WESTERN GOVERNORS' ASSOCIATION

The Heat Beneath Our Feet

The Initiative of Colorado Governor Jared Polis

Dear Friends and Colleagues,

When I was elected as Chair of Western Governors' Association by my colleagues, I knew that I wanted to choose an initiative with the potential to improve the lives of all Westerners. That is why I worked with Western Governors' Association to launch the Heat Beneath Our Feet initiative, which is taking a bold and bipartisan approach to advance the development and deployment of geothermal energy. Jump-starting the adoption of geothermal energy technologies can create new opportunities to boost local economies; provide low-cost, reliable power, heating, and cooling to communities; and assist in meeting our renewable energy and energy security goals.

As we move towards true energy independence, the environmental benefits of geothermal energy generation can help position the West for further economic, environmental, and quality of life success. While eliminating almost all emissions compared to traditional energy sources, geothermal resources do not sacrifice reliability and can generate much needed baseload power.

The West is uniquely situated to take advantage of this energy source. While the United States accounts for 25 percent of the world's installed geothermal energy capacity, western states contain fully 95 percent of that capacity. Geothermal energy holds the potential to create jobs and provide reliable, low-cost domestic and secure energy. Consumers also benefit from direct applications of geothermal energy. Geothermal heat pumps are estimated to use 25 to 50 percent less energy than conventional heating or cooling systems, saving people money.

The Heat Beneath Our Feet initiative evaluated strategies to scale geothermal technologies across the West. Factors such as available geothermal resources, differing energy policy landscapes, workforce maturity, and emerging technologies were taken into account when compiling this report. The recommendations contained within this report were generated through a rigorous stakeholder process and vetted by subject matter experts over the course of the initiative.

In true western fashion, businesses have embraced the entrepreneurial spirit and are growing the geothermal sector into a robust economic generator. Colorado is joined by other western states in working to ensure that these companies have our support on the front lines of geothermal innovation.

I would like to extend my gratitude to all our state, academic, industry, and federal partners, including the U.S. Department of Energy, as well as to our initiative sponsors who contributed their time and expertise to this initiative's workshops, webinars, and podcasts. I look forward to continuing to work with them to advance the development and deployment of geothermal energy to successfully tap the heat beneath our feet.

Sincerely,

Jared Polis

Governor of Colorado

WGA Chair

Greetings Friends of the West,

Very few know what it takes to provide reliable and affordable energy to millions of people, but you can be certain to count Western Governors among them. The West has long been a leader in American energy production and leads the nation in the new frontiers of clean renewable energy development. It is no surprise that Western Governors are at the forefront again, this time with geothermal.

Beginning in July of 2022, WGA Chair and Governor of Colorado Jared Polis launched his Heat Beneath Our Feet initiative aimed at exploring opportunities to accelerate the development of geothermal resources. As a result, WGA convened stakeholders from public, private, and non-profit organizations to drill down to the issues holding back the expansion of geothermal energy in the West.

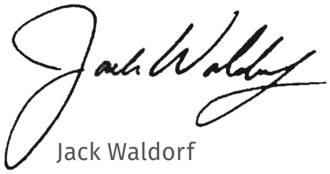
We are grateful to those who participated in our series of work sessions, webinars, and podcasts held throughout the year. Their enthusiasm was matched by the support of Governors who hosted initiative tours and work sessions, including former Governor David Ige of Hawaii, Governor Brad Little of Idaho, Governor Spencer Cox of Utah, and Governor Polis.

As geothermal is having a moment on the national stage, attracting the attention of policymakers at all levels of government, this report can be used by any stakeholder interested in learning about the potential of geothermal energy in the West and how its development can be supported. If the level of engagement from members of the geothermal community is any indication, this resource has a bright future.

If you have followed WGA's previous chair initiatives, you know they provide a rare venue for pragmatic, bipartisan policy discussions that lead to meaningful solutions. The effectiveness of past initiatives is evidenced by the support we received from Governors throughout the West to complete the work needed for this final report. It is also a testament to my predecessor, Jim Ogsbury, who saw nine Chair initiatives across the the finish line over the past ten years and set us up for success on Heat Beneath Our Feet.

I would like to extend my gratitude to Governor Polis for his leadership as WGA Chair over this past year – WGA would not exist without Governors, year after year, taking up the mantle to lead our organization. Further, the support we received from our sponsor community and stakeholders for this endeavor was immense and appreciated beyond measure. Our work on this initiative would not have been possible without them.

Sincerely,



Jack Waldorf

Executive Director

Western Governors' Association

EXECUTIVE SUMMARY

Colorado Governor Jared Polis, Chair of the Western Governors' Association (WGA), launched The Heat Beneath Our Feet initiative in 2022 to examine opportunities for and barriers to the accelerated development and deployment of geothermal energy technologies. The potential of geothermal energy in the West is vast, and offers significant advantages and benefits in efforts to expand the portfolio of renewable energy resources. Advances in technology and increased interest in developing domestic sources of low-cost, reliable, clean energy have brought greater attention to the energy potential of the heat beneath our feet.

Beneath Boise's City Hall lies an intricate network of pipes that act as a heat exchanger for the city's geothermal district heating systems. Idaho workshop participants toured the mechanical room at City Hall to view the infrastructure.

The initiative examined the various market, technology, and policy factors that affect the development of geothermal resources. Through a rigorous stakeholder process that included four workshops, six tours, a public survey, and a webinar series, the Heat Beneath Our Feet initiative generated recommendations for increasing the development and deployment of geothermal energy in the West including:

- **Improve resource assessment and data collection:** Increasing federal funding for resource assessments, coordinating efforts to target areas with the greatest potential, improving the federal repository of data relevant to geothermal development, and leveraging data from the oil and gas industry, as well as new technology, will increase our understanding of subsurface resources and foster additional geothermal development.
- **Mitigate risk in drilling and exploration:** Risk and uncertainty contribute to relatively high up-front costs for geothermal development. Those costs can be abated by continuing federal investment to reduce uncertainty in geothermal exploration, exploring models to help developers secure financing for exploratory drilling and mitigate drilling risk, and extending existing tax incentives for the oil and gas industry to include geothermal development.
- **Optimize permitting and improve regulatory certainty:** Permitting timelines can also be prohibitive for geothermal development. Lengthy delays can be mitigated by providing tools and resources to help stakeholders navigate the geothermal development process, increasing agency capacity for leasing and permitting, developing streamlined processes and categorical exclusions for geothermal leasing on par with other energy categories, expanding oil and gas exploration regulatory efficiencies to geothermal development, and collaborating with tribes and communities prior to and during project development.
- **Expand funding opportunities:** U.S. Department of Energy (DOE) funding for demonstration projects and the Geothermal Technologies Office (GTO) should be increased. Investment in energy transition communities should be encouraged.
- **Implement incentives for consumer adoption:** Expedite the deployment of tax incentives, rebates, and end-user applications to spur the adoption of geothermal heating and cooling.
- **Develop workforce and contractor ecosystem:** Geothermal energy can generate good jobs and create opportunities for workers and communities affected by the energy transition. Workforce development in the geothermal industry should be supported, including through the development of training and certification programs.
- **Increase awareness and education to develop geothermal markets:** Develop guidance for policymakers, regulators, and utilities to better promote geothermal energy.

The Heat Beneath Our Feet initiative report is a resource for policymakers and stakeholders. Initiative recommendations can assist in accelerating geothermal technologies, which can play a significant role in meeting the West's energy needs for a clean and sustainable future.

Background

Geothermal energy is a valuable but remarkably untapped resource in the West. The heat stored within the Earth can support a wide spectrum of end uses, including reliable, domestic, and renewable electricity generation for the grid, renewable building heating and cooling, underground thermal energy storage, and other direct use applications for agriculture, recreation, and industry. Advances in technology and increased interest in developing domestic sources of reliable, clean energy have brought greater attention to the underutilized potential of this ubiquitous energy resource.

Western states pioneered the development of geothermal technology and contain the vast majority of working geothermal resources in the United States. In the 1890s, Boise, Idaho, established the nation's first geothermal heating district, providing heat to residential and commercial buildings. Today, Boise's geothermal heating district, including the original Warm Springs Water District, is the largest in the nation, heating over six million square feet – including the Idaho State Capitol. The West pioneered the use of geothermal energy to generate electricity, too. The first geothermal electrical generation unit in the western hemisphere was constructed in California in 1960. The Geysers geothermal field is now the largest in the world, with a net generation capacity of more than 800 megawatts of electricity.[1]

Responsible development of geothermal power can address several critical needs for future U.S. energy demands. It is a domestic energy source, has a small surface footprint, and produces close to zero carbon and other air emissions, making it a clean and sustainable energy resource. Additionally, geothermal resources are always available, providing stability to the electric grid.

Passive geothermal energy can also address one of the biggest categories of energy use: building heating and cooling. Heating and cooling are the largest annual uses of electricity in the residential sector, accounting for more than 40 percent of an average home's electricity use.[4] Currently, natural gas is the primary heating fuel in much of the West. While natural gas prices can fluctuate based on market conditions, global events, and weather, the

Grid Stability Through Dispatchable Energy

Geothermal electricity generation provides consistent, reliable power. Geothermal power plants can have a capacity factor of 90 percent or higher, meaning that they operate at their maximum output level 90 percent of the time.[2]

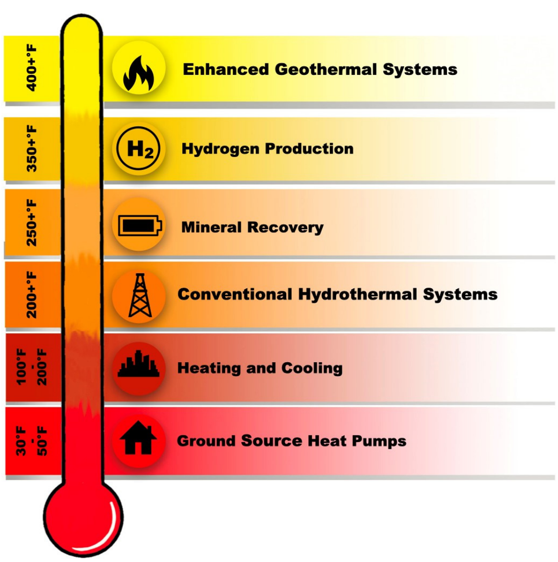
Geothermal power can also be dispatchable, meaning that electricity production can vary (ramp up or down) as needed. Dispatchable energy is an important complement to renewable resources that have more variable generation. As the West continues to decarbonize energy systems with variable sources of renewable power such as wind and solar, geothermal can balance these sources and ensure reliability in the system.

Compared to more traditional dispatchable energy sources like natural gas, the environmental impacts (e.g., land use footprint, greenhouse gas emissions, and air pollutants) of modern geothermal power plants are negligible. The surface footprint per GWh of electricity is smaller than coal, solar, or wind.[3]

Geothermal Energy 101

Geothermal energy is the thermal energy generated from natural geological processes and radioactive material decaying in the Earth's crust. In general, the temperature increases at an average background thermal gradient around 86 degrees Fahrenheit per kilometer (though portions of the West exhibit a higher-than-average geothermal gradient). The range of temperatures of geothermal resources can be harnessed for different purposes.

