From Core to Code

Powering the AI Revolution with Geothermal Energy

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Authors

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Executive Summary

The recent International Energy Agency report *The Future of Geothermal Energy* (2024) highlights the enormous technical potential of next-generation geothermal systems. These systems can provide enough electricity to meet global electricity demand 140 times over. Moreover, no country has more geothermal energy potential than the United States.

In this report, we present the findings of an in-depth techno-economic analysis for a theoretical 1 gigawatt-electric geothermal energy project aimed at a hyperscale data center situated in a theoretical U.S. region with outstanding geothermal resources, akin to those found in the western United States (Nevada, Utah, California, and Oregon).

We find that enhanced geothermal can achieve an $88 per megawatt-hour levelized cost of energy (LCOE), which is competitive with the upper 25% LCOE range for a combined-cycle natural gas project when investment tax credits (ITCs) are included.[1] More importantly, our analysis shows that there is a path to reducing enhanced geothermal LCOE to between $50 and $60 per megawatt-hour below the median natural gas LCOE by 2035.

A paper by Rhodium concluded that geothermal can economically provide 64% of U.S. data center energy needs.[2] Geothermal is unique in that it can provide both power and direct cooling. The insights presented in this paper build on the foundational work of Project InnerSpace's Global Volumetric Model (2024), which formed the basis for their Data Center Power and Cooling Module (2025) available via the GeoMap tool. The work of Project InnerSpace illustrates that geothermal energy is particularly well suited as an energy source for collocated data centers. Utilizing the comprehensive techno-economic model developed by Project InnerSpace, we have analyzed several scenarios for a single geothermal development with a total capacity of 1 gigawatt, which includes power and cooling.

The results presented complement those of the Rhodium Group's, demonstrating how geothermal energy can meet the needs of data centers in the artificial intelligence (AI) era.

- Our analysis shows a feasible path to reduce the LCOE of engineered geothermal systems (EGSs) to approximately $50 per megawatt-hour within the next 10 to 15 years. This reduction can be achieved through ongoing technology advancements, knowledge transfer from the oil and gas sector, consistent project investments to develop the geothermal market and supply chain, and reliable policy support. At this cost, geothermal energy would undercut nearly all combined-cycle natural gas plants.

- Without the inclusion of currently available ITCs, a 1 gigawatt first-of-a-kind (FOAK) geothermal project could achieve an LCOE of $119 per megawatt-hour. The LCOE we achieved through our modeling demonstrates that colocated geothermal is immediately viable in the Western United States, competitive with constrained gas, and significantly better than Lazard's current estimates for nuclear power ($140 per megawatt-hour).

- With current ITCs, a FOAK 1 gigawatt geothermal power and direct cooling project could achieve an estimated LCOE of $88/MWh. This price (and all LCOEs quoted) includes capital recovery for the developer at 9%.

It is important to acknowledge that the continuance of ITCs, production tax credits, and tech-neutral credits are an open question as of the publication of this report. Our analysis shows that these credits are critical to ensuring FOAK projects like the one we describe in this paper move forward. The importance of these credits then diminishes after the success of initial projects, leading to further cost reductions. With a 30% ITC, this 1 GW project would cost the federal government $2.6 billion in tax revenues. Based on the 13% learning rate we have seen in the onshore U.S. oil and gas industry, this $2.6 billion investment would bring the average LCOE of subsequent geothermal projects below $98/MWe without further subsidies. If the federal government chose to invest $10 billion in subsidizing enhanced geothermal projects (an amount that represents half of annual U.S. oil and gas subsidies), we estimate the subsequent unsubsidized EGS LCOE would fall below the median combined-cycle natural gas prices within 10 years. Reaching energy dominance and increasing power for data centers will be more difficult to achieve without the use of geothermal. Ensuring that those tax credits remain intact for geothermal can help ensure that next-generation geothermal plays a critical role in achieving the goals of the Trump administration.

Geothermal energy could be the most promising clean baseload power source for the United States. The cost of building new gas plants is skyrocketing. According to John Ketchum, president and CEO of NextEra Energy, wait times for turbines have increased to between 4 and 5 years over the past several years, and the price tag for gas-fired generation has tripled to between $2,400 and $2,800 per kWe.[3,4] This surge reflects soaring costs related to materials, labor, and financing, and it dramatically reshapes the economic landscape for energy infrastructure.

Unlike gas, geothermal costs are expected to follow the rapid learning curve of the fracking-enabled onshore U.S. oil and gas sector, declining with scale, innovation, and deployment. Three years ago, EGS was estimated as able to achieve an overnight capital cost of approximately $13,500/kWe for a stand-alone project and approximately $9,000/kWe for a near-field extension to an existing hydrothermal project.[5] Since then, Fervo's flagship Cape Station project has tripled its drilling speed and is quickly decreasing its drilling costs.[6] In the techno-economic model we present in this paper, we model a base case with an overnight capital cost of $8,934/kWe, which is within the range of current cost-curve projections. Our model demonstrates that geothermal energy is a competitive source of clean baseload power, particularly when taking into account its distinctive cooling capabilities. Moreover, integrating geothermal as a behind-the-meter energy source for data centers circumvents the bottlenecks associated with grid capacity and lengthy interconnection queues.

Enhanced geothermal is ideally suited for the 24/7, high-resilience, high-capacity demands of data centers. It also provides an additional critical benefit: Cooling can be directly integrated into the energy delivery system for data centers. When between 30% and 40% of a data center's energy is used for cooling, incorporating direct cooling through waste heat recovery (as demonstrated in this paper) within a geothermal system can save operators of a 1 GW data center hundreds of millions of dollars in annual operating costs over the project's lifetime. Additionally, such a system can provide an opportunity to allocate more power toward computing.

At a moment when gas supply chains are strained to their limit and nuclear projects face consistent cost overruns, supply chain shortages, and enormous permitting uncertainty, there is a major upside to investing in geothermal energy. Data centers represent a perfect opportunity to provide high-value power to a willing customer while taking advantage of geothermal power and cooling capabilities. By using its exceptional capabilities in drilling and harvesting energy, the United States can unlock this baseload power source, paving the way for the future of energy and AI.

Table of Contents

THE SCALE OF DATA CENTER ENERGY DEMAND: CURRENT TRAJECTORY IN THE UNITED STATES

Why does this analysis focus on data centers? Colocating baseload energy next to data centers may be the only solution to our crisis with regard to powering artificial intelligence (AI).

No day passes without a new report discussing data center market growth and attempts to project future demand. The magic date seems to be 2030—soon enough to be meaningful for policymakers and market participants and sufficiently far enough in the future to allow for scenario modeling under different stress regimes. The proliferation of content on this topic makes it difficult to choose what to trust and sift through the noise. The basis for the projections is also often lost behind the layers of quotes and references, as are the underlying assumptions.

In this section, we attempt to combine the estimates and forecasts for the U.S. market mentioned in many recent and notable publications. **Figure 1** presents a summary of these projections and quotes.

As **Figure 1** shows, there is quite a spread in the forecasts out to 2030. Projections vary from a modest increase in energy demand of around 215 terawatt-hours (TWh) to as much as 1,050 TWh in some of the reported upside cases. The notable anomaly in the trend is the projection presented in the paper *Situational Awareness*, which stipulates that AI will experience a much more aggressive growth in the United States and data centers will consume a whopping approximately 3,500 TWh of electricity in and around 2030 (approximately 85% of total U.S. electricity demand in 2024).[7]

Table 1 provides a clearer representation of these predictions using statistical measures of the distribution, given the broad and skewed range of potential outcomes.

GROWTH PROJECTIONS FOR U.S. DATA CENTERS' ENERGY DEMANDS

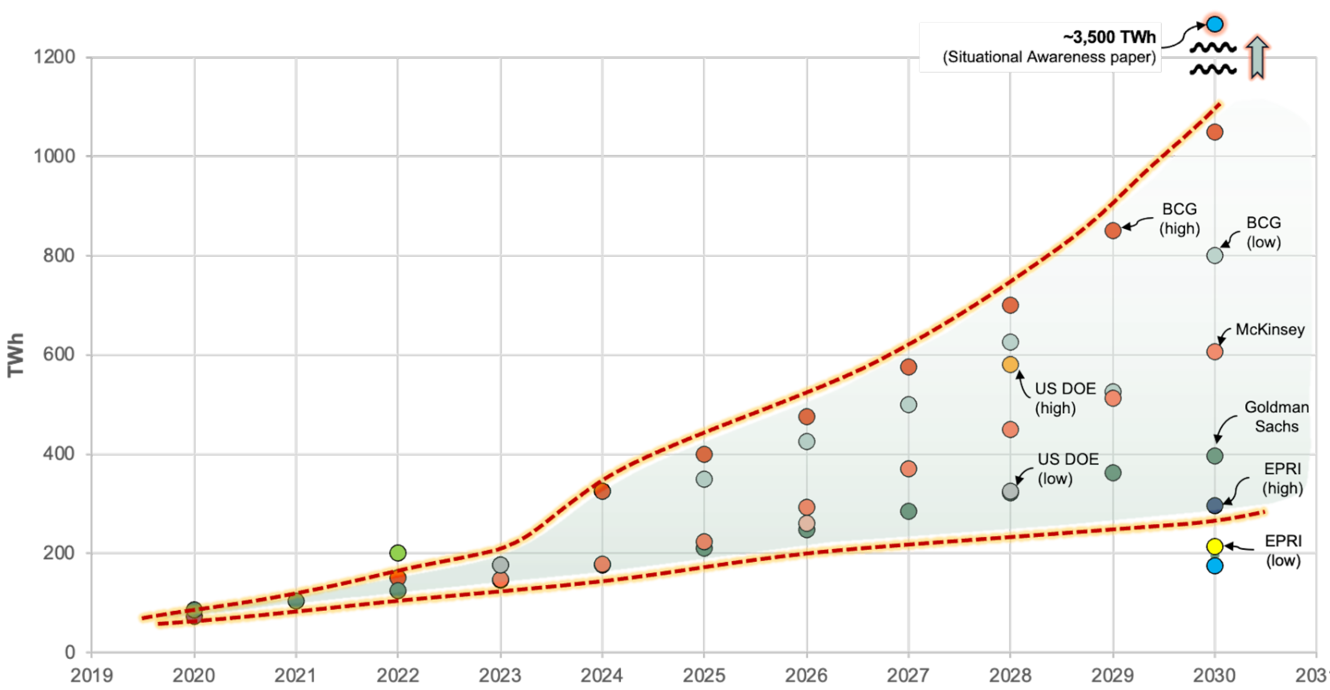


Figure 1. The combined growth projections for energy demand from data centers in the United States, compiled from various publications and publicly available reports published from 2024 through the first quarter of 2025. Source: authors' compilation and analysis of multiple studies.

