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Unlocking America's untapped energy potential through enhanced geothermal systems

About This Brief

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Top Lines

- Enhanced geothermal systems (EGS) represent a significant advancement from conventional geothermal technologies. By utilizing directional drilling tools and technologies perfected by the oil and gas industry as well as hydraulic fracturing to overcome limited geographic accessibility and reduce costs, EGS has unlocked the potential for widespread deployment across the United States, offering a cleaner, more affordable, and strategically advantageous energy solution.

- ESG offers a valuable solution to concerns of growing energy demand as economic competitiveness issues grow increasingly prominent. Innovations beyond conventional geothermal systems reduce operational costs over time and increase scalability, positioning EGS as a key driver for US decarbonization efforts while maintaining productivity and global competitiveness.

- Despite its potential and demonstrated interest from high-demand sectors like data centers, wide-scale commercial deployment of and investment in EGS requires streamlined permitting processes and reduced upfront capital costs to attract investment. Government support through legislation and funding, coupled with industry-led initiatives such as joint ventures, will be crucial to acceleration the adoption of EGS and unlocking its full potential in the United States' energy landscape.

Geothermal energy, with its potential to bolster economic competitiveness and energy security imperatives while supporting environmental sustainability, stands at the nexus of a unique opportunity to meet bipartisan energy and foreign policy objectives. While conventional geothermal and hydrothermal systems have historically faced opposition for their limited geographical accessibility and high upfront costs, the emergence of enhanced geothermal systems has significantly augmented the viability of widescale geothermal deployment to support a cleaner, more affordable, and strategically advantageous energy sector.

The Atlantic Council Global Energy Center develops and promotes pragmatic and nonpartisan policy solutions designed to advance global energy security, enhance economic opportunity, and accelerate pathways to net-zero emissions.

> "EGS is one of the most reliable energy sources available in the United States."

Distinguishing enhanced geothermal from conventional systems

Enhanced geothermal systems differ from conventional hydrothermal technologies primarily in their use of directional drilling and hydraulic fracturing to access geological heat. These advancements have mitigated several longstanding challenges associated with commercial-scale geothermal deployment:

Geographic viability: Conventional hydrothermal systems are, in large, geographically constrained to areas with natural hot water or steam deposits occurring at shallow depths near the Earth's surface and, therefore, are not a viable option across the United States. EGS, however, utilizes directional drilling and hydraulic fracturing that create more permeable pathways through rock formations, so these systems can extract higher temperature geothermal energy from deeper into the Earth's crust from nearly any region in the United States and more efficiently convert energy into electricity.

Operator control: Conventional hydrothermal systems rely on steam extracted from natural reservoirs to power a turbine to generate electricity. Conversely, enhanced geothermal injects water into the permeable rock fractures and pumps the water back to the surface. On its way, the water converts to steam and powers a turbine. That fluid is then recycled into the system's reservoir—with some losses—.[1] This allows the operator a greater degree of control over the flow rate, temperature, and pressure of the water to enhance the flexibility and efficiency of energy production.

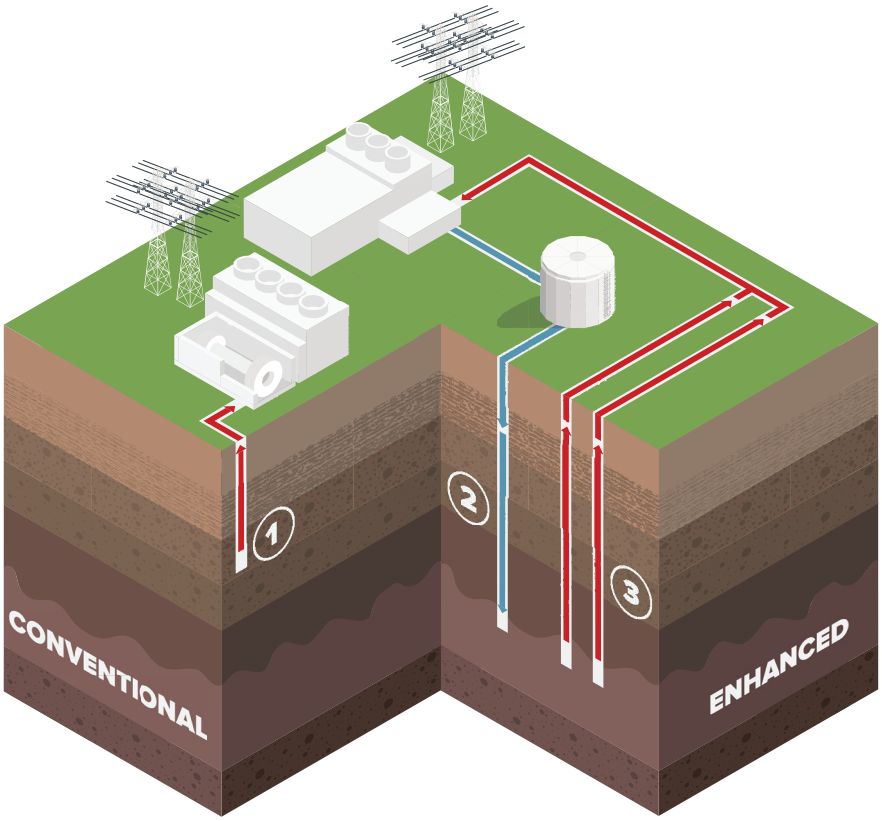
Department of Energy-funded geothermal research project, Utah FORGE, received breakthrough results to this effect in April of 2024: more than two-thirds of the water injected underground and circulated through rock formations returned adequately heated throughout a nine-hour test, long enough to prove a successful and efficient connection. Notably, there was no induced seismicity more than magnitude 1.9 during the test, falling well short of felt seismicity thresholds.[2]