At relatively shallow depths - a couple of feet to a couple hundred feet - subsurface temperatures are stable year-round and are typically similar to room temperature and can be used for heating in winter and cooling in summer. Deeper wells extending thousands of feet below the surface can intersect natural or enhanced geothermal reservoirs with much hotter temperatures to support electricity generation.



Preparing for drilling at the Puna Geothermal Venture, operated by Ormat Technologies Inc. The exploration and drilling phases often bring the highest risk for failure and the most cost to geothermal development.

costs of heating and cooling with geothermal are far more consistent. By harnessing the steady temperature of the Earth, geothermal systems can displace most of the energy needed to heat and cool buildings.

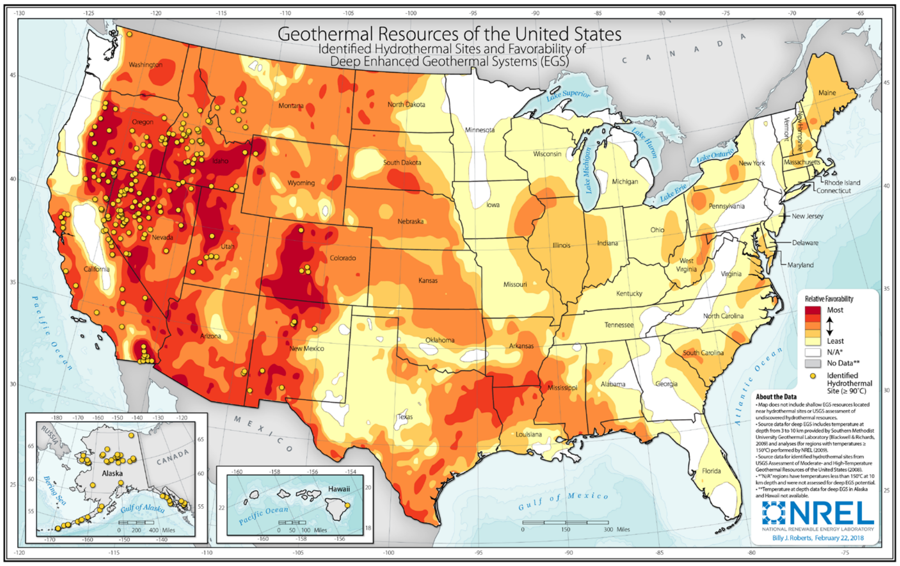
Opportunities to utilize passive geothermal energy for heating and cooling, electricity generation, and certain industrial, recreational, and agricultural applications have vastly expanded since the development of the early examples noted above. Yet despite the many benefits geothermal energy offers, it still accounts for only 0.4 percent of electrical generation in the United States and is not yet widely utilized at scale for heating and cooling applications.[5] Advancements in subsurface technologies from the oil and gas industry over the last two decades are improving the feasibility of geothermal systems. Expertise, efficiency, and safety practices in horizontal drilling and hydraulic fracturing have opened new possibilities for where geothermal developments can be located.

Geothermal is attracting the attention of policymakers at all levels of government.[6] Since WGA began work on this initiative, Congress has passed significant tax incentives for geothermal projects, DOE has committed hundreds of millions of dollars through the Energy Earthshots Initiative to research and develop geothermal energy, and states have begun to implement their own geothermal policies.

In 2019, DOE published GeoVision, an in-depth technical analysis detailing the vast potential for geothermal energy development in the United States. A comprehensive report on the current status of geothermal deployment is provided in the National Renewable Energy Laboratory (NREL) publication, 2021 U.S. Geothermal Power Production and District Heating Market Report.[7] The initiative toured geothermal sites in four states - Colorado, Utah, Hawaii, and Idaho - but geothermal energy is utilized throughout the West; examples of geothermal development in every western state and territory are included in the case studies section.

Geothermal Potential in the West

Geothermal energy can be used for a range of applications depending on the temperature and characteristics of the resource. Technological advancements are continually expanding the bounds of where and how geothermal energy can be harnessed cost effectively. Generally, high temperatures are needed to generate electricity, while lower temperatures can be utilized for industrial processes (e.g., agriculture) or building heating and cooling.



"This map depicts the potential for development of hydrothermal and EGS systems in the United States as of 2018. Further analyses, including the DOE's 2019 GeoVision report and NREL's 2023 Enhanced Geothermal Shot Analysis, modeled the associated potential electricity capacity. The 2023 analysis concluded that the United States potentially has 90.5 gigawatts of electricity capacity that could be deployed by 2050, mostly in the West, including over 80 gigawatts from enhanced geothermal system deployment after 2030. This is more capacity than the entire U.S. nuclear fleet in 2021.

Figure courtesy of the National Renewable Energy Laboratory.

Electricity Generation

Geothermal power plants utilize conventional hydrothermal reservoirs as well as emerging enhanced geothermal system reservoirs to produce geothermal fluids for power generation across a few differing power plant configurations (e.g., dry steam, flash, binary cycle). Produced fluids are reinjected to the subsurface reservoir after heat has been extracted. Additionally, modular binary power plant units, which use a heat exchanger with a working fluid with a lower boiling point, are an emerging technology area for coproduction from oil and gas wells. A comprehensive description of geothermal technologies and power plant configurations is available in the DOE GeoVision report.

Most geothermal power plants in use today utilize conventional hydrothermal resources, which are sources of naturally occurring hot water found at variable depths in the subsurface. Hydrothermal resources require a heat source, a fluid source (usually deeply circulating groundwater), and permeable pathways in Earth's crust allowing for fluid circulation (open faults, open fractures, and/or interconnected pore spaces in rocks). Hydrothermal resources are primarily found in western states, where geologic conditions cause naturally elevated heat flow and permeable pathways.

You may have experienced hydrothermal yourself: hot springs and geysers are expressions of underground hydrothermal systems and can aid in their identification, but many hydrothermal resources have no surface expression and are therefore more challenging to identify. These "hidden" systems hold significant potential in the West: The United States Geological Survey (USGS) estimates that the United States holds 23,038 megawatts of electricity of undiscovered hydrothermal resources compared to 5,128 megawatts of electricity already discovered.[8] Hidden hydrothermal systems are sometimes inadvertently discovered through mining exploration.

When a hydrothermal system is discovered, it must be characterized, usually by drilling test wells, to determine if enough heat, water, and permeability are present to produce cost-effective electricity. The investment necessary to characterize a system and deem it a viable resource can carry significant risk. As a result, an average of only 13.6 wells were drilled per year from 2015 through 2019.[9]

In locations throughout the West, there is sufficient subsurface heat, but water and permeability are often lacking. Enhanced geothermal systems (EGS) use advancements from the oil and gas industry, such as directional drilling and hydraulic fracturing, to engineer the necessary subsurface reservoirs to create permeability. This, combined with advancements in drilling technology, now allow for geothermal developers to potentially access resources beyond conventional hydrothermal systems, increasing the availability and locations of geothermal electricity resources.

To create EGS projects, a production-injection well is drilled into hot, dry rock with limited permeability and fluid content. Water is injected at high pressure to create or improve fractures within the rock to create a reservoir, then a second production well is drilled to intersect the fracture system and extract the heat from the rock mass. Additional production wells may then be drilled to meet power generation requirements.

EGS is not yet cost-competitive and technical challenges remain,[10] but the DOE Energy Earthshots Initiative has set a goal of reducing the cost of EGS to $45 MWh by 2035, in the same range as onshore wind today.[11] Research and development are underway to advance the commercial viability of EGS, most notably at the DOE-funded Frontier Observatory for Research in Geothermal Energy (FORGE) in Milford, Utah. This is complemented by other investments into research and development by DOE, such as the Geothermal Limitless Approach to Drilling Efficiencies (GLADE) project in Colorado. GLADE is exploring drilling deeper and faster by using existing and novel drilling technologies to reduce the cost of developing geothermal wells.

Additional advancements in technology could further broaden the utilization of geothermal energy. Closed-loop geothermal systems extract heat through sealed wells which recirculate the geothermal fluid, eliminating the loss of fluid to the surrounding formation. While this type of system is not yet commercial, closed-loop systems have significant potential and, if successful, advantages over other technologies since the type of fluid could potentially be changed from water to a more efficient heat transfer medium, such as supercritical carbon dioxide. Additionally, closed-loop systems may reduce environmental impacts and risk since fluid is not injected into underground reservoirs.

Co-production and conversion of oil and gas wells are also areas of potential growth. In co-production, hot water produced by oil and gas extraction is used to generate electricity. Converting orphaned oil and gas wells to geothermal production is also possible. Given the rising trend of the electrification of drilling rigs in the oil and gas industry, many wells are also co-located with transmission. The intersection of oil and gas electrification with the potential for end-of-life conversion to geothermal electricity is an important consideration when weighing if and when to cap wells at end of life.

Heating and Cooling

Geothermal heating and cooling applications leverage the shallow subsurface as a heat source and sink, using a variety of system configurations for space conditioning of buildings. These configurations include direct use of geothermal fluid extracted from a subsurface reservoir, closed-loop vertical borehole field ground heat exchanger, standing column wells, surface water ground loops, and horizontal slinky systems, among others.

Heating and cooling applications of geothermal energy utilize much lower temperatures than electricity generation. These technologies rely on either the constant temperatures in Earth's crust for heat exchange (geo-exchange, or heating/cooling via geothermal heat pumps), or shallow subsurface geothermal heat for direct use. Direct use applications use hot water from a hydrothermal resource piped to a building, greenhouse, or industrial facility.

Heat pumps use electricity to move heat from one area to another and have been used for over a century. Geothermal heat pumps, also called ground source heat pumps (GSHP) harness the steady temperature of the Earth at depths as shallow as 10 feet, which is warm relative to the air in winter and cool relative to the air in summer. GSHPs save the average homeowner money by using 25-50 percent less electricity than a conventional heating system, as they are able to move more heat than the direct electricity input.[12]

Direct use can be scaled up to serve multiple buildings in a district or community in what is called a district heating system. The largest and oldest heating district in the country is located in Boise, Idaho, and has been operational since 1893. Geothermal water is pumped from a well in the Boise Foothills and runs downtown through a pipe system to retain water heat. Water is then pumped through a heat exchanger that cools the effluent and the energy is used to heat buildings. There are 23 active geothermal heating districts in the U.S., all of which are located in western states.

GSHP technology can be used to heat and cool buildings of any size or across

Heating Efficiency

Heat pump technology is more efficient than traditional heating systems because it uses the existing heat in the ground or air, saving consumers money and helping reduce carbon footprint. An air-source heat pump uses the ambient temperature of the outside air to provide heating or cooling to a building. A GSHP takes advantage of the constant underground temperatures (about 55 degrees Fahrenheit), allowing it to run efficiently year-round regardless of weather conditions.

