new projects are concerned about how to improve and speed-up the interconnection process. Energy projects such as wind, solar, natural gas, and storage face major interconnection delays with an average of 23% reaching commercial operations countrywide for the period between 2000-2016, according to a 2021 Lawrence Berkeley National Laboratory study titled Queued Up: Characteristics of Power Plants Seeking Transmission Interconnection As of the End of 2021. The western U.S., where many companies are actively building out new geothermal power resources or applying new technologies, has about 15% completion rate. Moreover, it can take over 3 years to get interconnect approval. Therefore, interconnection queue is a major non-technical barrier for the geothermal scalability across the country and remains a priority area for the GRPC. The Regulatory and State Policy Subcommittee is focused on supporting regulatory reform at both the state and federal levels.

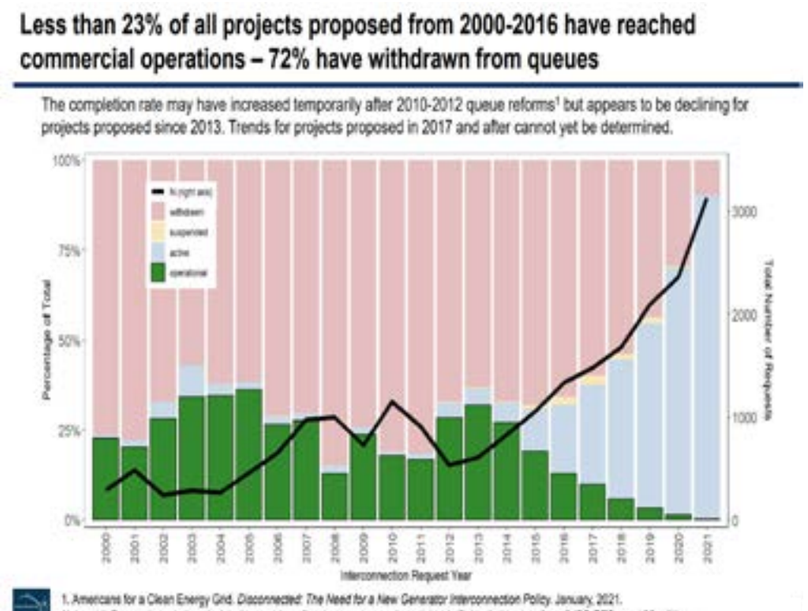


Figure 6: Status of clean energy projects between 2000 and 2021

Market development and financing

The Regulatory and State Policy Subcommittee is also taking a role in topics related to market development and financing, in coordination with the other subcommittees. Recently, DOE has shown interest in evaluating alternative government mechanisms for which it calls demand-side support for clean energy technologies, referring to methods for buying electric power and other services. In March and April 2023, the Regulatory and State Policy Subcommittee submitted two sets of comments in response to an OCED RFI on this topic (RFI-23-1). The comments identified reverse auctions, advanced market commitments, contract for differences, direct procurement and pooled offtake vehicles as potential demand side measure. If there is a positive response to these suggestions, we hope to continue this examination of alternative mechanisms, which may also have lessons for state and utility procurement.

Another recent contribution has been to address innovative financing methods. Under legislation signed in 2022, an independent, non-profit agency called the Foundation for Energy Security Innovation (FESI), is being established with a mandate to support the DOE mission generally, and more specifically, to increase private and philanthropic sector investments to accelerate the commercialization of energy technologies. In comments to DOE submitted in April 2023, we suggested that an initial area of such coordination could be mobilizing philanthropic support for geothermal innovation, since this has historically not been a major source of funding for our sector, and also engaging with our proposed venture capital fund. We will continue to monitor FESI's evolution.

Conclusions

In 2023, GR has already addressed a wide range of policy topics through the Policy Committee and its subcommittees. GR plans for continuation and expansion of these efforts. We anticipate a heavy and growing workload for the committees, particularly if our many recommendations for government initiatives described in this article reach fruition this year and next. Hence, the committees are developing strategic plans even as they address the many pressing issues which emerge each month. The Policy Committee is open to suggestions from GR members regarding priority topics not mentioned in this article.

Demand-side support measure	Geothermal Rising Initial Comments
Reverse auctions	In a reverse auction, the buyer (e.g., a government entity) runs an auction in which suppliers compete to provide the product. The geothermal sector is, of course, very familiar with utility RFOs, and compete with each in those RFOs, which tend to be either for renewable energy generally or sometimes what are called "all-source" RFOs. At the same time, having a targeted geothermal reverse auction is not a common approach historically for geothermal procurement and would need further assessment.
Advanced market commitments	Advanced market commitments have been typically used to support new technologies by providing a binding contract to purchase certain quantities of the resulting product (in this case, geothermal energy). These commitments provide investor certainty for highly capital intensive projects which otherwise might be too risky for commercial financing. The geothermal sector is supportive of further analysis of these types of mechanisms for new geothermal technologies...
Contracts-for-differences	Contracts-for-differences (CfD) are commonly used for variable energy resources to level contracted revenues over a particular term. For geothermal generation, which has a firm output, a CfD approach may not differ from a conventional power purchase agreement. It is possible that if the geothermal production is "shaped" to facilitate operations of other clean resources, such as solar generation, or if it includes a flexible component to provide ancillary services, such as operating reserves or frequency regulation, then a CfD approach could be worth investigating.
Direct procurement	The geothermal sector generally supports direct procurement by government buyers (e.g., see discussion of procurement for military bases in this article), but we also noted that this needs to be accompanied by sufficient expert advisory input into every stage of such a process.
Pooled offtake vehicles	The geothermal sector has experience with types of pooled procurement, in which one geothermal project may serve multiple buyers. The firm production from a geothermal project makes such arrangements more straightforward. The geothermal sector also has experience with geothermal contracts sourced from multiple geothermal projects. We have offered this experience to DOE for further consideration of such vehicles.