Project scale and cost-recovery: Reducing geographic limitations has improved the scalability of geothermal projects while also allowing co-location of projects nearer to centers of demand, thereby significantly improving the viability of geothermal to be a 24/7 clean power solution to facilities like data centers. Similarly, industry-wide improvements in siting and exploration—including advanced geophysical surveys, remote sensing technologies, and predictive modeling algorithms—enable more precise location and characterization of geothermal reservoirs, minimizing uncertainties in early stages of project development.

Due to these key advancements from conventional to enhanced geothermal systems, the economics of geothermal are beginning to shift. While the cost of geothermal energy has remained steady over the past decade, employing new techniques and technologies in EGS pilot projects has already helped lower geothermal energy prices. For example, Fervo Energy has seen significant improvements in drilling efficiency at its Cape Station project in southwest Utah that began in June of 2023, where its drilling costs have fallen from $9.4 million to $4.8 million per well.[3]

The geothermal industry is hopeful that investment flows will follow suit as geographic flexibility, improved project certainty, clearer return pathways,

Figure 1: How conventional and enhanced geothermal systems differ



1. Conventional geothermal systems use hot water from existing natural reservoirs near the surface to produce steam, which turns a turbine to generate electricity.

2. Enhanced systems inject water to deeper depths where it is heated by hot rocks.

3. These systems pump the heated water back to the surface and uses the steam that is generated to rotate a turbine to generate electricity.

Illustration: Gledis Bozo

and higher margins have improved the overall proposition for geothermal energy. Some of these investment flows have already begun. Earlier this year, the Department of Energy announced plans to invest $60 million to demonstrate the efficacy and scalability of EGS projects, a move that is poised to drive an increase in private sector contributions.[4]

And in May, the Canadian startup Eavor received a €45 million loan from the European Investment Bank to support the construction of enhanced geothermal plant near Munich. This loan expands on a previous €91.6 million grant that Eavor received from the EU Innovation Fund.[5]

Supporting energy and foreign policy objectives

As the convergence of technological innovation and energy priorities gains momentum, EGS offers a critical opportunity for the United States to combat climate change, improve energy security, and bolster economic competitiveness. In alignment with these priorities, EGS offers a pathway towards decarbonization, grid stability, and economic opportunity.

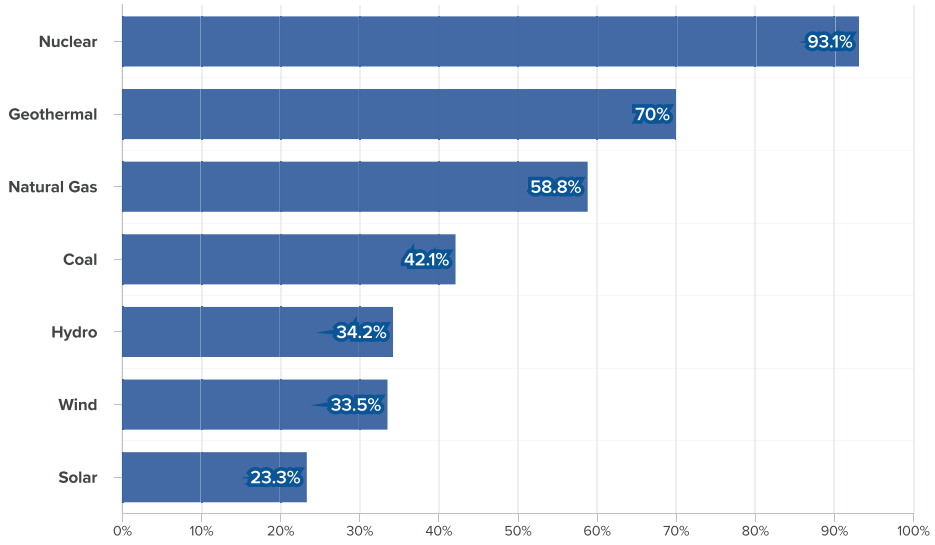
1. **Energy security and affordability:** EGS is one of the most reliable energy sources available in the United States because it operates around the clock and with minimal disruptions. It can produce electricity to be stored or dispatched as a complement to other renewables, such as solar and wind, which depend on optimal weather conditions. EGS even surpasses the reliability of coal and natural gas power plants, which are burdened by resource transportation and refueling logistics. EGS is also one of the most efficient energy sources, as it maintains a high percentage of its primary energy through conversion, while fossil fuels lose nearly two-thirds of their energy during conversion to electricity.[6]