This high level of efficiency can help balance utility electric grid capacity as buildings electrify their heating and cooling, with some research showing even higher efficiency gains for networked geothermal systems or thermal energy networks. For example, electric resistance heating produces approximately one unit of heat per one unit of electricity, while GSHPs may produce (i.e., move) three or four units of heat for each input of electricity. While direct use requires a hydrothermal or EGS resource, GSHPs can be utilized anywhere with the installation of a ground heat exchanger.

multiple buildings on a distribution network in what is called a geo-exchange system. A networked series of pipes circulate a working fluid to absorb or release heat, using a ground loop as a renewable heat source in the winter and a heat sink in the summer. These systems are highly efficient and can provide significant cost savings, making it a compelling option for universities, campuses, and large buildings like stadiums. After converting its campus to a geothermal heating and cooling system in 2008, Colorado Mesa University in Grand Junction, Colorado, reported an annual savings of over $1.5 million. In 2022, those savings went directly toward reducing student tuition by two percent.

To achieve an even larger scale, heat pumps can be integrated into thermal energy networks, which are utility-scale infrastructure projects that connect multiple buildings, neighborhoods, or subdevelopments into a shared network with sources of thermal energy. Rather than each building needing its own borehole, multiple buildings in a network can share the same thermal sources. Thermal energy networks can allow utilities to manage and operate geothermal systems for heating and cooling.

The drill at Utah FORGE, which is currently drilling a 10,000-foot-deep geothermal well to test Enhanced Geothermal Systems.

Additional Applications of Geothermal Energy

Geologic Thermal Energy Storage: Underground rock formations can be used to store energy over long periods. Excess energy can be captured and stored underground as thermal energy and then recovered and utilized when needed. This storage method can complement energy resources with higher variability to store for peak demand.

Hydrogen Production: Utilizing geothermal electricity production to power electrolysis of water to produce hydrogen creates "green hydrogen," a renewable, clean fuel source with little to no carbon footprint at the point of production.

Operating electrolyzers powered with geothermal energy consistently can reduce the cost of hydrogen production on a per unit basis. While other renewable energy sources such as wind or solar have variable production, colocation of geothermal electricity with hydrogen production could lower production costs and eliminate the need to build transmission to connect electrolyzers to the grid or distributed energy sources.

Mineral Extraction: Geothermal brines can contain a variety of dissolved minerals and salts, such as lithium. Lithium extraction from geothermal brines is an active area of research, particularly at the Salton Sea geothermal field in southern California. This technology makes geothermal a potential domestic source for the production of some critical minerals.

Direct Air Capture (DAC): Direct air capture is the process of moving air over material that captures carbon dioxide from the atmosphere, which then can be injected into the subsurface for permanent storage or utilized for a variety of industrial processes. Solid system direct air capture requires temperatures ranging from 176-248 degrees Fahrenheit (80-120 degrees Celsius) and a reliable source of electricity, both of which can be provided by geothermal energy systems. Additional research on the potential synergy between direct air capture and geothermal energy systems could provide viable technology to address carbon capture needs potentially at much lower operating costs than other approaches to powering DAC.

Recommendations

The Western Governors' *Heat Beneath Our Feet initiative*, under the leadership of WGA Chair, Colorado **Governor Jared Polis**, examined the various market, technology, regulatory, and policy factors that affect the development of geothermal resources and evaluated strategies to accelerate the deployment of geothermal technologies across the West. WGA conducted a rigorous stakeholder process, engaging with over 500 stakeholders through an online survey, tours, work sessions, and a webinar series.

These discussions with energy experts, state and federal agencies, and other stakeholders brought together a wide array of perspectives. Their expertise and input are reflected in the policy recommendations included in this section. Recommendations are organized into three categories based on the type of geothermal resource and use they apply to: electricity generation, heating and cooling, and market development and transition opportunities.

Electricity Generation

Improve Resource Assessment and Data Collection

A significant barrier to the development of new geothermal electricity generation projects is the upfront cost and risk. De-risking geothermal projects can result in much lower costs. Much of the immediate potential for electricity generation in western states is in the development of conventional hydrothermal resources without surface features. Since electricity generation depends on site-specific factors like the subsurface heat and permeability of the rock, even when a hydrothermal resource is found there is no guarantee development will succeed. Existing technologies and exploration methods can also estimate where they may occur, but with low reliability. Innovative exploration methods and improved data are needed to better image the subsurface and improve prospecting for these types of resources.

Recommendation: Increase federal funding for resource assessments.

Better data and the development of regional resource assessments can increase the rate of exploration success. At the federal level, USGS is responsible for mapping and assessing energy and mineral resources, including national-scale geothermal resource assessments. This data can be used to develop models, analyses and decision-making tools for geothermal resource targeting.

Geothermal resource identification requires relatively granular data, which is lacking in much of the West and both costly and time consuming to collect. USGS, in partnership with DOE's GTO, is pursuing several projects to collect data at the needed scales across the West.

GTO led an initiative from 2015 to 2020 to develop a Play Fairway Analysis (PFA) for geothermal resource assessments. A PFA is a data mapping method adopted from the oil and gas industry to create a geostatistical map of probable geothermal resources. Assessments are conducted at a basin or regional scale. Further federal development or support of PFA mapping initiatives to assess geothermal resources would assist in the siting of geothermal projects.

Congress should provide USGS and DOE with funding to increase the pace and scale of data collection, mapping and resource assessments and facilitate collaboration with state geological surveys. DOE should also leverage synergies with other programs, such as USGS's Earth Mapping Resources Initiative (MRI) that are complementary efforts and in which states are already partners, to expedite efforts to assess geothermal resources. Large scale mapping and data collection can benefit from significant economies of scale and generate far greater return than a hit or miss approach from private funding sources that would add to project costs.

Recommendation: Coordinate with states to target areas with greatest potential.

Partnership with states and state geological surveys is critical, both to identify areas with the highest potential for geothermal development across a range of factors, and to leverage relevant data states already possess. States serve a critical function as primary sources and stewards of geospatial, scientific, and technical datasets that support the development of renewable energy resources. State geological surveys should have the opportunity to provide input and recommendations on where USGS and GTO prioritize resource assessment efforts in their states.

Recommendation: Improve the federal repository of relevant geothermal development data and the ability to interact with it.

When siting projects, geothermal developers consider multiple factors such as heat gradients, grid capacity, transmission, and environmental justice. The federal geothermal data repository should seek to incorporate data relevant to those factors, such as mapping overlays of critical habitat for endangered species, hydrological data, and existing transmission capacity. These resources, while not all directly related to geothermal development, capture unique aspects of regional and basin specific landscapes and other characteristics that affect the siting and deployment of geothermal projects. This data will allow for locations ideal for the siting of geothermal development to be more easily located. This federal repository could build on NREL's Geothermal Prospector and should be publicly available and easily accessible online.

Recommendation: Leverage data from the oil and gas industry.

The oil and gas industry and the mining industry are natural partners in the development and deployment of geothermal technology and resources. Both industries rely heavily on subsurface expertise that could help reduce the exploration and drilling costs of the geothermal industry. These operators should be encouraged to share data from existing operations with geothermal developers. Further, public-private partnerships with DOE should be encouraged to reduce the cost of drilling for geothermal wells through project demonstration grants.

Governors can facilitate the collection of data from existing oil and gas wells and facilitate geothermal permitting under a similar structure as existing drilling. Orphaned oil and gas wells under the state's control or directive could be used to collect temperature gradient data or could even be converted into a geothermal resource. Developing and sharing, in an open call for collaboration, an inventory of orphaned wells could save states the cost of plugging wells and reduce exploration and drilling costs to geothermal developers.

Mitigate Risk in Drilling and Exploration

While Play Fairway Analysis mapping provides a good estimate of where geothermal resources may be located, subsurface activities are needed to confirm their presence. Often requiring drilling, the confirmation of viable resources can cost millions of dollars without the promise of success. This risk drives up the cost of financing geothermal developments. Federal agencies should consider reducing risk in this phase of development through support for technological advancements, insurance, tax incentives, and regulatory improvements.

Recommendation: Continue federal investment in reducing uncertainty in geothermal exploration.

In 2020, DOE launched the Hidden Systems Initiative to provide grants for the research and development of innovative subsurface technologies. Research and development from these grants could tailor drilling technologies to geothermal resources and provide useful geological data, both of which help minimize the financial risk of confirming a resource. Congress should extend authorization and increase funding for the Hidden Systems Initiative.

Recommendation: Explore models to help developers secure financing for exploratory drilling.

The high risk and high upfront cost of geothermal development resulting from uncertainty in the viability of resources is a significant barrier to the industry's growth. To offset some of the risk and encourage investment, DOE offered several programs from the late 1970s

Governors Jared Polis and Spencer Cox with join the team from Cyrq Energy at its Thermo Geothermal Power Plant in Utah.

to the late 1980s. One of those programs was the User-Coupled Confirmation Drilling Program (UCDP) cost-sharing grant, through which a developer paid 80 percent of the cost if a project was successful and only 10 percent if the resource did not prove to be viable. The U.S. experienced the most growth in geothermal power capacity during the period this program was offered.

Globally, programs to mitigate the upfront risk of geothermal development, such as guaranteed loans and public financing, are common. European markets have addressed this challenge by offering insurance for geothermal exploratory drilling. In the U.S., there are currently limited programs at the federal level to help geothermal developers get past the high-risk early stages of development. DOE should explore the feasibility of cost share programs, such as guaranteed loans, insurance, and grants, and assess the effect these mechanisms would have on the geothermal industry.

Recommendation: Extend existing tax incentives for the oil and gas industries to geothermal development.

Despite the similarity of exploration activities in the geothermal and oil and gas industry, some regulatory and tax incentives that currently apply to exploratory wells drilled for oil and gas do not apply to geothermal exploration. Oil and gas companies can deduct intangible drilling costs, defined as costs related to drilling that have no salvageable value, from their income tax. Congress should extend this tax treatment to the geothermal industry.

Optimize Permitting and Improve Regulatory Certainty

Difficulty navigating the permitting process can also hinder geothermal development. Opportunities exist to optimize those processes that could result in shorter development timelines, thereby reducing costs for developers and encouraging more exploration and discovery of geothermal resources.

Many geothermal resources are located on federal lands managed by the Bureau of Land Management (BLM) and U.S. Forest Service (USFS). Timelines for permitting approval can include up to six separate environmental reviews, which typically can require seven to ten years to complete. Regulations also vary by state and by the type of geothermal development. Efficient permitting and a clear and consistent regulatory environment would help foster the geothermal industry.

Recommendation: Provide tools and resources to help proponents navigate the geothermal development process.

DOE should coordinate with states to maintain publicly available resources detailing the state and federal requirements that apply to geothermal development in each state. DOE's Regulatory and Permitting Information Desktop

Advancements in geothermal drilling technology, such as those developed at Utah FORGE, are increasing the rate of drill penetration and reducing the cost of developing geothermal wells.