STATISTICAL RANGE OF DATA CENTER POWER DEMAND

	U.S. Data Centers' Power Demand in 2030	U.S. Data Centers' Power Capacity in 2030	Additional Capacity Needed in 2030 (Relative to 2023)	% of Total U.S. Power Demand in 2030 (Relative to 2024)
P10 (10th percentile)	210 TWh	24 GW	4 GW	5%
P90 (90th percentile)	1,540 TWh	176 GW	156 GW	38%
Mean	534 TWh	61 GW	41 GW	13%
Standard Deviation	1,041 TWh	119 GW	34 GW	26%

Table 1. This table shows the statistical range of predicted power demand from data centers, build-out capacity, and overall impact on U.S. energy consumption across different scenarios. See Figure 1 for an illustration of projected power demand from data centers. Source: the authors.

This analysis shows that the energy demand for data centers clearly will continue to grow. However, the rate of that growth is highly uncertain and depends on many interdependent factors. Taking the mean value, an additional 41 gigawatts (GW) of capacity will be needed by 2030, and data centers could consume as much as 13% of today's total U.S. power demand. These numbers could be much higher, of course, if we consider the 90th percentile (P90) of this skewed distribution (i.e., 156 gigawatts of additional capacity needed and 38% of today's U.S. power demand). It is worth noting that this additional capacity assumes a baseload 24/7, highly reliable power. The actual build-out capacity will need to be much higher if supply relies on intermittent renewable sources such as solar or wind, which have low capacity factors. The inclusion of battery storage can certainly mitigate intermittency, creating a pseudo baseload power profile. However, the additional costs, project complexity, redundancy measures, and extended timelines may be prohibitive, making this integration unfeasible everywhere.

The United States has seen a significant increase in renewable energy capacity over the past five years, with approximately 160 GW of new wind, solar, and battery storage added. In 2024 alone, around 45 GW of solar and wind capacity were added, and natural gas power plant capacity also increased by approximately 4.8 GW. Although this trend may give stakeholders confidence in our ability to meet the rising energy demands of data centers, the reality is more complex.

The United States is undergoing rapid electrification in various sectors, including transport, buildings, and industries, all of which contribute to an unprecedented surge in electricity demand. Additionally, the intermittent nature of renewable energy sources—which have fluctuating and lower actual energy delivery than the stated nameplate capacity—further strains the grid. Although battery storage capacity has grown significantly, from 2 GW in 2020 to 18.2 GW in 2024, the capacity remains inadequate to provide a reliable grid-balancing optionality. The growth of gas power plants is slow and hindered by supply chain delays and inflationary pressures, and the planned decommissioning of old plants is approaching quickly (approximately 3 GW of capacity from gas power plants are expected to be retired and cease operation in 2025).

This mismatch between the rapid growth in demand and the complexities of energy supply has placed immense pressure on grid operators, utilities, and grid infrastructure. Grid bottlenecks, lengthy interconnection queues, and outdated power infrastructure are major obstacles that hinder not only data center expansion but also the overall progress of electrification in the United States. In addition,

the uncertainty around the pace of growth, as discussed earlier, affects plans for infrastructure upgrades and utility companies' local strategies.

The core of the problem is that the increase in U.S. electricity demand has remained relatively stable at between 0.6% and 0.7% annually for the past two decades. During this period, utilities have concentrated on maintaining a consistent market and managing an aging power grid, with investments primarily focused on ensuring grid reliability, managing extreme weather events, and enhancing overall system safety.

The rate of annual U.S. electricity demand growth has increased five times in the past few years compared with the previous two decades. Utility growth forecasts over five years have also seen a similar five-fold jump in just two years. This rapid growth is happening while utilities take between five and seven years to increase generation capacity and between 15 and 20 years to add new transmission. Suddenly, the conservative and slow-growing utility industry is being asked to move at the speed of Big Tech companies that are fighting to capture as much market share as quickly as possible. The scale of investment from Big Tech has been astounding,[8] with most of the spending going toward the AI infrastructure and data centers.

With this backdrop, in some key markets, utilities have been staring down what seems to be an impossible problem. From the perspective of U.S. utilities, data centers present several major difficulties:

- *Time differentials:* Data centers typically take between two and three years to build, whereas new power lines in the United States can take 10 to 20 years to construct.

- *Concentrated power:* New "hyperscale" data center campuses consume massive amounts of electricity. Amazon's development outside Pittsburgh, Pennsylvania, uses more electricity than 750,000 homes. Microsoft and OpenAI are planning a Stargate campus that would use more power than 3 million homes. These sites often need to be in or near population centers, where the grid and water supply are already stretched to their limits.

- *Zero flexibility:* By industry conventions, a Tier 4 data center must be able to run 99.95% of the time (meaning only approximately 20 minutes of downtime per year). This lack of flexibility means that during a heat wave, when households blast air conditioning and the grid is pushed to the limit, utilities cannot rely on data centers to power down.

As a result of Big Tech's need for speed, increasing constraints on available grid-connected power, the slower-moving nature of utilities, and the need for strong local reliability, many data center developers are investigating the possibility of colocating their energy sources.

Regardless of which AI load forecasts one believes and which direction one thinks the market will take, the past year has seen a spending frenzy dedicated to data centers and associated energy projects. Whether fueled by speculation or the fear of being left behind, one thing is certain: AI and its energy infrastructure have become the most discussed issues in business and policymaking communities across the globe. At the center of this major technological shift are the national security considerations and the AI arms race with China.

China represents the fastest-growing market for data center energy consumption. By 2030, data centers in China are expected to account for the largest electricity consumption by any single country, reaching 380 terawatt-hours.[9] This would position China ahead of the United States and Europe in total data center energy usage.

Currently, mainland China has the largest number of data centers in the Asia-Pacific region, with Beijing ranking as the second-largest data center market globally by power consumption capacity, behind only Northern Virginia.[10,11]

On the grid infrastructure, China is the world leader in generating and moving power. No other country comes close. In the 11 years it took for the United States to add two reactors to the Alvin W. Vogtle Electric Generating Plant, a nuclear power plant near Augusta, Georgia—the country's only new reactors in three decades—China built almost 40 reactors. Meanwhile, between 2022 and 2023, China added more solar capacity than the rest of the world combined.[12,13,14]

A 2023 RAND study revealed that China is significantly ahead of the United States in long-distance power transmission technology, driven by its Global Energy Interconnection (GEI) initiative.[15] China leads in three out of four key rankings for these systems and holds the top position in academic publications and patents related to ultra-high voltage (UHV) infrastructure and submarine cables. While China currently operates 34 UHV lines, the United States has yet to establish any.

Although there is some uncertainty in the exact magnitude of future demand, the power needs of data centers will be substantial. The real urgency lies in the fact that data centers are critical infrastructure that support essential services in various sectors, and they are the backbone of AI development and leadership. Addressing the power requirements of data centers is not merely a matter of meeting future growth but also a matter of ensuring national security.

GEOTHERMAL ENERGY: AN UNDERESTIMATED SOLUTION

Geothermal is a great solution to the AI power crunch. The continuous and high-capacity nature of geothermal power directly addresses the 24/7 operational requirements of data centers, offering several key advantages over traditional energy sources and even other renewable options:

1. *Consistent baseload power:* Unlike intermittent renewable sources such as solar and wind, geothermal energy provides a continuous, stable, and predictable power supply. Geothermal power plants typically have a capacity factor of 90% or higher, meaning they can generate electricity on a near-constant basis throughout the day and year. This capacity aligns perfectly with the uninterrupted operational demands of data centers that support the modern digital ecosystem, ensuring 24/7 availability for crucial services. This baseload reliability is essential for data centers, which are often reluctant to curtail operations during peak reliability periods.

2. *Energy security and reduced grid dependence:* By tapping into local geothermal resources, data centers can reduce their dependence on potentially strained grid infrastructure and the uncertainties associated with it, such as long interconnection lead times. The increasing demand from data centers and other large loads is already challenging grid planners. Off-grid or behind-the-meter geothermal solutions can enable data centers to bypass these delays and provide a dedicated power source.

3. *Potential for dual use for power and cooling:* Geothermal systems can be utilized not only for electricity generation but also for efficient cooling of

data centers. Cooling typically accounts for between 30% and 40% of total energy consumption. Unlike conventional power sources, geothermal systems can directly provide cooling through efficient absorption chillers or through heat exchangers using naturally available geothermal fluids. By using geothermal for direct cooling, data centers can significantly reduce their electrical cooling loads, cutting their total power consumption dramatically. This integrated cooling capability reduces overall energy demand, lowers operating costs, and improves data center efficiency, all of which help create a substantial economic advantage for using this capability instead of natural gas or nuclear, neither of which can efficiently integrate direct cooling. These advantages and the overall system are described in more detail in the next section, "Integrating Geothermal Power with Direct Cooling to Enhance Data Center Profitability."