Table 2: Summary of all support letters and/or public comments

Appendix B: GRPC Regulatory Activity 2023

Hawaii Activity
SB 458: relating to the use of geothermal royalties

Texas Activity
SB 785: clarification of geothermal ownership rights
SB 786: consolidation of closed-loop permitting at RRC
SB 1210: repurposing orphaned oil and gas wells into geothermal wells

California Activity
California CAISO's Subscriber PTO RFI
Misinformation at CA Energy Market Watch media outlet

Federal Activity
DOE OCED RFI #1
DOE OCED RFI #2
FESI RFI
FY 2024 Appropriations Letter (https://geothermal.org/our-impact/blog/geothermal-rising-releases-fy2024-appropriations-request-geothermal-industry-united) submitted comments and quotes in support of the geothermal provisions included in the House Natural Resources Committee permitting reform bill (H.R. 1).

GR President and WING Global Team-Global Executive Kelly Blake (foreground) greeting at WING booth at GRC2022.

WING Celebrates 10 years

A decade of empowerment! WING, which stands for Women in Geothermal, was started in 2013 at the GRC meeting in Las Vegas. Since that time, WING has grown to over 3000 members in 89 countries with 36 country chapters. The organization promotes the education, professional development, and advancement of women in the geothermal community. 30% of all WING members are men, which falls short of our 50% goal, however, it is increasing each year. There is no cost for membership and membership is open to all. All members belong to the global organization with local involvement available within each country chapter.

The New Zealand WING team designed the current WING organizational structure and led as the WING Global Team from initial formation until 2020. In 2020, the Global Team reins were handed over to WING USA, led by Global Chair Ann Robinson-Tate and Global Executive Kelly Blake. In the last 3 years, WING USA formed as a non-profit corporation, created a new website, and started a new database with email and newsletter capabilities. The Global Team has continued to work with country Ambassadors (country chapter leads) so that numerous WING chapters around the world have the support they need to run their own organizations to fit their own culture.

WING events at global conferences

Over the past few years, WING chapters have been actively promoting WING with events and booths at various geothermal conferences. These include:

- GRC - Reno
- Stanford Geothermal Workshop
- IIGCE - Indonesia
- Türkiye Geothermal Congress
- WGC 2021 - Reykjavik
- Germany
- New Zealand
- ARGeo Kenya

At GRC 2022, WING had a booth in the Expo hall throughout the meeting, convened a panel session on Work-Life Balance, hosted a fun run, a yoga session, and present-

WING Turkey team will take over Global Operations from the US team in July 2023.


Anu Choudhary with her winning poster at GRC 2022.


WING members enjoying the 'Geothermal Good Life' at GRC-including Global Team Member Paul Schwering (left), Irene Wallis, Core Value Award Winner Jill Haizlip (second from right), Carmen Winn, and Lisl Lewis (behind).

ed the WING Core Value Award winners. WING awarded scholarships to 10 students to attend the meeting and also helped with judging of the student posters. In 2022, the 1st place student poster was awarded to Anu Choudhary. Anu was also one of the conference scholarship recipients. Anu is the current head of the GRC Student Chapter Subcommittee.

- WING achievements in the past few years
- Quarterly newsletter
- Mail/newsletter system used by numerous chapters
- WINGman training
- Core Value Awards
- Future Leaders Program
- Student scholarships to attend GRC
- Updated website-https://womeningeothermal.org/
- Stronger presence on social media
- Global sponsors
- WING speaker event at GRC
- Collaboration with Geothermal Rising Diversity Equity and Inclusion committee
- Added 9 new country chapters since 2020

WING Global Team Transition

In July of this year, the Global Team will transition from the US to Turkey. The US and Turkey teams have been working together to make the transition a smooth one. WING Turkey is excited to become the next Global Team!

WING 10th anniversary celebration at GRC2023

There will be several WING events at GRC this year in Reno, October 1st to 4th. On Sunday night, 10 years of WING will be celebrated at the Egg Geo after party. Monday night's mixer will feature a special WING cocktail. WING will have their annual booth in the expo hall, and the WING Core Value Awards Ceremony with a panel on Women in Drilling and Operations on Tuesday at lunchtime. Everyone is encouraged to participate in the WING activities. Make sure to visit the WING booth for some special swag!

For more information about WING, or to join WING, see our website https://womeningeothermal.org/

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