(RAPID) toolkit is an excellent tool to provide easy access to federal and state permitting information and best practices. The RAPID toolkit should be updated to include all western states and maintained to ensure that it reflects up-to-date and accurate information.

Because the majority of geothermal resources in the West occur on BLM land, BLM should also ensure that relevant information and regulations are easily accessible to developers. BLM maintains a resource page for geothermal development, but more information on the conversion of oil and gas wells to geothermal development would be helpful, as would integration of BLM's information with DOE's RAPID toolkit.

Recommendation: Increase agency capacity for leasing and permitting.

BLM and USFS need adequate staffing and expertise at their local offices to approve and process geothermal lease nominations. Geothermal lease nominations for projects proposed on federal surface lands not managed by BLM must be approved by both agencies, meaning that both agencies must complete an environmental review process under the National Environmental Policy Act (NEPA). This process can take up to four years. While it is critical to conduct thorough and comprehensive environmental reviews, the length of that process can be affected by staffing shortages, competing priorities, and inexperience with geothermal development.

After leasing, geothermal projects require at least two subsequent NEPA reviews conducted by BLM for resource confirmation activities and utilization plans. Field offices with experience permitting geothermal development are generally more efficient and able to process permits more quickly than those that have not. These additional steps are above and beyond those generally required for similar activity on state, tribal, or private land and therefore largely exclude federal land from geothermal opportunities.

The Department of the Interior (DOI), USFS, and Congress should ensure that the relevant agencies are adequately staffed to review permits in a timely fashion. DOI and USFS should also ensure agency staff have access to technical experts to build staff expertise in geothermal development. A partnership with DOE's GTO should develop training materials, standard operating procedures, and provide technical support to field and district offices.

Recommendation: Develop streamlined processes for geothermal leasing on par with other energy categories.

In 2008, BLM and USFS released the Final Programmatic Environmental Impact Statement for Geothermal Leasing in the Western United States to facilitate decisions on geothermal lease applications. This remains an effective tool to help the agencies process lease nominations. As a next step, BLM should establish priority leasing areas for geothermal energy, as it has done for wind and solar energy in Instruction Memorandum No. 2022-027. Priority leasing areas should shorten development timelines for projects with the greatest technical and financial feasibility and the least anticipated natural and cultural resource conflicts on BLM-administered lands.

Cyrq Energy's Thermo Geothermal Power Plant, which sustainably produces power used in Anaheim, California.

Recommendation: Expand oil and gas exploration regulatory efficiencies to geothermal development.

Exploration in the oil and gas industry has benefited from Section 390 of The Energy Policy Act of 2005, which authorizes BLM to apply a categorical exclusion when approving exploratory drilling for oil and gas resources. Categorical exclusions apply to categories of activities that an agency has determined have no significant impact to the human environment and thus do not require an environmental assessment or environmental impact statement under NEPA. They can be an effective tool to streamline environmental review processes in specific circumstances defined by the agency. Congress should expand Section 390 to include geothermal exploration, which would allow agencies to use the existing categorical exclusion to facilitate increased geothermal exploration and the discovery of new resources without compromising environmental protections.

Recommendation: Fund research on the water usage of EGS.

Increasing the share of U.S. electricity produced from geothermal energy is not expected to increase the water demand of the power sector overall. Geothermal technologies do not require fresh water and can operate with brackish or even municipal wastewater – a significant benefit in the arid West. Water can also often be retained in a closed system. Air cooling and passive geothermal cooling also represent viable alternatives to water cooling in arid areas.

It is also critical to ensure the efficient use and protection of water resources for the development of EGS. DOE should fund water efficiency research as part of the Enhanced Geothermal Shot and related EGS efforts.

Lauren Boyd, the Acting Director of the Geothermal Technologies Office, addressed Governor Jared Polis and Alejandro Moreno, the Acting Assistant Secretary for Energy Efficiency and Renewable Energy, during an initiative workshop at the National Renewable Energy Laboratory in Golden, Colorado.

Recommendation: Collaborate with tribes and communities, including consultation prior to and during project development.

Geothermal resources can occur on tribal lands across the western United States. Even when these opportunities are not on tribal land, they can occur in areas with historical or cultural significance to tribes. Where relevant, it is important to consult tribes at the beginning of a potential geothermal project and ensure that the resource is developed in a way that does not damage sensitive historical and cultural resources. To help developers consider these factors in siting decisions, data layers incorporating the location of these resources should be included in federal geothermal repositories and considered in the development of priority leasing areas.

Expand Funding Opportunities

Improved data leading to higher confidence in locating resources and permitting process improvements that shorten development timelines will help reduce uncertainty and risk in geothermal development and make it more attractive to investors and capital markets.

Recommendation: Expand funding for demonstration projects.

Congress should expand funding for programs that support geothermal demonstration projects such as those under the DOE Loan Program Office's Title 17 Clean Energy Financing program. Further demonstration of geothermal projects could open market avenues for electrical generation and heating that spur private investment.

Congress should continue to fund the FORGE project and establish additional EGS demonstration projects in the West. The FORGE demonstration project is developing technologies and techniques necessary to commercialize EGS and build confidence in the industry.

Recommendation: Encourage development in energy transition communities.

The Inflation Reduction Act (Pub. L. 117–169) includes bonus credits for renewable energy development that occurs in energy communities, which are defined to include communities with substantial employment driven by the coal, power plants, and the oil and gas sector. This is an important provision to stimulate job creation and economic development in communities

Jon Gunnerson, the Geothermal Coordinator for the City of Boise, explains to workshop participants how the Boise Warm Spring Water District has expanded operations from heating just a handful of buildings in 1892 to now sustainably heating 6 million square feet of building space.

affected by the energy transition. Where the economic benefits are justified, DOE should target funding towards these communities for the conversion of existing oil and gas wells to geothermal energy as part of a just transition. Due to years of development in these areas, the local geology is well understood, thereby lowering the risks and costs associated with exploration. Areas with existing coal and natural gas power plants also have transmission infrastructure already in place.

Recommendation: Increase funding levels for the Geothermal Technologies Office.

The Energy Act of 2020 authorized funding for GTO at $170 million annually through Fiscal Year (FY) 2025. Appropriations in recent years have been significantly below the authorized level. In FY23, Congress appropriated $118 million for the office, the lowest level among DOE renewable energy offices. Congress should appropriate sufficient funds to the GTO to establish a strong research and development capability and to execute the recommendations contained in this report.

Heating and Cooling

Implement Incentives for Consumer Adoption

Home-, neighborhood-, and subdevelopment-level passive heating and cooling applications of geothermal energy are proven technologies that have been used in the West for over a century. The Inflation Reduction Act extended the 30 percent investment tax credit through 2032 for geothermal projects that meet prevailing wages and apprenticeship requirements. Project developers can receive up to an additional 20 percent if projects meet domestic content requirements and are located in energy communities. The efficient rollout of these programs to end-users is critical to the adoption of geothermal heating and cooling systems, including networked geo-exchange systems or thermal energy networks, and the following recommendation would assist in developing these underutilized assets.

Recommendation: Expedite the deployment of tax incentives, rebates, and end-user applications.

The Inflation Reduction Act both increased and expanded the tax credits and rebate program for the installation of geothermal heating systems. The Internal Revenue Service should move quickly to implement these programs so that consumers can begin taking advantage of them as soon as possible and define domestic content requirements in as expansive a manner as permissible under federal law.

Transitional Opportunities and Market Development

Growing the geothermal industry will create jobs and economic opportunity for workers across the West. Geothermal electricity generation creates long-term jobs in the operation of geothermal power plants and has a fully domestic supply chain, making these projects strong candidates for the full federal investment tax credit with opportunities for apprenticeship programs. The following recommendations would help develop the workforce needed to take advantage of geothermal energy potential and address the need for greater public awareness of the benefits of geothermal energy deployment.

Develop Workforce and Contractor Ecosystem

The initial phases of geothermal exploration and resource assessment are valuable job creators and utilize much of the same equipment, contractors, and expertise as the oil and gas industry. Heating and cooling also offer significant potential for job growth in manufacturing, design, installation, and maintenance. In both cases, the skills in demand are transferable across multiple sectors.

Recommendation: Create opportunities for workers and communities affected by the energy transition.

Since many of the skills and positions needed for geothermal energy development are highly transferable from the oil and gas industry and conventional power plant operations, there is an opportunity to target investment to communities that are experiencing the loss of jobs and economic activity due to the closure of power plants and other effects of the energy transition. As technology advances, it may even become possible to repurpose shuttered coal- or natural gas-fired power plants as geothermal power plants. Conversion of oil and gas wells could also provide transition opportunities to communities and workers affected by the energy transition. Congress should establish a mechanism within DOE that leverages existing expertise and relationships in the national labs to conduct education and workforce development. Congress and DOE, in conjunction with other federal agencies, should also consider opportunities to target these communities with resources and training, and collaborate with relevant trade unions to expedite its deployment in communities.

Amanda Kolker, the laboratory program manager for Geothermal at the National Renewable Energy Laboratory, discussed the benefits of geothermal energy during a WGA workshop at the facility in Golden, Colorado.

Recommendation: Support workforce development in the geothermal industry.

For consumers to adopt GSHPs, homebuilders, contractors, and heating and cooling specialists will need to have the expertise and skilled workforce to offer those services at competitive prices. Policymakers should support the development of industry-wide training opportunities and collaborate when applicable with trade unions that perform this work. The industry should work closely with states to develop and scale up training pathways to meet this workforce demand.

Increase Awareness and Education to Develop Geothermal Markets

Lack of awareness of geothermal energy and its potential in the West is another barrier to greater use of geothermal resources. The geothermal market has many stakeholders, including policymakers, regulators, utilities, consumers, local governments, and tribal communities. Understanding of geothermal energy needs to be raised in each group of stakeholders to increase the deployment of geothermal projects in the West.

Recommendation: Develop guidance for policymakers, regulators, and utilities to conduct cost-benefit analyses of geothermal energy.

Many of the advancements in geothermal energy have been made in the last decade and incorporating novel advancements into utility resource planning can be challenging. One difficulty is that the value of geothermal energy is not always fully realized in traditional methods of calculating energy costs, such as the levelized cost of energy, and attributes of geothermal such as the dispatchable nature, extremely low operating costs coupled with longevity, reliability, and negligible emissions, are often left out of planning. Working with utilities to understand how integration of geothermal resources would work within their market or dispatch construct could help capture the total cost and savings to their system. Greater awareness of the firm, clean nature of geothermal energy could build more confidence in the resource and lead to utilities encouraging geothermal solicitations in their bids. DOE should develop guidance on how to incorporate the full value of geothermal projects into resource planning.

Workshops, Webinars and Podcast

Colorado Mesa University Geo-Exchange Tour

September 27, 2022

The Heat Beneath Our Feet Initiative kicked off with a tour of the geo-exchange heating and cooling system at Colorado Mesa University (CMU).