4. *Scalability through next-generation technologies:* While conventional hydrothermal geothermal power is limited by specific geological conditions, next-generation geothermal technologies such as engineered geothermal systems, closed-loop geothermal systems, and advanced geothermal systems have the potential to be deployed in a much wider geographic area. An engineered geothermal system (EGS) uses advanced drilling and reservoir engineering techniques to extract heat from rock formations that do not naturally host hydrothermal reservoirs. Closed-loop geothermal systems circulate a working fluid through either a system of interconnected horizontal wells or within a single well, harnessing near-wellbore thermal energy. However, it is important to note that advanced geothermal system (AGS) technologies are not as advanced as those for an EGS and may not be able to address the necessary scale of data centers economically in the short term. EGS technology, on the other hand, has seen significant advancements and cost-based proof points over the past several years, giving stakeholders additional confidence in this technology's near-term viability for the use case explored in this paper. These advancements significantly expand geothermal energy's potential to meet the growing scale of data center power demands.

5. *Economic competitiveness:* Geothermal energy is becoming increasingly competitive with regard to cost, particularly when considering the long-term stability and reliability it offers. Analyses suggest that a behind-the-meter EGS can be economically viable compared with retail electricity rates, especially when factoring in a willingness to pay a green premium for clean, firm power. Furthermore, when data centers are strategically located in areas with high-quality geothermal resources, the levelized cost of electricity (LCOE) can be significantly lower. The consistency of geothermal power also contributes to its value, as it potentially reduces the need for extensive backup provisions.

6. *Oil and gas industry expertise:* The oil and gas industry possesses transferable skills, data, technologies, and supply chains that can significantly boost the cost-effectiveness and speed of geothermal development. As much as 80% of the investment required in a geothermal project involves capacities and skills that are common in the oil and gas sector, such as drilling and well completion. In a 2024 report, the International Energy Agency (IEA) highlighted the fact that some of the largest overlaps between the skills and expertise of the oil and gas industry and geothermal projects include project evaluation, planning, and management; drilling and completion; surface facility construction and maintenance; and operations and production monitoring.[16] For next-generation geothermal technologies, IEA estimated that more than three-quarters of the required investment is closely related to oil and gas industry skills and expertise. This alignment of the available skills and expertise with the needs of geothermal can help reduce costs and accelerate the deployment of geothermal solutions for data centers.

7. *Clean and sustainable energy:* Geothermal power is a clean, renewable energy source with low or zero greenhouse gas emissions. The use of this clean energy can allow data centers—particularly hyperscalers with ambitious greenhouse gas and clean electricity targets—to meet their sustainability goals while securing the necessary power for their operations. The transition to carbon-free energy sources also provides more certainty related to energy costs in the long run.

ENERGY FLOW OF INTEGRATED GEOTHERMAL POWER AND COOLING SYSTEM

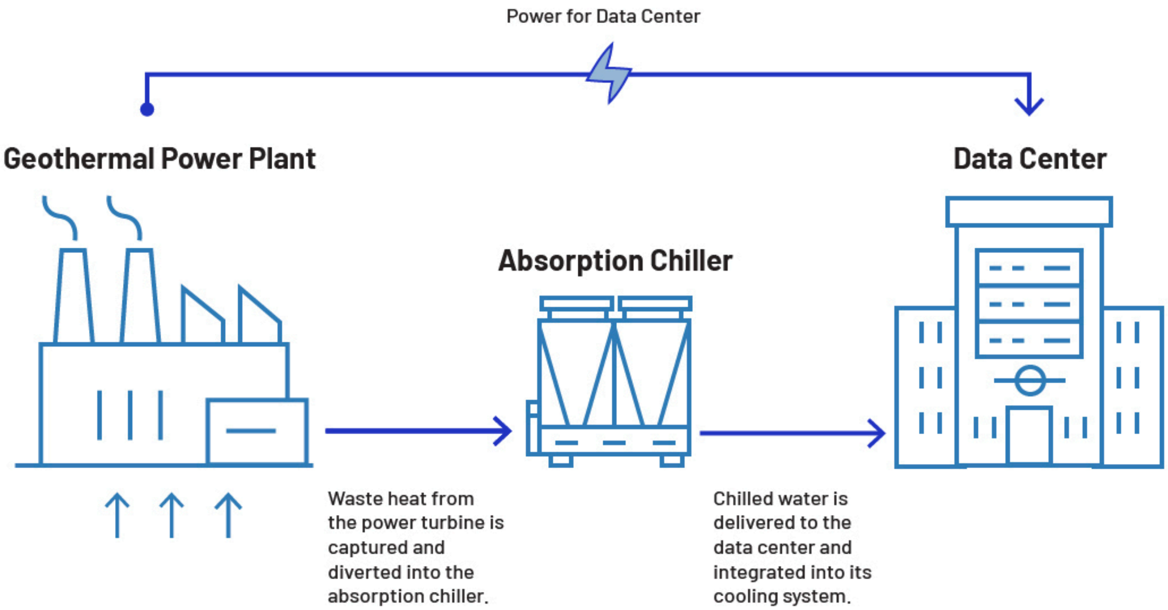


Figure 2. This simplified diagram shows the energy flow of the integrated geothermal power and cooling system discussed in this paper. Source: the authors.

INTEGRATING GEOTHERMAL POWER WITH DIRECT COOLING TO ENHANCE DATA CENTER PROFITABILITY

Importance of cooling in data centers. Effective cooling is critical to data center operations. Without proper cooling, server performance rapidly degrades, leading to downtime and equipment failures. As computing density continues to grow, driven particularly by advanced AI workloads, the demand for cooling capacity has risen significantly.

Energy demand for cooling. Cooling typically accounts for approximately 30% to 40% of total data center energy consumption. Data center compute efficiency is measured using power usage effectiveness (PUE), the ratio of total facility energy usage to information technology equipment ("compute") energy. Improvements in cooling technology and facility design have gradually reduced the average industry-wide PUE from approximately 2.0 in 2011 to approximately 1.5 as of 2022.[17] Although the average PUE has stalled near 1.5 recently, newer data centers are achieving PUEs near 1.1 and 1.2 by improving cooling technology and recycling some waste heat. Even with these advances, cooling still represents the largest noncomputational energy demand within data centers.

Benefits of integrating geothermal power with direct cooling. Our model demonstrates that geothermal energy can uniquely improve PUE. In addition, integrating geothermal power and direct cooling provides substantial economic benefits. Based on interviews with hyperscalers, we determined that each additional megawatt of available power can generate approximately $25 million to $50 million in annual revenue, translating to roughly $10 million to $25 million in annual profit.

Each additional megawatt of available power can generate approximately $25 million to $50 million in annual revenue, translating to roughly $10 million to $25 million in annual profit.

We do not factor this additional revenue and profit into our model, but it is important to note this benefit. We do, however, factor in the savings in the operating costs, which are reflected in the LCOE calculation. Our modeling indicates that by using waste heat from a geothermal power plant and circulating that fluid through an absorption chiller (see **Figure 2**), the operator of a 1 gigawatt data center could potentially save around $3.2 billion in operating costs during the 30-year lifespan of the project—a savings of approximately $107 million annually.

There are other ways to use geothermal energy directly for cooling as well, independent of electricity generation and without an associated power plant. Depending on the available geothermal resources, there are two possible pathways for cooling a data center:[18]

- A subsurface temperature of less than 21°C (70°F) allows for the direct use of naturally cooled fluid to cool data centers, such as through shallow aquifers and abandoned mines. This pathway could also include pairing the subsurface energy storage with waste heat recovery from the data center.
- A subsurface temperature of greater than 82°C (180°F) allows for the use of absorption chillers to transform hot fluids into cold refrigerants. Abu Dhabi National Oil Company, for example, uses this method to provide 6°C (43°F) refrigerant to cool Masdar City.

GEOTHERMAL RESOURCE POTENTIAL: FUTURE HUBS OF BIG TECH ADOPTION

Leading technology companies already recognize the significant potential that geothermal energy can offer their data centers. Meta, for instance, has partnered with Sage Geosystems for engineered geothermal power, while Google is collaborating with Fervo Energy for enhanced geothermal power and with Baseload Capital for conventional geothermal in Asia.[19,20,21] Microsoft is also exploring geothermal as an energy source alongside nuclear technology.[22] This growing