   EGS can also support the increasing demand for electricity without compromising affordability for consumers. Despite high fixed costs up front, minimal variable costs for occasional maintenance and repairs make it cost-effective in the long run compared to fossil fuel power plants that require continuous resource extraction, processing, and transportation. And with new efficiencies in drilling technologies and enhanced exploration and extraction processes, initial costs have decreased as well.

2. **Energy independence and economic competitiveness:** EGS is still in its nascent stage of development, with growth propelled by infrastructure and technologies produced and honed by the oil and gas industry in the United States. By cultivating energy sources that rely largely on domestically produced components—from drills to turbines—EGS can strengthen energy independence and reduce US reliance on China for clean technology inputs, such as polysilicon, ingot, and wafers for solar panels and steel, copper, and rare earth elements for wind turbines.

   EGS also offers a 24/7 clean power alternative for emissions-heavy sectors such as transportation equipment, minerals and metals, and heavy machinery, which collectively contributed to more than $659

Figure 2: Capacity factor by energy source, 2023

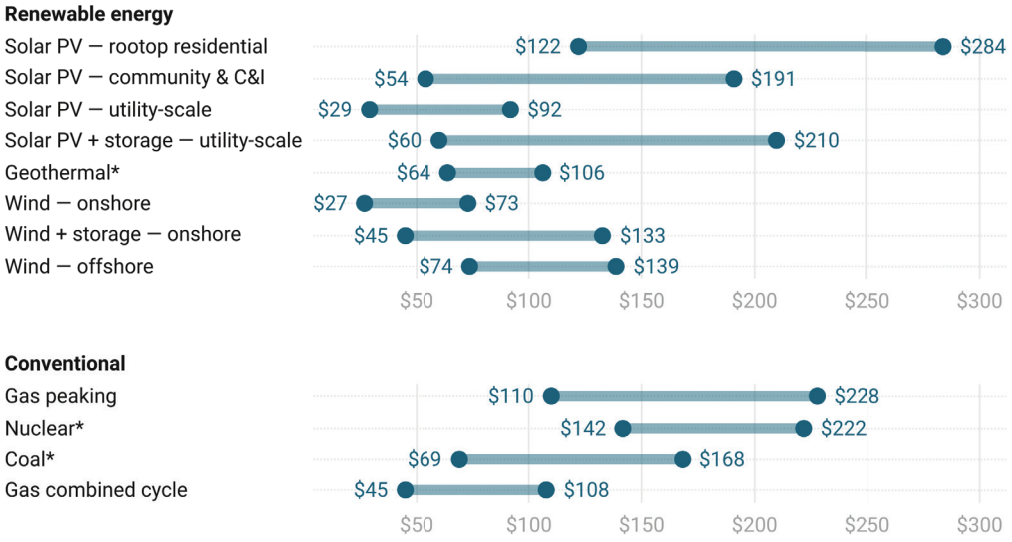


Capacity factor measures a power plant's actual generation compared to the maximum amount it could generate in a given period without any interruption.

Source: Office of Nuclear Energy | US Department of Energy (@GovNuclear), "ALWAYS ON: U.S. nuclear power plants operate at FULL power more than 93% of the time and have held capacity factors north of 90% since the early 2000s.," X, October 18, 2024, 12:21 p.m., https://x.com/GovNuclear/status/1847311955549147283

Figure 3: Levelized cost of energy comparison—unsubsidized analysis

Selected renewable energy generation technologies are cost-competitive with conventional generation technologies under certain circumstances. **(Levelized Cost of Energy ($/MWh)**



Note: Here and throughout this publication, unless otherwise indicated, the analysis assumes 60 percent debt at an 8 percent interest rate and 40 percent equity at a 12 percent cost.
**: Given the limited public and/or observable data available for new-build geothermal, coal, and nuclear projects the LCOE presented herein reflects Lazard's LCOE v14.0 results adjusted for inflation.*

Source: "Lazard's Levelized Cost of Energy Analysis – Version 17.0" in LCOE, Lazard, June 2024, https://www.lazard.com/media/xemfey0k/lazards-lcoeplus-june-2024-_vf.pdf

billion (31.9 percent) of US exports in 2020.[7] Deploying geothermal to power these sectors would advance US decarbonization efforts while maintaining productivity, thus bolstering the nation's competitive advantage in a manner not achievable by intermittent renewable sources. Furthermore, as a first mover in geothermal technologies, the United States can export both traditional project development as well as technical expertise to compete in global clean energy markets, providing an alternative to emerging economies like Indonesia, Kenya, and Mexico who are interested in deploying geothermal energy to support baseload electricity requirements for their rapidly growing populations.