Using less than half of the electricity required by a traditional HVAC system, the geo-exchange heating and cooling system at CMU controls the climate in 70 percent of the buildings on campus (1.2 million square feet).

In the summer, it absorbs excess heat from the buildings on campus and either stores it underground for later use or transfers it to other facilities in need – it even heats the University's Olympic-sized swimming pool. In the winter, the system pumps the geothermally heated water 500 feet below the school into the buildings on campus for heating purposes. Doing so reduces the University's carbon footprint by nearly 18 metric tons a year and saves $1.5 million a year on energy costs, savings that were passed directly along to reduce student tuition.

It has been so successful, the University is not only expanding the system to all of the new construction on campus, but it is also working with the city of Grand Junction to explore options for expanding the system into the surrounding community.

"This is an exciting example of community-scale geothermal," Colorado Governor Jared Polis said at the workshop. "Once we build this great geothermal heating and cooling system, we can leverage it to help extend the benefits and savings to the community."

TOP: Governor Jared Polis toured the geo-exchange system at Colorado Mesa University (CMU) with University President John Marshall. With additional state funding approved by Governor Polis, CMU hopes to become the first university in the country to use geothermal energy to heat and cool 100 percent of its campus. BOTTOM: During his tour, Gov. Polis also met with CMU students who received a 2 percent reduction in tuition last year due to the energy savings from the University's geo-exchange system.

As the country looks to electrify much of its heating and cooling needs, Amanda Kolker, Geothermal Program Manager at the National Renewable Energy Laboratory, said, "This is one of the few solutions" to successfully do so without overwhelming the grid.

"The 'electrify everything' pathway will be a difficult one for the grid to accommodate unless our alternatives to gas-fired heating and cooling are highly efficient and resilient," she said. "That's why the work being done [at CMU] is so important to highlight and build on."

Following the tour, WGA hosted a webinar with Will Toor, the Executive Director of the Colorado Energy Office, and Kent Marsh, the Vice President for Capital Planning Sustainability and Campus Operations at CMU. Together they discussed the nuances of geothermal heat exchange systems, opportunities to replicate this technology throughout the West, and challenges to implementation.

Hawaii Workshop

October 9-10, 2022

To learn about the potential for geothermal electricity generation, former Hawaii Governor David Ige hosted a workshop for the Heat Beneath Our Feet initiative at Puna Geothermal Venture in October of 2023.

"Geothermal energy can be a bipartisan solution to our energy challenges across the West and I am proud that Hawaii can be an example to the nation and the world for renewable energy," Governor Ige said.

Located atop the Kapoho Geothermal Reservoir in the East Rift Zone of the Kīlauea volcano, the Puna Geothermal Venture uses mile-deep production wells to bring geothermally heated fluid to the surface and produce steam, which is then used to power turbines that generate 38 megawatts of electricity for the Big Island of Hawaii each year – roughly 10 percent of the community's use. With the potential for the Kapoho Geothermal Reservoir to produce 200 megawatts of power each year, Ormat Technologies, Inc. plans to expand the plant's capacity by another 8 megawatts in the coming years.

Following a tour of the power plant, experts from DOE, USGS, Los Alamos National Laboratory, and the Colorado Energy Office discussed the potential for geothermally generated electricity to stabilize the grid when the sun isn't shining or the wind isn't blowing, as well as to sustainably power emission-reducing technology like carbon capture plants, green hydrogen production, and electric vehicles.

By expanding the state's use of its geothermal resources, Scott Glenn, the Chief Energy Officer for the Hawaii State Energy Office, said Hawaii hopes to become a net-negative carbon emitter by 2045.

TOP: "Workshop participants tour Puna Geothermal Venture in Hawaii, which provides up to 10 percent of the Big Island's power." BOTTOM: "During the workshop, participants got a chance to visit Volcanoes National Park, where the power of geothermal was on full display.

"[Geothermal energy] can drive our negative emission goals by helping to power direct air capture or some of these other really innovative, cutting-edge technologies that are very expensive right now," Glenn said. "The low, low price that geothermal can offer, makes them much more viable and puts them on the table."

In addition to the environmental benefits that come with being a net-negative carbon emitter, Paul Thomsen, the Vice President of Business Development at Ormat Technologies, Inc. added that doing so could cut the state's energy costs.

"The energy rate [for geothermal] that's before the Public Utilities Commission today is 5.7 cents per kilowatt hour," Thomsen said. "Most western states are 9 to 12 cents. In Hawaii, they're paying rates as high as 20 cents per kilowatt hour. So geothermal has the ability to save ratepayers in Hawaii $60 million a year in the price of energy."

After exploring the Puna Geothermal Venture in Hawaii, WGA hosted a webinar featuring Glenn, Thomsen, and Nicole Lautze, principal investigator with the Hawaii Groundwater and Geothermal Resources Center at the University of Hawaii. Their conversation focused on the potential for geothermally generated electricity to stabilize the grid and sustainably power emission-reducing technology like carbon capture plants, green hydrogen production, and electric vehicles.

Idaho Workshop

October 24, 2022

TOP: At Boise's Warm Springs Water District production wells, system operators demonstrate the importance of materials selection when designing district heating systems. Despite high corrosion rates, Boise has successfully avoided system failures by implementing engineering and technological advancements. BOTTOM: Idaho Governor Brad Little discussed the benefits the city has reaped as a result of Boise's use of its geothermal resources.

In 1892, The Boise Warm Springs Water District in Idaho became the first community in the world to tap into a geothermal reservoir for heating purposes. Though the system initially only provided heat to a handful of buildings, today it encompasses four water districts that collectively heat over six million square feet of building space and over 300 homes.

Ultimately, it reduces the city's carbon footprint by approximately 20,000 tons of carbon dioxide per year – the equivalent of removing more than 4,000 cars from the road – and saves the city millions of dollars per year on electricity costs.

"You just can't beat the value of geothermal," Idaho Governor Brad Little said during the Heat Beneath Our Feet initiative workshop that he hosted in October.

While the expansion of the Boise Warm Springs Water District over the last 130 years is a perfect example of how geothermal resources can be leveraged to sustainably meet a community's heating needs, most areas do not have such easy access to geothermal resources as Boise does.

"We know more about the bottom of the ocean or the surface of Mars than we do about what's underneath half of Nevada," James Faulds, the Nevada State Geologist and a professor at the University of Nevada Reno's Bureau of Mines and Geology, told the geothermal experts that attended the workshop.

However, by extrapolating subsurface data and drilling technologies from other industries – especially the oil and gas industry – geothermal resource mapping can be radically improved and reduce the financial risk of developing geothermal resources.

"Through various kinds of statistical analysis," Faulds said, "we came up with an algorithm that allows us to go out there and say, 'that spot in the middle of this valley looks very promising for geothermal.' Those are hidden resources that our estimates suggest are three-quarters or more than our current resources."

This kind of innovative analysis, Nick Goodman, the CEO of Cyrq Energy, said will drive geothermal development for years to come – especially if geologists like James Faulds get access to better data.

"A lot of the geothermal that's operating today came from data in the '70s and '80s," he said. "Conventional geothermal systems of tomorrow are going to come from these hidden systems and industry doesn't have the ability to do that upfront work, it's just not set up for it... I guarantee you that 10 years from now we will have operating geothermal plants that are a result of the work these labs are doing."

To continue the conversation after the workshop, [WGA hosted a webinar](#) to discuss strategies for improving geothermal resource assessment mapping and project permitting. It featured Claudio Berti, the Director and State Geologist at the Idaho Geological Survey, Lorenzo Trimble, the Geothermal Program Lead at the Bureau of Land Management, and Jon Gunnerson, the Geothermal Coordinator for the City of Boise.

Utah Workshop

December 12, 2022

EGS can augment the power potential of existing geothermal reservoirs, or even create geothermal reservoirs where they are not naturally occurring, by improving the permeability of subsurface rock.

To advance the development of EGS technologies, DOE funds an underground field laboratory in southwestern Utah, the Frontier Observatory for Research in Geothermal Energy (Utah FORGE).

WGA hosted a workshop in Cedar City, Utah, to discuss the potential for this exciting technology and what can be done to make it commercially viable.

"Geothermal potential is inexhaustible… but you can't meet U.S objectives to produce 60 megawatts [of geothermal power] using conventional hot spring systems," Dr. Joseph Moore, the principal investigator at Utah FORGE, said. "They're just not big enough. We need to be able to drill everywhere across the country… and if you want an electrical plant anywhere, you could use EGS."

The key innovation that is required to deploy EGS around the world, Dr. Moore said, is tools capable of withstanding the sustained heat encountered drilling geothermal wells.

"New tools are absolutely required to build an EGS system," he said. "Our project at Utah FORGE is not to generate electricity, it's to de-risk these tools and to create the reservoir… to develop the road map so that developers and others in any country can take the road map and build the system."

To learn more about this exciting technology and its potential use across the West, WGA hosted a webinar with Dr. Moore and Jaina Moan, the Director of External Affairs with the Nature Conservancy. They discussed the tools and technology necessary to make EGS commercially viable, including strategies for navigating the permitting process.

Colorado Workshop

February 24, 2023

The Colorado workshop of the Heat Beneath Our Feet initiative was hosted at the NREL Energy Systems Integration Facility in Golden, Colorado, where Colorado Governor Jared Polis was joined by Alejandro Moreno, the Acting Assistant Secretary of the U.S. Department of Energy and Deputy Assistant Secretary for Renewable Power.

During the workshop, experts from Geothermal Rising, Fervo Energy, and BlueGreen Alliance, among others, spoke with utilities about strategies for incorporating more geothermal energy onto the grid.

"There's enormous potential for everything from geothermal passive heating and cooling systems to geothermal electricity," Governor Polis said. "We want to make sure we have an accelerated process in place, given the nature of the climate emergency, for geothermal to be deployed."

"This needs to be a nationwide approach," Moreno said. "The federal government has really significant

Dr. Martin Keller, Director of NREL, spoke about the need to scale geothermal energy use in a similar fashion to that of wind and solar power.

resources to accelerate this transition… but we know that the real work in making this happen is going to take place in states across the West. It's the decisions made at the state and local level every day that ultimately determine what this energy future looks like."

The biggest hurdle to deployment, utilities said, is a lack of quality subsurface mapping and access to drilling and transmission technology that can effectively work in extreme temperatures. While these issues add a significant layer of cost and complexity to geothermal deployment, industry advocates noted that the 24/7 reliability, long-term cost savings, lack of carbon emissions, and job opportunities for oil and gas workers must be considered in the cost-benefit analysis if this technology is to reach its full potential.

"Solar took 30 years to go from super expensive to now being one of the cheapest ways to produce electricity," Martin Keller, the director of NREL and president of the Alliance for Sustainable Energy, said. "But we don't have 30 years for some of these new technologies. We only have about 10 to bring these technologies to scale and then deploy."