ACTIVE AND IN-DEVELOPMENT GEOTHERMAL SITES

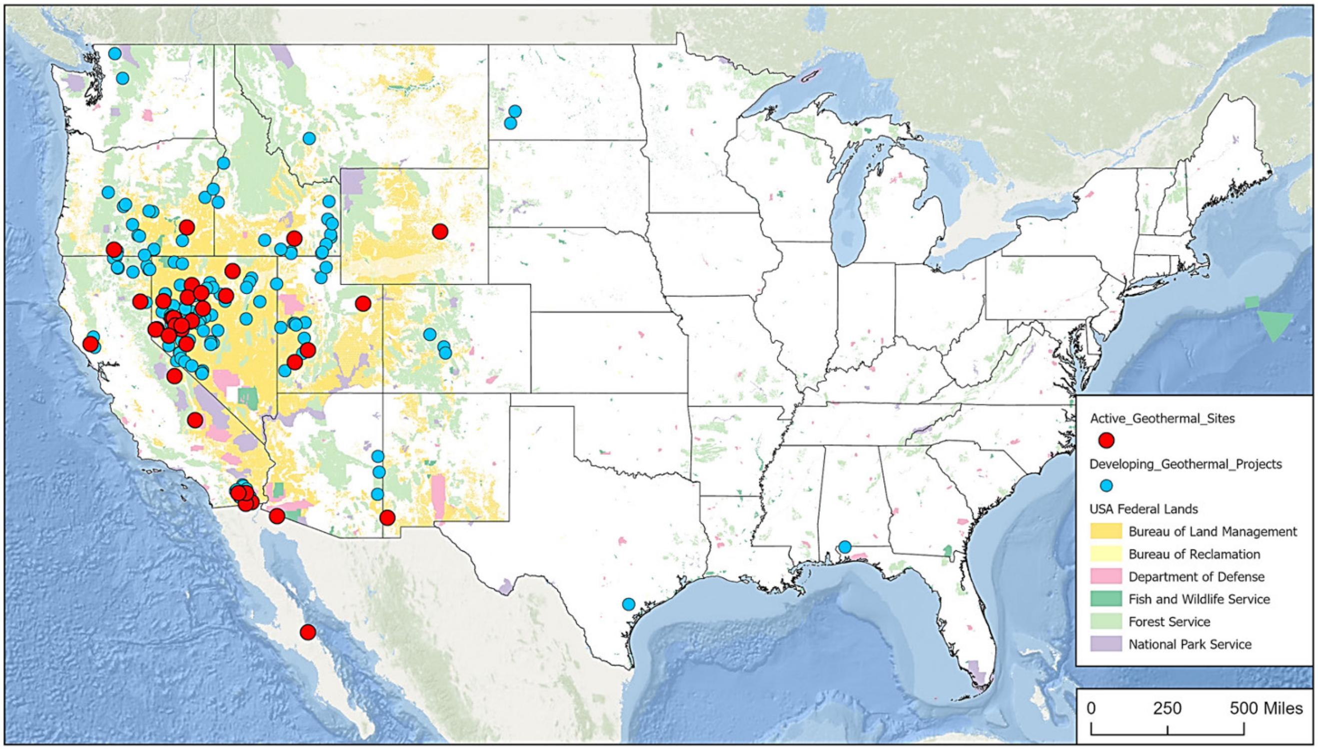
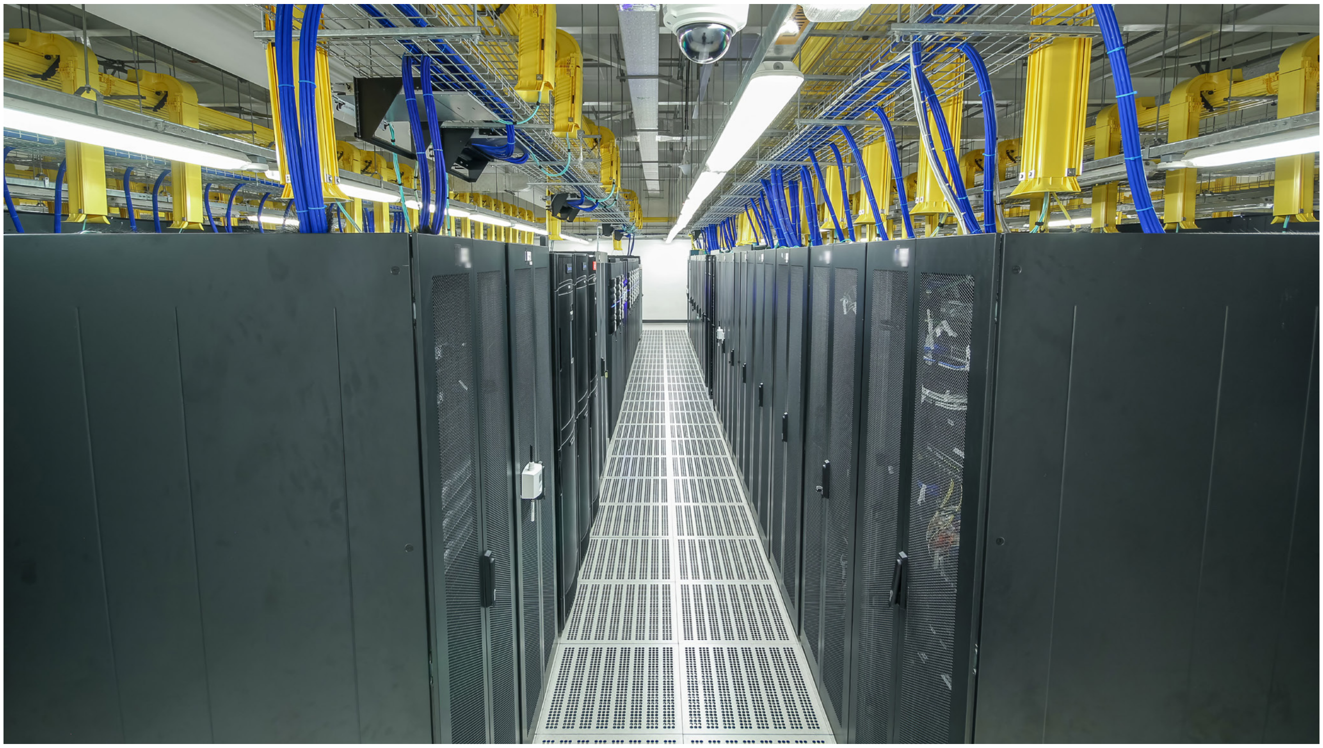


Figure 3. Active and in-development geothermal sites with the overlay of U.S. federal land. Sources: Data consolidated from IGA - Global Geothermal Energy Database; Global Energy Monitor. (2024, May). *Global Geothermal Power Tracker*. https://globalenergymonitor.org/projects/global-geothermal-power-tracker/; National Renewable Energy Laboratory. (2025, May 8). *Renewable energy potential on federal lands analysis*. https://www.nrel.gov/analysis/renewable-energy-potential-on-federal-lands; Bureau of Land Management. (2022). *BLM National SMA Surface Management Agency Area Polygons*. U.S. Department of the Interior, Bureau of Land Management, 2024. Last updated May 29, 2025. https://gbp-blm-egis.hub.arcgis.com/datasets/6bf2e737c59d4111be92420ee5ab0b46/about; and Coro, G., & Trumpy, E. (2020). Predicting geographical suitability of geothermal power plants. *Journal of Cleaner Production*, *267*, 121874. https://doi.org/10.1016/j.jclepro.2020.121874. All data are available in Project InnerSpace's GeoMap data repository.



interest from Big Tech signals a shift toward embracing geothermal as a viable and strategic solution for powering the expanding digital infrastructure.

The United States currently has approximately 4 gigawatts of installed geothermal capacity, primarily from conventional hydrothermal systems in California and Nevada (see **Figure 3**). However, this capacity is merely the tip of the iceberg in terms of the full potential of this underutilized resource. Recent innovations have dramatically expanded the geographic viability of geothermal energy. Engineered geothermal systems use tried-and-tested technologies from the oil and gas industry and have the potential to access deeper, hotter rocks without relying on permeable hot hydrothermal aquifers. These advancements allow geothermal development in regions that were previously considered unsuitable for traditional geothermal approaches.

In addition, one important characteristic of geothermal energy that is often overlooked in the context of data centers (and more generally) is that the Earth's thermal energy can be used directly for cooling (and heating, for applications outside of data centers). The direct application for cooling does not necessitate drilling deep wells, as the required temperatures can be accessed at shallower depths. This feature significantly enhances the economics and efficiency of geothermal development and expands its geographical reach.

Project InnerSpace recently launched a dedicated Data Center module within its GeoMap tool to showcase the technical potential and related energy resources of geothermal worldwide, highlighting regions that may be most suitable for data centers. This analysis considers both subsurface conditions and surface factors such as proximity to fiber nodes, surface topography, protected areas, and environmentally sensitive regions, among other factors. This tool provides a leading estimate of geothermal suitability for data center power and cooling.

The GeoMap Data Center module divides geothermal potential into two categories: today's potential and future potential. Today's potential refers to the cumulative geothermal resource (gigawatts) accessible down to a depth of 5 kilometers (approximately 16,000 feet) with a temperature cutoff of 150°C (302°F), which is the minimum threshold (though not an optimal one) for power generation. The 5 kilometer limit is recognized as a practical technical and economic boundary beyond which the complexities increase significantly and typically necessitate substantial technological advancements. This depth aligns with the standard operating range familiar to experts in the oil and gas sector.