3. **Environmental sustainability:** Like conventional geothermal, enhanced geothermal systems provide an emissions-free alternative to carbon-based fuels, which is key to combatting climate change. Fossil fuel power plants emit greenhouse gases when burning coal, oil, or gas to heat and convert water into steam, which powers a generator to produce electricity. While EGS also relies on steam for generating electricity, it uses the heat from deep in the Earth's crust to heat and vaporize water without producing emissions.

Overcoming obstacles to scalability and commercialization

Recognizing the potential of geothermal energy to support the above priorities, the US government has taken steps to improve the feasibility of EGS, including the Bureau of Land Management's (BLM) finalization of a new categorical exclusion for operations on public lands, including the drilling of wells, to confirm the presence of geothermal resources as well as launching the Enhanced Geothermal Shot initiative, which seeks to reduce the cost of EGS by 90 percent by 2035.[8]

However further policy development and industry-led initiatives targeting scalability and commercialization are required to enable existing measures, like BLM's CATEX, to fulfill its potential value to high-demand, economically competitive sectors.

First, despite innovations in geothermal technologies, investors remain apprehensive due to the unpredictability and length of project development timelines driven by federal permitting processes for exploration, drilling, and utilization of geothermal resources and power plants. To reduce these risks and encourage investment:

- Congress should pass S.3954—Geothermal Energy Opportunity Act to extend categorical exclusions to geothermal projects and shorten the permitting timeline.[9]

- Geothermal companies should undertake standalone EGS projects—like Fervo Energy's commercial pilot with Google—to demonstrate proof of concept to potential investors.[10]

Second, EGS projects require substantial upfront costs, which constitute a significant barrier to entry for developers. The capital-intensive nature of this sector arises from various factors such as exploration and resource assessment, drilling and infrastructure development, and further technology development and innovation. To mitigate capital restrictions:

- Congress should increase funding for a series of large-scale EGS demonstration projects to highlight the feasibility and cost-effectiveness of EGS to encourage private sector investment in the new technology.

- Geothermal companies should engage in joint ventures with established oil and gas companies to leverage cost-effective, proven technologies and competencies surrounding drilling and wells to accelerate the deployment of projects, including on sites of previously retired oil and gas plants.

Third, to advance geothermal energy as a central component of the US energy strategy, the Trump administration should take a more deliberate and bespoke approach to integrating it into the energy dominance agenda rather than relegating it as a climate technology. While geothermal has historically been grouped within broader clean energy initiatives like the IRA and IIJA, lacking individualized focus at the federal level, EGS presents an opportunity to treat geothermal as a distinct and scalable energy resource much like oil, gas, and nuclear energy, as acknowledged by Secretary of Energy Chris Wright and Secretary of Interior Doug Burgum. To achieve this:

- The administration should establish a Geothermal Subcommittee within the National Energy Council to provide a dedicated forum for federal and state government collaboration on geothermal policy, ensuring it receives strategic attention and investment.

- The Department of Energy should carve out exemptions for geothermal energy projects under new executive actions, such as Executive Order 14154, "Unleashing American Energy", that pause disbursement of funds appropriated through the IRA and IIJA, which appropriated $84 million for EGS demonstration projects.[11]

Owing to transformative innovations from conventional to enhanced systems, geothermal energy shows promise as a vital component of the United States' energy strategy.

Looking ahead

Moving forward, continued research and development into next-generation geothermal technologies, predominantly advanced geothermal systems that utilize heat from sub-surface rock rather than reservoirs, will enhance the efficiency, cost-effectiveness, and scalability of geothermal energy. And, as the technology continues to develop, a more thorough exploration of geothermal energy's multifaceted potential to enhance national security and geopolitical strategy is warranted. Harnessing EGS's capacity as a standalone energy source has the potential to support off-grid installations for defense and military bases or data centers, enhancing their resilience and security, particularly when operating in volatile countries for an extended period. The United States can conversely export its knowledge and technological capacity to allied countries, especially emerging economies interested in geothermal deployment, effectively promoting energy security and sustainable development while fortifying its global leadership in clean energy technologies.

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Endnotes

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