Topics of discussion at the workshop, including integrating geothermal resources onto the grid, opportunities to transition energy workers to the geothermal sector, and geothermal public education and market development, were highlighted in a subsequent webinar. It featured Amanda Kolker, the laboratory program manager for Geothermal at NREL, Chris Markuson, the Western States Director with the BlueGreen Alliance, and Bryant Jones, the Executive Director of Geothermal Rising.

Utah FORGE

June 9, 2023

In June, the initiative returned to Utah, where Colorado Governor Jared Polis was joined by Utah Governor Spencer Cox to visit Utah FORGE. During the visit, Utah FORGE was actively drilling a geothermal well that will reach a total length of 10,700 feet. Once finished drilling through hard crystalline granite, the well will reach a vertical depth of 8,265 feet, where the temperature will be 440 degrees Fahrenheit. "[Utah FORGE] is an essential stepping stone to large scale EGS development" Dr. Joseph Moore, the principal investigator at Utah FORGE, said. "It is being used to build the roadmap for EGS, any developer or country can take this roadmap to build these systems... Worldwide there is no other field-scale facility for EGS research."

The two Governors also visited the Thermo Geothermal Power Plant in Minersville, Utah. This power plant, operated by Cyrq Energy, has a capacity of 14.5 megawatts, generated by three production wells and five injection wells. Thermo supplies electricity to the City of Anaheim, California, through transmission completed by PacifiCorp.

TOP: Governors Jared Polis and Spencer Cox with WGA's Executive Director Jack Waldorf and the team from Cyrq Energy at its Thermo Geothermal Power Plant in Utah. BOTTOM: Dr. Joseph Moore, the managing principal investigator at the Utah FORGE lab explained his work on Enhanced Geothermal Systems to Governor Jared Polis and Governor Spencer Cox.

Webinars

More Than Just Heat

While geothermal energy is often associated with electricity generation and heating and cooling needs, its ability to store huge amounts of energy is another critical component of its community benefit. To explore this potential, WGA hosted a webinar with **Keith Malone**, the public affairs officer for the Hydrogen Fuel Cell Partnership, and **Sarah Jewett**, the Vice President of Strategy for Fervo Energy.

Renewable Energy Incentive Parity

The Inflation Reduction Act transitioned current investment tax and production tax credits to a "technology-neutral" tax credit for low-carbon technologies and energy sources. In light of this development, WGA hosted a webinar with **Sean Porse**, the data, modeling, and analysis program lead at the U.S. Department of Energy, **Bryce Carter**, the program manager for emerging markets and geothermal at the Colorado Energy Office, and **Landon Stevens**, the senior program director for the electricity sector at Clear Path Energy, to discuss strategies for leveraging these new tax credits and providing developers with stable, long-term funding.

Geothermal Energy at Home

GSHPs are a proven technology to heat and cool buildings of many sizes and use. To explore the deployment of geothermal heating and cooling applications, WGA hosted a webinar and was joined by **Jeff Hammond**, Executive Director of the International Ground Source Heat Pump Association, **Heather Deese**, Senior Director of Policy & Regulatory Affairs at Dandelion Energy, **Ryan Dougherty**, President of The Geothermal Exchange Organization, and and **Terry Proffer**, GeoExchange Designer and Geologist with Major Geothermal.

Podcast

The Well of the Future: Repurposing Oil and Gas Wells for Geothermal Energy Production

With over 80,000 orphaned oil and gas wells in the U.S., repurposing those wells for geothermal energy production would not only save millions of dollars in costs to cap wells, but also reduce the financial burden of drilling a geothermal well. WGA hosted an episode of its Out West podcast series with Johanna Ostrum, the Chief Operating Officer of Transitional Energy; Will Pettitt, the Geothermal Discipline Lead at Baker Hughes; and Will Gosnold, a professor of geological engineering at the University of North Dakota to explore how this could help make both industries more efficient and sustainable.

Case Studies

Alaska

Chena Hot Springs, a remote off-grid community near Fairbanks, Alaska, has successfully implemented a geothermal microgrid that has been operating since 2006. The 680 kW isolated geothermal plant offsets diesel generation, resulting in significant cost savings for the community. In the first year of operation, the plant saved more than $650,000 in diesel fuel costs and reduced electricity costs from $0.30 to $0.05/kWh.[14]

The geothermal plant utilizes the lowest-temperature geothermal electricity source in the world at 71°C, with power generation enabled by the availability of near-freezing river water and seasonal subzero air temperatures for power cycle heat rejection. Creating a cascade-of-use system, waste heat from the plant is used for district heating, greenhouses, seasonal cooling using absorption chilling, a spa, and other uses.

Additionally, the Aurora Ice Museum at Chena Hot Springs utilizes geothermal energy to maintain a year-round frozen environment. An ammonia-water-based absorption chiller runs on 73°C geothermal heat and provides 15 tons of -29°C chilling. The chill brine circulates through an air handler, which cools an annular space in the ice hotel between the ice walls and the external insulation. The success of these geothermal projects in Alaska demonstrates the potential for geothermal energy to provide cost-effective and sustainable energy solutions in remote communities.

American Samoa

In 2015, DOI awarded American Samoa $1.13 million to support a geothermal drilling program to test for resource potential on the island of Tutuila. The American Samoa Power Authority partnered with DOI office of Insular Affairs and NREL to complete a resource assessment with hopes that geothermal energy could be developed into a baseload energy source for island communities. The drilling program was completed and found that although the islands may have volcanic resources, assessments suggested the resources would be too high risk for geothermal development and electricity generation would not likely be commercially viable with current technologies.[15]

Arizona

Arizona has abundant low-temperature geothermal resources that have been tapped for aquaculture and other direct use applications. Nearly all aquaculture operations in Arizona use geothermally heated water to produce shrimp, tilapia, and catfish. Using waters 20-40°C, farmers are able to grow larger and healthier fish faster and longer throughout the year. The benefits of controlled rearing temperature have been found to increase growth rates by 50-100%, raising the number of harvests per year, resulting in increased profits.

California

California's successful geothermal energy industry can be attributed to a combination of favorable geologic conditions, supportive policies, and market demand. California's unique geologic features, characterized by high volcanic and tectonic activity, provide the foundation for some of the oldest geothermal installations in the U.S. The Geysers, located in the Mayacamas Mountains, has been operating since the 1960s and is the largest geothermal field in the world. Its 18 geothermal power plants and more than 350 wells use dry steam cycles to continuously generate more than 800 MW of electricity.[16]

Geothermal resources are also abundant in Imperial Valley, which has become a testbed for research and technology testing and is being developed for power production as well. Salton Sea is the site of 11 commercial-scale geothermal power plants, as well as a lithium research site funded by DOE. In partnership with Lawrence Berkeley National Lab and Geologica Geothermal Group, the project will seek to characterize and quantify lithium deposits in the hypersaline geothermal brine, providing additional value to the area's vast geothermal resources. Community education and engagement has helped spur support for geothermal development throughout the region, bringing in tax dollars and good paying jobs to a previously disadvantaged community.

In addition to significant resources, California has implemented supportive policies that have created a favorable environment for geothermal energy development. Recent bills passed by the California Legislature codified the state's goal of achieving 90% renewable energy and zero-carbon electricity by 2035, creating new opportunities for renewable energy projects including geothermal. The California Energy Commission and the California Public Utilities Commission have also implemented programs to reduce resource risk and encourage the growth of the geothermal industry such as loan guarantees, low-interest loans, and grants for exploration and drilling.

The expensive costs of electricity in the state have helped increase the competitiveness of geothermal as a power source. Throughout California, market demand for geothermal energy has grown due to the rising demand for power purchase agreements (PPAs) from community choice aggregators (CCAs). Since 2020, California's CCAs have been key drivers in the growth of the geothermal industry, committing to long term agreements with geothermal energy suppliers like Cyrq, Ormat, Controlled Thermal Resources, and Calpine to generate nearly 300 MW of new-build resources in the next decade.

Colorado

For decades, Colorado has leveraged geothermal resources for direct use applications and residential heating and cooling. Geo-exchange installations like those at Colorado Mesa University have been effective at reducing energy costs and continue to be installed throughout the state. In recent years, Colorado has become a leading proponent for geothermal energy, creating state programs and offices to bolster the development and implementation of geothermal statewide. In 2023, Governor Polis signed a regulatory pathway for gas utilities to develop thermal energy networks and, working with the legislature, passed an estimated $140 million in refundable tax credits for geothermal energy over the next ten years, including $35 million for a merit-based state investment tax credits for geothermal electricity projects.

In 2022, DOE awarded a $9 million grant to Occidental Petroleum to test geothermal drilling technologies in the Denver-Julesberg Basin through the Geothermal Limitless Approach to Drilling Efficiencies (GLADE) project. Partnering with NREL and Colorado School of Mines, the project will drill twin, high temperature geothermal wells using existing and innovative drilling technologies to drill deeper and at higher temperatures at a faster rate, ultimately seeking to increase daily drilling rates by at least 25%. The twin wells system allows for drilling speeds to be compared and validated for a multitude of systems, including EGS.

Governor Jared Polis toured the facilities at the National Renewable Energy Laboratory in February, where he was able to see several renewable energy demonstration projects and learn how they compare to geothermal energy.


A lava flow from the eruption of Kilauea in 2018 is visible beyond Puna Geothermal Venture.

Guam

A team from NREL and the U.S. Navy's Geothermal Program Office conducted a reconnaissance assessment on the geothermal potential in Guam in 2010. Although Guam has no obvious surface features suggesting geothermal potential and had never been explored for geothermal resources, researchers located a steam vent and hot water well, suggesting the presence of geothermal fluids in the subsurface.[17] Using LIDAR technology, the Navy conducted additional assessments and provided funding to drill temperature gradient wells in the locations identified for geothermal potential. To date, no commercial or large-scale geothermal projects have been developed in Guam.

Hawaii

In 2008, the State of Hawaii, in partnership with DOE, signed a Memorandum of Understanding to collaborate on reducing the state's dependence on imported fossil fuels. This MOU, which was recommitted in 2014, launched the Hawaii Clean Energy Initiative, which created ambitious energy and climate goals and made the state to be the first to commit to 100% renewable energy by 2045. Today, renewable portfolio standards (RPS) and net negative emissions targets are central to Hawaii's clean energy policy. The RPS established in 2015, aims for 40% net electricity generation by 2030 and The 2018 Zero Emissions Clean Economy Target revised previous statues to target net negative carbon emissions statewide by 2045. The state continues to rapidly move towards these goals and since establishing the renewable portfolio standard in 2015, usage of renewable energy usage has nearly doubled statewide.

Hawaii's unique geography and geologic features make geothermal an especially attractive and viable renewable energy option. Hawaii's electricity system is comprised of six standalone grids, independently creating and delivering power for each island. Currently, commercial scale geothermal electricity generation is only operational on Hawaii Island (at Puna Geothermal Venture) and accounts for roughly 18% of total electricity consumption on the island. At current capacity, Hawaii Island's grid is the most manageable for geothermal, but ongoing research and development efforts by the state, as well as private developers, are investigating ways to develop geothermal resources on other islands, especially on Oahu, the population center of the state with the highest energy needs.