U.S. TECHNICAL POTENTIAL FOR GEOTHERMAL POWER

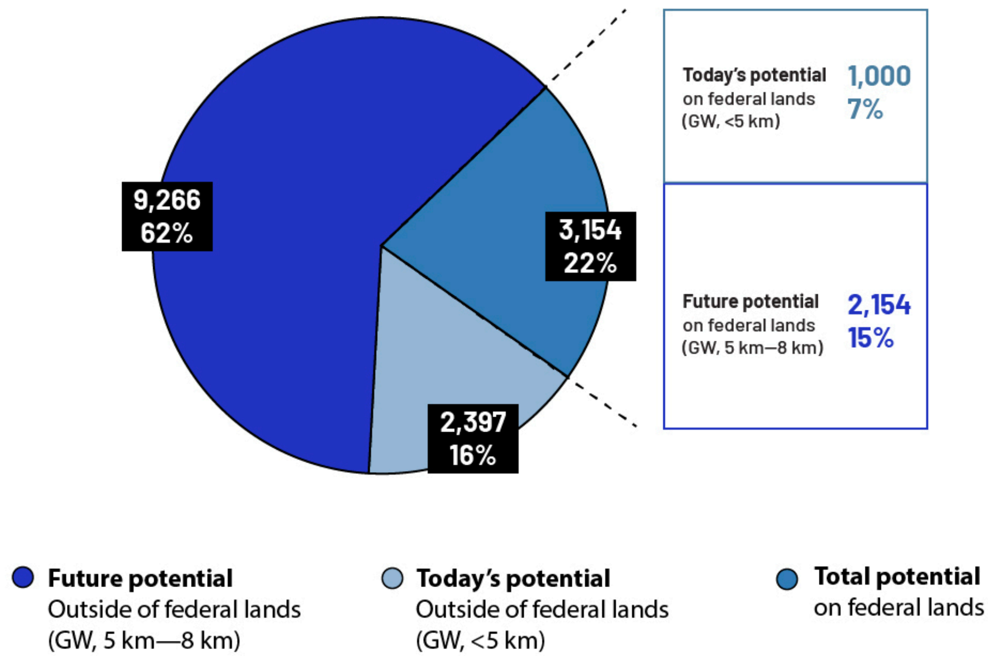


Figure 4. Total U.S. technical potential for geothermal power. GW = gigawatts. Source: Compiled from the Data Center layer in Project InnerSpace. (2025). *GeoMap.* https://geomap.projectinnerspace.org/map-selection/

In contrast, future potential encompasses the cumulative geothermal resource available down to 8 kilometers (approximately 26,000 feet) at the same temperature cutoff of 150°C (302°F). This much-greater depth approaches the technical limits of current drilling capabilities and will necessitate technological innovations and enhancements in drilling performance.

Based on analysis by Project InnerSpace, there are approximately 3,400 gigawatts of technical potential for geothermal power generation in the United States that are accessible with today's drilling methods and technologies (see **Figure 4**). An additional approximately 11,400 gigawatts of future geothermal potential can be unlocked with advancements in technology and drilling of deeper and more complex wells.

Stakeholders should also consider the geothermal potential found in U.S. federal lands, as these areas fall under the executive order that facilitates the development of energy projects for data centers and AI infrastructure. Approximately 3,200 gigawatts of technical power potential are located within federal land, but only about 1,000 gigawatts of that potential can be accessed using current technologies.[23]

Contrary to common belief, geothermal potential exists and is accessible with today's technologies throughout most of the United States, as shown in **Figure 5**. The states in the Western part of the country are notable for having the largest scale of geothermal resources, with California, Nevada, Arizona, and Oregon exhibiting the greatest potential. It is no coincidence that these regions have been the sites of most U.S. geothermal development efforts to date. Texas also stands out, however, as it benefits from an established regulatory framework for geothermal development, possesses existing infrastructure and a supply chain that are transferable from the oil and gas sector, and has an abundance of subsurface data from decades of oil and gas exploration. Texas holds significant untapped geothermal resources and has the potential to become the next geothermal frontier in the United States.

Most of the geothermal resources within federal lands are concentrated in the Western United States, with Nevada, California, Oregon, and Arizona exhibiting the largest potential.

It is worth noting that, in recent announcements, the U.S. Department of Energy (DOE) has intended to colocate AI data centers with new energy infrastructure on federal

TECHNICAL GEOTHERMAL POTENTIAL DOWN TO < 5 KILOMETERS, BY STATE AND ON FEDERAL LANDS

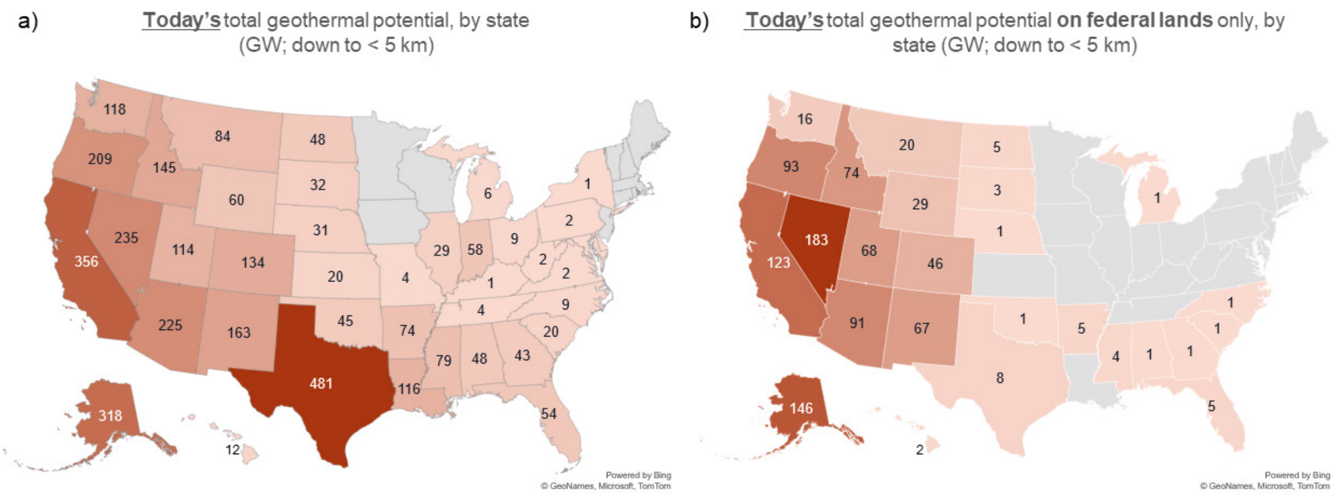


Figure 5. Technical geothermal energy potential accessible down to 5 kilometers (today's potential) by state: Total (left) and on federal lands only (right). Source: Data extracted from Project InnerSpace. (2025). *GeoMap Data Center analysis layer*. https://geomap.projectinnerspace.org/map-selection/

lands, leveraging existing energy infrastructure and fast-tracking permitting. A Request for Information was released to encourage public-private partnerships, targeting AI infrastructure operation at select sites by the end of 2027. Project InnerSpace and Sage Geosystems responded and highlighted the benefits of colocating AI data centers with geothermal energy. Their analysis of 16 DOE sites identified Los Alamos National Laboratory, Idaho National Laboratory, Sandia National Laboratories, and the National Renewable Energy Laboratory as promising places for geothermal development. Los Alamos National Laboratory is a top candidate due to its favorable geology, high geothermal gradients, existing high-performance computing infrastructure, expansion plans, available land, subsurface temperatures suitable for engineered geothermal systems, supportive ecosystem, local material availability, cooling technology fit, and historical geothermal data.

The correlation between existing and growing data center infrastructure and geothermal potential is strong in several states, notably Texas, California, Arizona, Oregon, Colorado, Washington, and Florida (**Figure 6**). In contrast, states such as New Mexico, Idaho, and Alaska have significant geothermal potential but little to no data center presence, largely due to the remoteness of these areas and infrastructure access, both of which play a significant role in data center clustering. However, the new frontier of AI development may present opportunities for a shift and expansion toward these regions and new ones as well.

The technical geothermal potential described in this section does not reflect what can be developed economically. To illustrate economic viability, we should consider other recent studies.

A recent Rhodium Group report (March 2025), produced in partnership with Project InnerSpace, suggests that U.S. geothermal energy could supply up to 64% of the anticipated increase in data center power demand in a cost-effective way by the early 2030s.[24] Furthermore, by strategically locating data centers in regions with abundant geothermal resources, this renewable energy source could potentially satisfy all projected data center power demand growth at prices between 31% and 45% below those in the current market clustered approach.

CURRENT GEOTHERMAL ENERGY POTENTIAL PER STATE VS. NUMBER OF DATA CENTERS

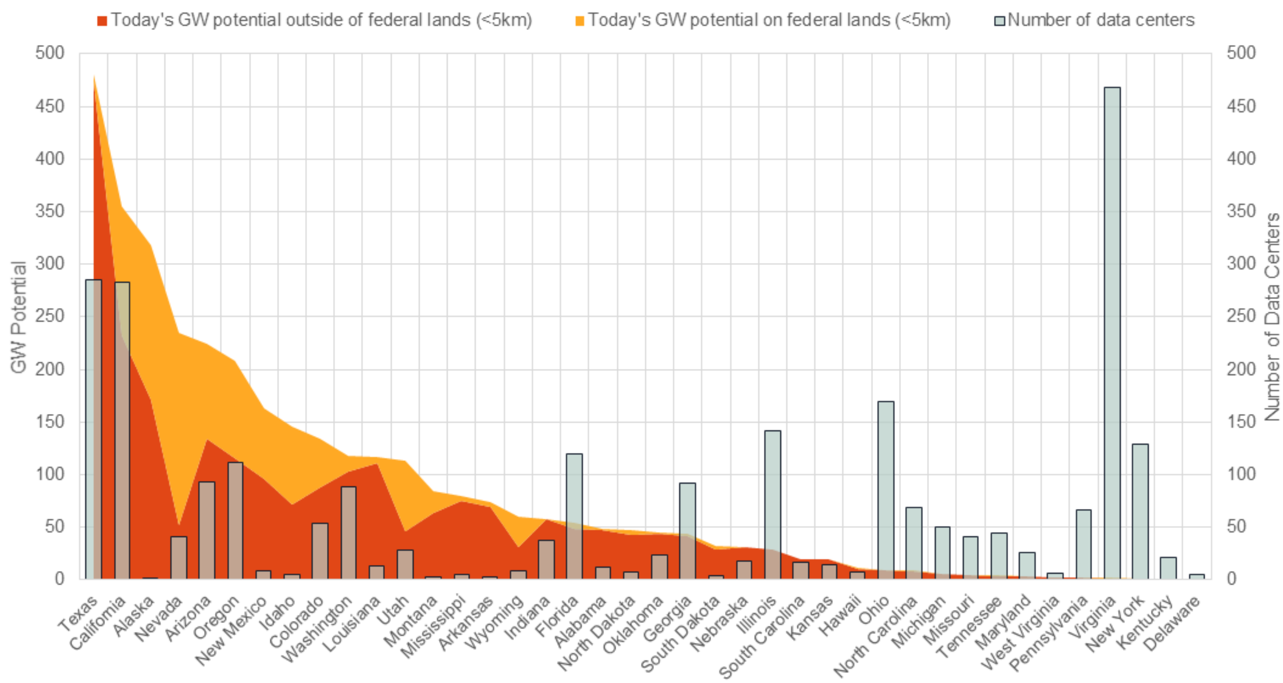


Figure 6. Technical geothermal energy potential accessible by today's drilling technologies (GW, down to 5 kilometers) relative to the number of data centers, by state. Sources: GW potential by state from Project InnerSpace. (2025). *GeoMap Data Center module*. https://geomap.projectinnerspace.org/map-selection/; Data Center Map. (2024, December). *Data centers*. https://www.datacentermap.com/datacenters/. (Licensed from site.)