Idaho

Idaho's volcanic landscape makes it an ideal location for geothermal energy development. The state has over 1,000 wells and 200 springs that can be used to extract geothermal energy and has several commercial geothermal power plants, including the Raft River Enhanced Geothermal System Project, which provides about 11 MW of net capacity.

In addition to generating electricity, geothermal energy is also used to heat buildings and grow plants. Boise is home to the nation's first geothermal district heating system, and the city's geothermal heating utility delivers naturally heated water through over 20 miles of pipeline to more than 6 million square feet of building space. The Idaho Statehouse is the only geothermally heated capitol building in the nation, and district heating is also currently being used for space heating at several of the Boise State University campus buildings.

Kansas

GSHPs are deployed in a variety of commercial and residential buildings across the state: In Lawrence, the Castle Tea Room was retrofitted with a GSHP system during renovation to provide heating and cooling, as well as hot-water radiant floor heating; the Regional Correctional Facility at Fort Leavenworth includes a GSHP system with 480 bore holes drilled up to 280 feet deep, providing heating, cooling, and refrigeration; Greensburg, Kansas, which was devastated by a tornado in 2007, has been rebuilding with an emphasis on green technology, including GSHP systems in several new or rebuilt homes and buildings, such as a school campus, city hall, and the Kiowa County Courthouse.[18]

Montana

Montana State University researchers helped pilot a new type of geothermal heating and cooling system that could reduce the cost of the technology. The team of engineering faculty and students guided the installation of an innovative closed-loop piping configuration as part of a major expansion at a rural school in Winifred. The closed-loop configuration utilizes shallower geothermal boreholes than a traditional system, resulting in shorter drilling periods. Since drilling is typically the biggest expense associated with geothermal heating and cooling systems, the technique could lead to significant cost savings.

If the cost savings in installation significantly overcome any reduction in energy performance from the shallower boreholes, there could be a wide range of applications for this new type of geo-exchange system, including residential development or in places where deep boreholes are prohibitive due to shallow aquifers or other limitations.

Cross-industry partnerships and collaboration between trade workers, engineers, geothermal designers, and academics facilitated innovative technology design, ultimately reducing costs and demonstrating how a traditionally expensive system can be viable in a rural and underserved community.[19]

Nebraska

Located in Lincoln, The Bridges is the state's first fully geothermal residential neighborhood. The development has six large geothermal ponds, which provide the foundation for the geothermal heat exchange unit used in each home. Residents are required to utilize geothermal heating and cooling and the geothermal transfer lines that connect homes to the cooling unit are included in the price of the house. Homeowners save between 30-70% on energy costs and use significantly less electricity.

Nevada

As one of the top producers of geothermal energy in the country, Nevada has a well-established geothermal industry and strong industry expertise. This technical expertise and a streamlined state permitting process allow projects in Nevada to advance relatively quickly, making it an attractive location for both startups and established developers.

Collaboration and robust stakeholder engagement have also been instrumental in the success of geothermal energy in Nevada. The industry has worked closely with government agencies, local communities, and research institutions to develop projects that are socially responsible and environmentally sustainable. Located in Churchill County, Enel's Stillwater Triple-Hybrid Plant is a first of its kind facility, combining binary cycle geothermal power with solar photovoltaic and solar thermal. Enel's collaborative approach from the outset was a key factor in the project's success. Project proponents held public forums to educate local communities, address concerns, and incorporate feedback. Partnering with the Desert Research Institute, extensive environmental studies were conducted to understand wildlife, vegetation, and environmental risks and to establish a mitigation plan. Since being commissioned in 2009, Stillwater has provided hundreds of jobs, millions of dollars in local investment and has generated enough electricity to power more than 17,000 homes annually.[20] Electricity generated at this facility is also used to power Wynn Las Vegas, made possible by a PPA signed in 2018 with the resort.

Additionally, Nevada has favorable policies and incentives that have supported the growth of the geothermal industry. For example, the state offers a 55% property tax abatement for geothermal power systems with at least 10 MW capacity. Nevada has also focused on streamlining administrative processes and permitting authorities for developing geothermal resources, with state-level geothermal legislation and policy development active in the state.

New Mexico

With the sixth-highest geothermal potential in the U.S., New Mexico has attracted the interest of developers who are actively looking to develop the resource. In 2021, Canadian company Eavor successfully drilled an 18,000-foot well bore in southwest New Mexico using their new technology, proving that it can potentially access deep subsurface hot-rock formations that offer massive amounts of clean, renewable energy. The completed well is the deepest hole ever drilled in New Mexico and has demonstrated enormous potential for unleashing a virtually unlimited source of clean energy for electricity generation and for heating and cooling.[21]

Beyond demonstrating drilling potential, Eavor's operation exemplified the lucrative employment opportunities for oil and gas industry workers in geothermal. Two conventional drilling rigs were used on this project, employing dozens of oil and gas workers. Partnerships and investments from drilling rig operating companies ensure stability and provides continual opportunity for workers.

In 2022, the state legislature formed a geothermal working group, comprised of private developers and other stakeholders, to explore local development potential and recommend action to increase investments in both geothermal electricity generation and heating and cooling. Work group findings may pave the way for future legislation to help further encourage geothermal development across New Mexico.

North Dakota

A team from the University of North Dakota introduced a geothermal energy project to the community of New Town. The project proposal, which was recognized by DOE GTO's Geothermal Collegiate Competition, involves using existing gas wells to draw hot water from deep aquifers, generating geothermal energy to heat buildings, grow food, and create jobs.[22]

The project sought to raise awareness about geothermal district energy generation and to provide a forum for discussion among local tribal leaders to consider renewable energy sources like geothermal. Project proponents engaged with members of Mandan, Hidatsa, and Arikara Nations to understand the cultural and historical contexts of energy in the area and to design a project to maximize community impact. Meaningful tribal consultation in proposal development sparked a new interest in geothermal amongst some New Town tribal leadership.

Northern Mariana Islands

Initial resource assessments conducted in 2008 suggest that there is significant potential for geothermal energy in the Northern Mariana Islands. On South Pagan, the size of the hydrothermal reservoir and the chemistry of the hot springs suggests a geothermal reservoir exists with an estimated generating capacity of 50-125 MW. On other islands like Saipan, deep faulting may allow deep thermal waters to migrate upwards, creating opportunities for low and medium temperatures resources.[23] Deeper temperature gradient wells would be necessary to determine full potential for geothermal power generation.

Oklahoma

As part of DOE's Wells of Opportunity program, researchers at the University of Oklahoma were awarded $1.7 million in 2022 to repurpose abandoned oil and gas wells for geothermal energy. The project uses four hydrocarbon wells to produce geothermal energy for an elementary and middle school in nearby Tuttle.[24] The benefit from recycling existing oil and gas well infrastructure is expected to create considerable savings for the schools.

Retired oil wells may give Oklahoma significant advantage in developing geothermal assets, given the risk, cost, and environmental impact of drilling geothermal wells is significantly reduced by utilizing retired or abandoned infrastructure. Of the many retired wells in Oklahoma,
a large number are believed to be viable for geothermal energy and in many cases, are located near schools, farms, factories, and other structures that could be beneficiaries of the energy produced.

Oregon

In recent years, Oregon has seen significant growth in geothermal energy production, in particular for direct use and heating and cooling. In 2020, Oregon produced 2.9 trillion Btu of geothermal energy, with 1.2 trillion Btu used for heating and cooling residential, commercial, and industrial spaces.[25] The city of Klamath Falls has long utilized geothermal heat sources to heat buildings, residences, pools, and sidewalks. Other examples of direct use of geothermal heat in the state include drying agricultural products, aquaculture, heating greenhouses, swimming pools and hot springs resorts. Oregon has more than 2,000 thermal wells and springs delivering direct heat to buildings, communities, and other facilities, demonstrating the versatility of geothermal energy as a renewable source of heat.

Beyond direct use applications, Oregon's volcanic geology has supported geothermal power production for more than a decade. Since 2010, AltaRock Energy's Newberry EGS Demonstration project, NEWGEN, has conducted ongoing research to stimulate fracture zones, demonstrate diverter technology, and develop a conceptual model of the EGS reservoir. The project site, located on the western flank of Newberry Volcano, is one of the largest geothermal heat reservoirs in the West and could generate up to 10 GW of electricity using super hot rock extraction technology.[26] If successful, NEWGEN would likely become world's first super hot rock demonstration project and could lead to the construction of a 35MW binary cycle geothermal plant that could generate electricity to be exported or used to power surrounding communities.

Oregon's success in geothermal energy has been bolstered by state-level financial assistance programs, such as property tax exemptions for properties equipped with alternative energy systems, as well as programs that support the development of geothermal heating systems. Additionally, Oregon's designated authority from the Environmental Protection Agency to issue Class V injection permits has
been effective at expediting the exploration and development process.

South Dakota

Geothermal district heating is being used in various parts of South Dakota for space heating. In Midland, a municipal well drilled in 1969 supplies hot water to heat approximately local buildings and spaces including schools, churches, campgrounds, downtown municipal buildings, residential buildings and homes. This system is relatively low maintenance and requires few personnel to maintain, making it a cost-effective solution for a rural town.[27]

Texas

Since 2021, the Texas geothermal industry has seen rapid growth, with more than a dozen geothermal startups establishing themselves in the state. Many of these ventures are led by oil and gas industry veterans and have leveraged that extensive expertise to develop innovative technology solutions and form valuable partnerships.

Sage Geosystems and the Bureau of Economic Geology at the University of Texas at Austin launched a joint venture aimed at developing a prototype using advances in oil and gas drilling technologies to drill multiple wells to produce electricity by circulating a fluid deep in the earth to absorb heat from the magma. The 2021 Phase I feasibility study used nearly 50-year-old abandoned oil and gas wells in South Texas to test the model. The project is designed to demonstrate geothermal ability to provide constant, load-following power generation in an isolated microgrid at Ellington Field Joint Reserve Base and meet 100% of the Base's current electricity needs.[28] Phase I and II of the project were funded through a Small Business Technology Transfer award, under the Air Force Innovation Program and if successful, Sage Geosystems is expected to build the first prototype geothermal project at Ellington.

Utah

Situated within the Basin and Range Province, Utah provides immense potential for not just conventional hydrothermal systems, but also EGS and other innovative technologies. Rapid and innovative development has been bolstered by supportive state policies and initiatives. In the early 2000s, the state established a Utah Geothermal Working Group to facilitate collaboration between industry stakeholders, regulators, and local communities, fostering a supportive environment for geothermal projects. Today, recent programs and policies aimed at incentivizing geothermal development have spurred advancements in the state. The Utah Renewable Energy Systems Tax Credit provides financial incentives for the installation of geothermal systems, reducing the upfront costs for property owners. In addition to federal investments such as Utah FORGE, private developers continue to site projects in Utah, most recently, Thermo, a 14MW generating facility operated by Cyrq.