COST MODEL FOR A 1 GIGAWATT GEOTHERMAL-POWERED DATA CENTER IN THE WESTERN UNITED STATES

Can geothermal energy development scale to meet the needs of AI data centers? We explore this question using an intentionally aggressive thought experiment.

Using the comprehensive techno-economic model developed by Project InnerSpace, we have analyzed several scenarios for a single geothermal development with a total capacity of 1 gigawatt, which includes power and cooling as described in the previous section.

To demonstrate the realistic potential of a specific project, we have anchored the base case to representative boundary conditions (shown in Table 2) that are similar to those expected in the Western United States and known geothermal provinces with the highest "near-surface" potential (e.g., regions with a geothermal gradient above 50°C/km). This case aims to assess the feasibility of large-scale geothermal development using the best available geothermal resource.

Figure 7 shows the main cost categories and their proportions for the initial first-of-a-kind (FOAK) base-case scenario. This breakdown of the overall budget is key to understanding the project's financial structure, identifying major cost drivers, and informing decisions about resource allocation and risk management for future deployments.

Next, we provide a summary of key cost assumptions.

- *Power plant costs:* The power plant cost component for our proposed 1 gigawatt geothermal data center is estimated at approximately $4.5 billion, which represents roughly 50% of the total capital

KEY PARAMETERS AND TESTED SENSITIVITIES OF MODELED BASE CASE

	Base Case	Tested Sensitivities
Geothermal gradient	55°C/km	35°C/km, 45°C/km, and 60°C/km
Production temperature	200°C	150°C and 250°C
Flow rate/Well	100 kg/s	60 kg/s and 120 kg/s
Derisking time (exploration phase)	3 years	1 year and 4 years
Wells and plant construction time	2 years	5 years and 6 years
Target depth	3.7 km (~12k ft)	Not tested
Horizontal well length	1,500 m (4.9k ft)	Not tested
Total well count	318 wells	Not tested
Total	180 hectares (445 acres)	Not tested
Average net power output per well	6.3 MWe/well	Not tested
Cost per well	$10.3 million	Not tested

Table 2. The table shows the key parameters and tested sensitivities of the modeled base case. The outcome of the sensitivity analysis is presented in the "Sensitivity Analysis" section.

BASE CASE COSTS OF 1 GW GEOTHERMAL PLANT PAIRED WITH FULL COOLING SYSTEM

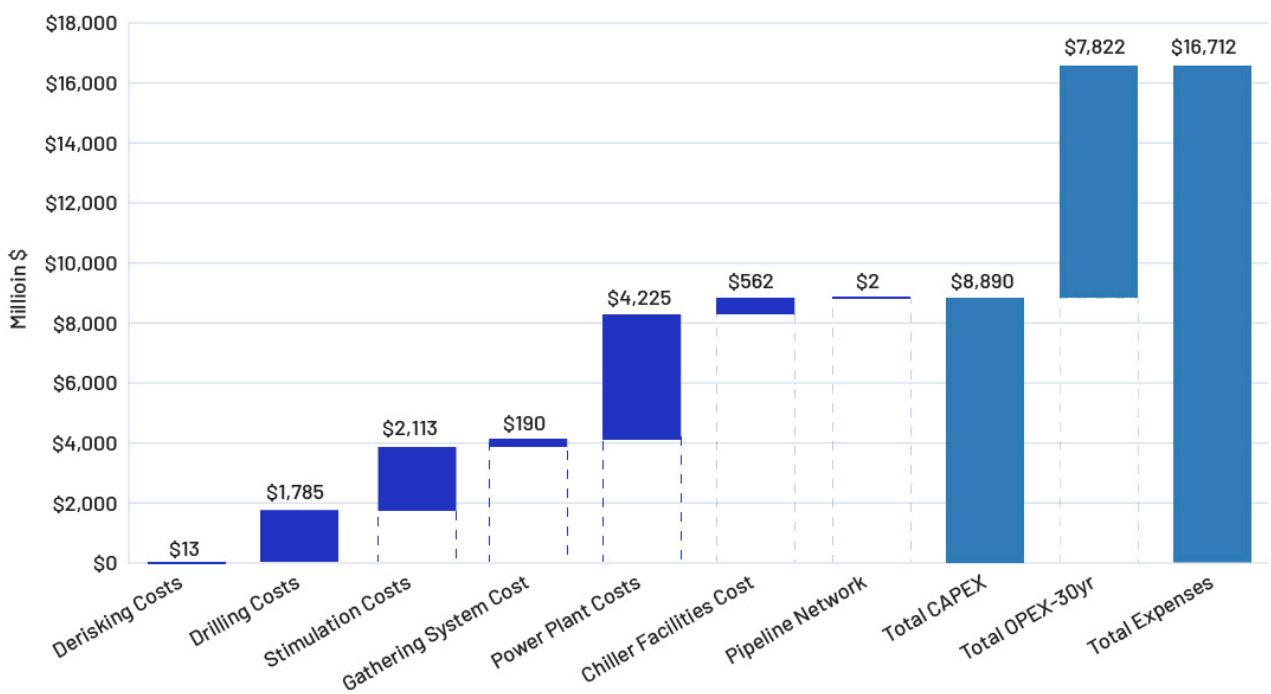


Figure 7. This waterfall graph shows the base-case costs of a 1 gigawatt geothermal plant paired with a full cooling system. CAPEX = capital expenditure; OPEX = operating expenditure. Source: the authors.

expenditures budget. This estimate includes the costs associated with procurement, construction, and commissioning of binary Organic Rankine Cycle power generation units, heat exchangers, turbines, cooling infrastructure (including absorption chillers), fluid handling systems, gathering network from wells to facilities, and all necessary electrical equipment. For modularity and scalability, the plant will consist of standardized, factory-built units, each capable of generating approximately 30 megawatts to 40 megawatts, which is the current range of available plant configurations. Over time, the market is anticipated to trend toward a minimum of 50 megawatt power plants, driven by modular design and larger project sizes. Factory-built modularization allows for streamlined production processes and shorter lead times, and it significantly reduces site-specific engineering and construction complexity. We anticipate that future projects—by leveraging these standardizations—will realize cost reductions of approximately 10% to 15% on topside equipment, further enhancing geothermal's competitiveness when compared with conventional energy sources.

Future projects—by leveraging these standardizations—will realize cost reductions of approximately 10% to 15% on topside equipment, further enhancing geothermal's competitiveness when compared with conventional energy sources.

- *Drilling and wellfield development:* Drilling and wellfield development account for around \$3.7 billion (approximately 40% of total costs). This component involves drilling approximately 320 wells (roughly 160 production wells and 160 injection wells) to an average depth of around 4 kilometers. Each well is estimated to cost approximately \$10.3 million on average, which includes casing, completion, and stimulation (for an engineered geothermal system). We assume a reservoir temperature of around 200°C (392°F), yielding a net (after removing all parasitic loads) of 6.3 megawatt electric per well. Considering our reference case assumes the flow rate of 100 kilograms per second and calculations referencing the Non-Random Two-Liquid (NRTL) model, we have confidence in these outputs. Notably, Fervo is currently achieving 9.5 megawatt electric per well gross (not net).

- *Exploration and reservoir characterization*: Around \$0.5 billion (approximately 5% of the total costs) is estimated for exploration and reservoir characterization. Before full development occurs, a significant investment is required to identify and confirm the geothermal resource. This phase includes geophysical surveys, exploratory drilling and testing (slim holes and a full-size exploratory well), reservoir static and dynamic modeling, and full subsurface risk and uncertainty evaluation. The advantage of the Western United States is that there are known and active hydrothermal systems with a large amount of field data, knowledge, and analogues related to geothermal energy extractions. Targeting near-field potential next to the known geothermal system enables faster subsurface evaluation, narrows subsurface uncertainty, and reduces exploration risk to some degree. The Texas Gulf Coast is another advantageous region for the FOAK project, as it offers abundant subsurface data from decades of oil and gas exploration that can help reduce costs and technical uncertainty. An established regulatory framework and existing infrastructure further enhance cost efficiency. The Gulf Coast's high-porosity, high-permeability aquifers maximize geothermal potential through efficient fluid flow and tiered resource utilization, which especially benefits data centers. We have allocated around \$0.5 billion for upfront exploration and site derisking, which covers several full-scale test wells.

- *Permitting and land acquisition:* Permitting and land acquisition account for less than \$0.1 billion (less than 1% of the total cost). Geothermal projects require permits (e.g., environmental assessments, drilling permits, water use), but these "soft costs" are relatively small in out-of-pocket terms—on the order of a few tens of millions. We assume the project is largely on federal or state land, with either low-cost leases or purchases of the necessary acreage. The land footprint for 1 gigawatt is about 180 hectares (approximately 445 acres) based on our wellfield layout. Even valuing land at \$5,000 per acre, that land would only cost around \$2 million. Thus, land cost is trivial in the budget (though securing land access can be a time-consuming task). Permitting costs (e.g., studies, consultants, legal) might be on the order of between $10 million and $20 million. Permitting has a greater impact on the timeline (discussed in the "Sensitivity Analysis" section) rather than on the financial cost.