Governor Jared Polis and Governor Spencer Cox get an up-close tour of Cyrq Energy's Thermo Geothermal Power Plant in Utah.

Washington

Washington has potential for geothermal energy production due to its location along the Cascade Range. However, the low cost of electricity generated from the state's abundant hydropower has limited the development of geothermal resources. In addition, there are challenges associated with geothermal exploration in the state, such as the lack of high-temperature resources.[29] In 2010, Washington Public Utilities District conducted an exploratory drilling study in Snohomish County to test geothermal potential. Exploratory efforts ceased in 2012 after drilling hit bedrock. In 2014 and 2017, DOE awarded funds to the Washington Geologic Survey to validate additional areas of geothermal potential; WGS published these results in a favorability map. Most of Washington's urban areas like Tacoma and Seattle lie outside of feasibility areas for potential geothermal electricity production. However, GSHPs in these areas capitalize on the regions' low-temperature geothermal resources.

Wyoming

In 2022, Petrolern published a study for the Wyoming Energy Authority assessing the feasibility of geothermal opportunities in Wyoming. The study found that Wyoming's geothermal resources are generally moderate to low temperatures and situated in localized regions throughout the state. Low temperature geothermal utilization technologies such as geothermal heat pumps, direct use heating, and Organic Rankine Cycle electricity generation are applicable to these resources. Financial analysis showed that new drilling of prospects has low commercial viability, while repurposing existing wells has moderate viability. Synthetic Geothermal Reservoir has potential for high commercial viability, but additional work is needed to fully assess its economic viability.[30] Though protected from development, Wyoming's most notable geothermal feature, Yellowstone National Park, continues to be a significant economic source for the state, bringing in millions of tourism dollars annually.

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ORMAT

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Grand Junction, Colorado
September 27, 2022

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- Jennifer Livermore, Senior Geothermal Project Analyst, U.S. Department of Energy Geothermal Technologies Office
- Brad McCloud, Area Manager, Community Relations Western Colorado, Grand Junction Lions Club, Xcel Energy
- Lorenzo Trimble, National Geothermal Program Lead, Bureau of Land Management
- Lyn White, Director of Government Relations, Western Governors' University

CMU Recap Webinar

October 6, 2022

- Kent Marsh, Vice President for Capital Planning, Sustainability, and Campus Operations, Colorado Mesa University
- Will Toor, Executive Director, Colorado Energy Office

Hawaii Workshop

October 9-10, 2022

- The Honorable David Ige, Governor of Hawaii
- William Aila, Chairman, Hawaiian Homelands Commission
- Erick Burns, National Geothermal Resources Investigations Project Leader, U.S. Geological Survey
- Suzanne Case, Chairperson, Hawaii Department of Land and Natural Resources
- Allen Clarkson, Director of Government Relations, Western Governors Association
- Luke Frash, Research Scientist, Los Alamos National Laboratory
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- Nick Goodman, Chief Operating Officer, Cyrq Energy
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- Riley Saito, Energy Specialist, County of Hawaii
- Monique Schafer, Renewable Energy Project Specialist, Hawaii State Energy Office
- Paul Thomsen, Vice President of Business Development, Ormat Technologies
- Michael Turner, Director of Building Innovation and Energy Finance, Colorado Energy Office
- Lyn White, Director of Government Relations, Western Governors' University

Hawaii Recap Webinar

October 20, 2022

- Scott Glenn, Chief Energy Officer, Hawaii State Energy Office
- Nicole Lautze, Principal Investigator, Professor, Hawaii Groundwater and Geothermal Resources Center

Idaho Workshop

Boise, Idaho October 24, 2022

- The Honorable Brad Little, Governor of Idaho
- Eric Anderson, President, Idaho Public Utilities Commission
- John Anderson, Economic Development and Innovation Advisor, Idaho Power Company
- Claudio Berti, Director and State Geologist, Idaho Geological Survey
- Erick Burns, National Geothermal Resources Investigations Project Leader, U.S. Geological Survey
- Alexis Clark, Hydrogeologist, Idaho Geological Survey
- Grant Cummings, Policy Associate, ClearPath
- Jared Dalebout, Geologist, Bureau of Land Management
- Patrick Dobson, Geothermal Systems Programs Lead, Lawrence Berkeley National Laboratory
- Juan Escobar, Head of Geoscience, Eagle Ford Asset, BPX Energy
- Jim Faulds, Nevada State Geologist, Professor, Nevada Bureau of Mines and Geology, University of Nevada, Reno
- Nick Goodman, Chief Executive Officer, Cyrq Energy
- Richard Horsley, Energy Manager, U.S. Air Force
- Bryant Jones, Executive Director, Geothermal Rising
- Jennifer Livermore, Senior Geothermal Project Analyst, U.S. Department of Energy Geothermal Technologies Office
- George Lynch, Legal Counsel, Idaho Governor's Office of Energy and Mineral Resources

- Travis McLing, Research Scientist, Idaho National Laboratory
- Andrew Mendoza, Deputy Base Civil Engineer, United States Air Force 366th Civil Engineer Squadron
- Roy Mink, Geohydrologist, Mink Geo-Hydro Inc.
- Scott Nichols, Regulatory Affairs Manager, Ormat Technologies
- Jim Ogsbury, former Executive Director, Western Governors' Association
- Richard Stover, Administrator, Idaho Governor's Office of Energy and Mineral Resources
- Mick Thomas, Division Administrator, Minerals, Navigable Waterways, Oil and Gas, Idaho Department of Lands
- Lorenzo Trimble, National Geothermal Program Lead, Bureau of Land Management

Idaho Recap Webinar

November 7, 2022

- Claudio Berti, Director and State Geologist, Idaho Geological Survey
- John Gunnerson, Geothermal Coordinator, City of Boise
- Lorenzo Trimble, National Geothermal Program Lead, Bureau of Land Management

Utah Workshop

Cedar City, Utah December 12, 2022

- The Honorable Spencer Cox, Governor of Utah
- Phillip Ball, Chief of Geothermal Innovation, Clean Air Task Force
- Bryce Carter, Emerging Markets Program Manager, Geothermal, Colorado Energy Office
- Patrick Dobson, Geothermal Systems Program Lead, Lawrence Berkeley National Laboratory
- Joel Edwards, Chief Technical Officer, Zanskar Energy
- Robin Hansen, Petroleum Engineer, Geothermal Program Lead, Bureau of Land Management
- Amanda Kolker, Geothermal Program Manager, National Renewable Energy Laboratory
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- Travis McLing, Research Scientist, Idaho National Laboratory
- Jaina Moan, External Affairs Director, The Nature Conservancy
- Joseph Moore, Principal Investigator, Utah FORGE, EGI, University of Utah
- Johanna Ostrum, Chief Operating Officer, Transitional Energy
- Jeffrey Sallow, Geologist, U.S. Forest Service
- Greg Todd, Director, Utah Governor's Office of Energy Development
- Mike Visher, Administrator, Nevada Division of Minerals

Utah Recap Webinar

December 19, 2022

- Joseph Moore, Principal Investigator, Utah FORGE, EGI, University of Utah
- Jaina Moan, External Affairs Director, The Nature Conservancy

NREL Workshop

Golden, Colorado February 24, 2023

- The Honorable Jared Polis, Governor of Colorado
- John Anderson, Economic Development and Innovation Advisor, Idaho Power Company
- Koenraad Beckers, Research Engineer, Energy Conversion and Storage Systems Center, National Renewable Energy Laboratory
- Kelly Blake, Division Director, President, Navy Geothermal Program, Geothermal Rising
- Lauren Boyd, Acting Director, U.S. Department of Energy Geothermal Technologies Office
- Bryce Carter, Emerging Markets Program Manager, Geothermal, Colorado Energy Office
- Cynthia Connor, Policy Director, Offsets and Emerging Technology, Chevron New Energies
- Kristin Elowe, Planning and Environmental Coordinator, Bureau of Land Management
- Juan Escobar, Head of Geoscience, BP
- Neil Ethier, Vice President of Business Development, Eavor
- Jonathan Ho, Energy System Modelling Engineer, National Renewable Energy Laboratory
- Joseph Islas, Geologist, Bureau of Land Management
- Sarah Jewett, Vice President of Strategy, Fervo Energy
- Bryant Jones, Executive Director, Geothermal Rising
- Kimilia Jones, Commercial Manager, Chevron New Energies
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- Amy Robertson, Senior Manager, State Government Relations and External Affairs, Tri-State Generation and Transmission Association
- Michelle Slovensky, Intelligent Campus Program Manager, National Renewable Energy Laboratory

- Faith Smith, Researcher, Strategic Energy Analysis Center, National Renewable Energy Laboratory
- Mark Silberg, Special Advisor on Climate and Energy, Colorado Governor Jared Polis
- Will Toor, Executive Director, Colorado Energy Office
- Lorenzo Trimble, National geothermal Program Lead, Bureau of Land Management
- Kathryn Valdez, Director, Carbon-Free Technology Policy, Xcel Energy
- Jack Waldorf, Executive Director, Western Governors' Association

NREL Recap Webinar

March 2, 2023

- Bryant Jones, Executive Director, Geothermal Rising
- Amanda Kolker, Geothermal Program Manager, National Renewable Energy Laboratory
- Chris Markuson, Western States Director, BlueGreen Alliance

Webinar: More Than Just Heat

January 23, 2023

- Sarah Jewett, Vice President of Strategy, Fervo Energy
- Keith Malone, Public Affairs Officer, Hydrogen Fuel Cell Partnership

Webinar: Renewable Energy Incentive Parity

March 29, 2023

- Bryce Carter, Emerging Markets Program Manager, Geothermal, Colorado Energy Office
- Sean Porse, Data, Modelling, and Analysis Program Lead, U.S. Department of Energy Geothermal Technology Office
- Landon Stevens, Senior Program Director, Electricity, ClearPath

Webinar: Geothermal Energy at Home

May 3, 2022

- Jeff Hammond, Executive Director, International Ground Source Heat Pump Association
- Heather Deese, Senior Director of Policy and Regulatory Affairs, Dandelion Energy
- Ryan Dougherty, President, Geothermal Exchange Organization (GEO)
- Terry Proffer, GeoExchange Designer and Geologist, Major Geothermal.

Podcast: The Well of the Future: Repurposing Oil and Gas Wells for Geothermal Energy Production

November 2022

- Will Gosnold, Professor of Geological Engineering, University of North Dakota
- Will Pettitt, Geothermal Discipline Lead, Baker Hughes
- Johanna Ostrum, Chief Operating Officer, Transitional Energy

Survey Respondents

- Anzar Consulting
- B2E Consultation
- Bain Geophysical Services, Inc.
- Baker Hughes
- Baseload Power US
- Billings County, North Dakota
- California Department of Conservation
- California Geothermal Heat Pump Association
- Chaffee County, Colorado
- City of Salida, Colorado
- Clean Air Task Force
- ClearPath
- Colorado Public Utilities Commission
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- Fire and Ice Geothermal Heating and Cooling LLC
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- Nevada Department of Wildlife
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