- *Interconnection infrastructure:* The costs for interconnection infrastructure are negligible for behind-the-meter energy generation solutions. Because the geothermal plant will directly supply the data center campus, no new high-voltage transmission line or lengthy interconnection process is needed. We assume the data center will consume essentially all output. Any excess or maintenance downtime can be handled via the grid as a backup, but the project is intended to be an islanded operation. Thus, we include only the cost of on-site electrical integration (e.g., connecting the geothermal power plant to the data center's power distribution units, likely at medium voltage). This cost is small relative to other costs. If this were a grid-connected 1 gigawatt plant, interconnection upgrades could easily cost hundreds of millions of dollars and add multiyear delays. Avoiding such impacts is a key advantage of the behind-the-meter approach.

When taking all of these potential costs into account, the total overnight capital cost (OCC) to power and cool this 1 gigawatt data center project, including a full cooling system, is approximately $8.9 billion. This total

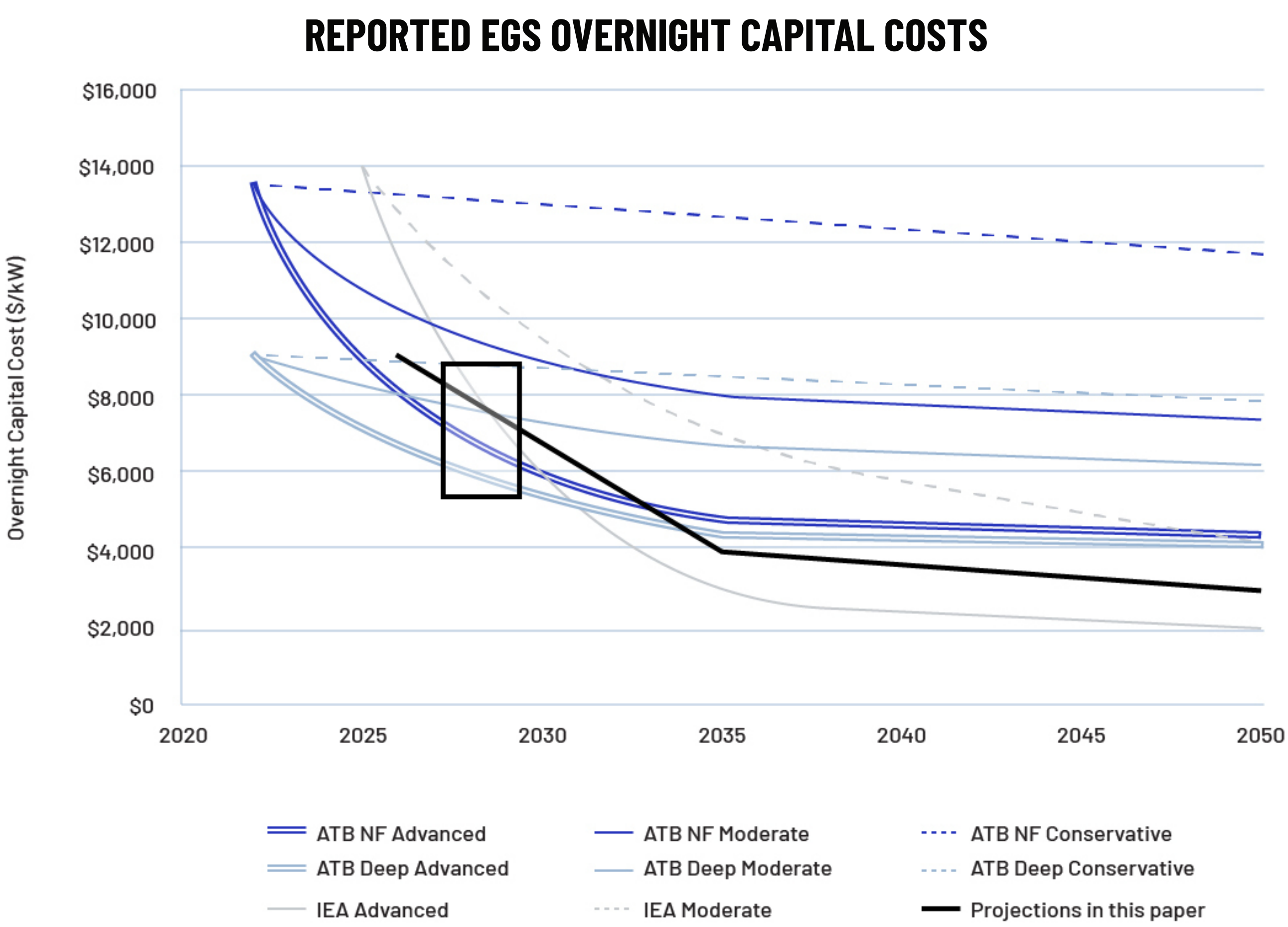


Figure 8. Range of overnight capital costs from a range of sources with overlay of baseline and sensitivities modeled in this paper (yellow box and yellow line). ATB = Annual Technology Baseline; IEA = International Energy Agency. Source: authors' compilation and assessment of multiple studies..

represents $8,930 per kilowatt, which is more than 10% less than the cost of recent nuclear projects—and it can be built potentially years sooner.[25]

Next-generation geothermal OCC estimations have significantly progressed in recent years. Starting from more than $32,000 per kilowatt,[26] developments such as the Frontier Observatory for Research in Geothermal Energy (FORGE) program in Utah by the Geothermal Technologies Office and FERVO's work have had notable impacts. The FORGE project has reduced drilling costs and time by applying physics-based methods,[27] setting a new benchmark with drilling costs of less than $400 per foot. With improvements in horizontal drilling, real-time fiber-optic monitoring, and closed-loop reservoir management, FERVO achieved a 70% reduction in drilling time.[28] Consequently, current OCC projections for engineered geothermal systems by the National Renewable Energy Laboratory[29] and the International Energy Agency[30] now range between $9,000 and $14,000 per kilowatt, depending on the scenario and the proximity to geothermal hydrothermal sites. These projections are illustrated in **Figure 8**.

It should be noted that the base case OCC is approximately 6.5 times the current capital cost of a similarly sized combined-cycle gas plant.[31,32] However, operating expenses are lower because no fuel purchases are required, and there is a clear path to rapidly bring geothermal costs below those of most natural gas projects. Including investment tax credits (ITCs) could also reduce the overnight cost of such a geothermal project by between 30% and 40%. By relying on economies of scale, technological improvements, learning, optimization, and modularization, an OCC of $3,000 per kilowatt could be well within reach.

At a 90% capacity factor, our 1 gigawatt plant produces approximately 7.9 million megawatt-hours per year. At this rate, over a 30-year project life, approximately 236,520,000 megawatt-hours would be produced.

The levelized cost of a FOAK project comes out to **$119 per megawatt-hour** (11.9¢ per kilowatt-hour) without ITCs. After ITCs are applied, we estimate that geothermal would have an LCOE of $88 per megawatt-hour. We anticipate that each major cost component will decline significantly, due to economies of scale, technology learning, and optimization programs.

INNOVATION AND COST-REDUCTION PATHWAY

Building a FOAK 1 gigawatt geothermal data center is the first step in making geothermal a widely deployable, cost-competitive solution for data center power needs. To that end, we present some back-of-the-envelope calculations on potential cost reductions and outline several innovation and cost-reduction opportunities that collectively form a **pathway to reduce the LCOE to approximately $50 per megawatt-hour** by sometime between 2035 and 2040.

The onshore U.S. oil and gas industry saw a 13% drop in well costs for every doubling of production.[33] Similarly, footage per rig in unconventional wells has more than tripled over the past 21 years, while the percentage of directional wells has increased from 12% to 85%. (All things being equal, directional wells should be more expensive to drill.) Since many of the costs involved in drilling are time-based, the increase in footage per rig implies a reduction in the time required to drill each foot and therefore results in a proportionate cost reduction. These advancements are made possible by the economies of scale achieved through factory-style drilling, efficient supply chain management, responsive regulatory and commercial frameworks, and rapid knowledge-sharing.

Enhanced geothermal is a young industry, but it has already made rapid progress. Based on Fervo's published numbers, the company's drilling rate has increased by 70% over the past three years, and the cost per well has been reduced by half, from approximately $9 million to $4.5 million. Fervo claims that its learning rate has been 35% over the course of drilling the company's first eight wells.[34]

As Fervo's drilling learning rate is likely higher in the early stages of development, and this learning curve is only associated with drilling speed, we should assume the long-term learning curve for the geothermal industry will be lower than Fervo's. For our initial back-of-the-envelope, simple calculation, we believe it is reasonable to use the same learning rate as observed in onshore U.S. unconventional oil and gas plays (13%).

There are currently fewer than 20 EGS wells drilled in the United States and fewer than 50 megawatts of power generated.[35,36] There are plans for the generation of another 300 megawatts. By our calculations, a 1 gigawatt project would cost $8.9 billion. Assuming similar learning rates to those in the onshore U.S. oil and gas sector, this project would result in a cost reduction of around 20%, which would result in savings of $1.78 billion on subsequent projects and an LCOE of $98 per megawatt electric, even without ITCs. By the time the thousandth well is drilled, an EGS could achieve an unsubsidized median LCOE comparable to that of natural gas. By the time that 5,000 wells have been drilled, the LCOE of an EGS could be 25% lower than that of typical combined-cycle natural gas projects. Finally, once 10,000 wells have been drilled, the EGS may surpass nearly all combined-cycle natural gas plants in terms of cost efficiency.

Our model projects:

$11.6 billion ITC drives a **61% improvement** in the levelized cost of geothermal to **$50/MWh** or less by 2035.

It is important to note that our simplistic approach assumes a smooth learning curve. The learning curve is likely to be more jagged, dropping rapidly and then flattening as new innovations and optimizations occur and increased knowledge takes place, then rebounding slightly with every step-out into a new geological setting. The learning rate also does not account for the impact of inflation and increases in the costs of the supply chain and services, which could erode any gains achieved through optimization and scaling.

EGS GEOTHERMAL LCOE: CLEAR ROUTE TO LOWER PRICES THAN NATURAL GAS

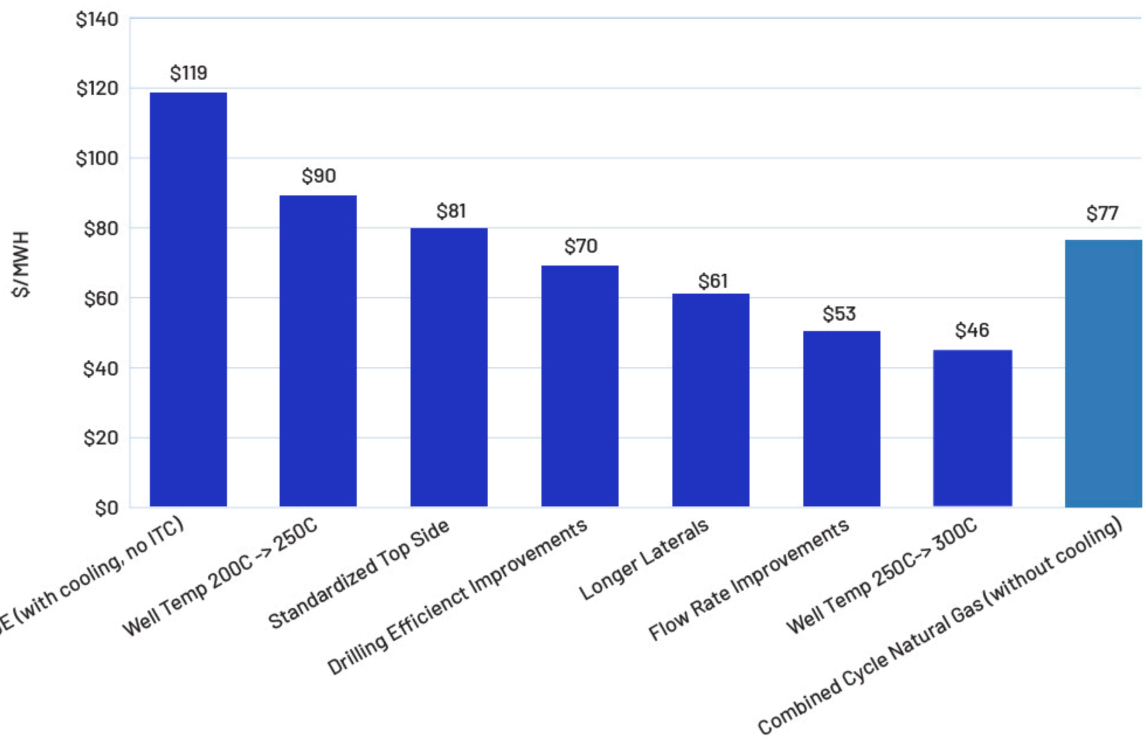


Figure 9. Comparison of predicted geothermal levelized cost of electricity (LCOE) in 2024 dollars and supply chain costs without any federal tax credits and including all cooling needs (leftmost bar). Each subsequent orange bar shows estimated LCOE after achievable learning improvements. For comparison, the blue bar on the right shows Lazard's median estimated combined-cycle natural gas LCOE ($77 per megawatt-hour), which will fluctuate based on fuel and supply chain costs. ITC = investment tax credit; MWH = megawatt-hour. Source: authors' analysis.

Are these well numbers achievable? The number of wells drilled in the United States every year fluctuates between 7,000 and 15,000.[37,38] Globally, between 40,000 and 70,000 wells are drilled each year.[39] Achieving 10,000 wells over a 10-year period is definitely achievable from a technical perspective.

Figure 9 illustrates a reasonable path to bring the initial levelized cost of enhanced geothermal from around $119 per megawatt-hour initially to near $50 per megawatt-hour. The rest of this section summarizes the factors that can contribute to achieving this goal.

Higher-Temperature Resources

Resources that can work at higher temperatures (ranging from 200°C to 300°C) can dramatically increase power output per well. At 200°C, we estimate a single well produces 6.3 megawatts electric. At 250°C, net production per well jumps to 14 megawatts electric. And by 300°C, net production increases to 20 megawatts electric, which is more than three times the output of a 200°C well. In our model, at around 250°C only 144 wells might be needed to produce 1 gigawatt (compared with 320 wells at 200°C). This decrease in the number of wells slashes drilling requirements in half. At 250°C, the total capital expenditure in this scenario drops to $5.6 billion, and when the cooling load is factored in, the equivalent LCOE matches that of a natural gas system.

Achieving higher EGS well production temperatures requires technological innovation: Horizontal drilling and steering have challenges as temperatures climb above approximately 200 °C (e.g., electronics fail, seals and elastomers degrade, drilling fluid properties change). New technologies—such as Hephae Energy Technology's high-temperature directional drilling system (designed to operate up to 225°C, with a goal to have tools that can operate at 300°C)—are being developed.[40] Such systems use advanced downhole motors, high-temperature telemetry, and robust materials to continue drilling accurately in extreme heat. Improved elastomers (e.g., packers, seals) and metallurgy (e.g., casing alloys that maintain strength at red-hot temperatures) are also in development. For our project's horizon, focusing on reaching around 200°C (or hotter) with EGS in the Western United States is feasible (as illustrated in **Figure 10**) if we can target regions with the highest

THEORETICAL VOLUMETRIC POTENTIAL AT 4,000 METERS

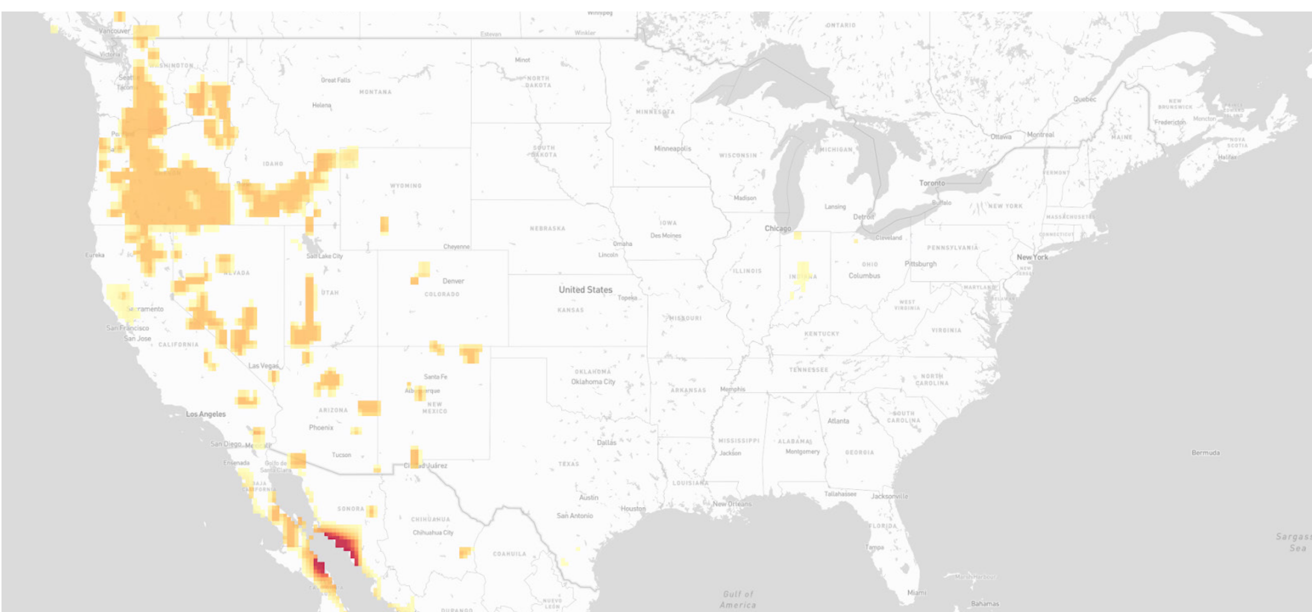


Figure 10. Theoretical volumetric potential (PJ/km^2) at 4,000 meters deep for a temperature threshold of 200°C. Source: Project InnerSpace. (n.d.). *GeoMap Global Volumetric model.* https://geomap.projectinnerspace.org/map-selection/

potential (from 4 kilometers to 5 kilometers deep at an approximately 55°C per kilometer gradient) and use emerging drilling technologies.

Our base case assumes a production temperature of 200°C, but as technology advances, it could be possible to deepen existing wells or to drill new ones into hotter zones. The payoff would be enormous: A 10°C increase in resource temperature can raise plant output by several percentage points and significantly reduce the cost per megawatt. If the FOAK project demonstrates the output of a well with a reservoir temperature of 250°C, this outcome could validate the concept and set the stage for the full deployment of tools at 300°C in follow-up projects.

Topside Plant Standardization

The initial 1 gigawatt design will likely involve bespoke engineering, but future plants can be modular and repeatable. If we design a 50 megawatt binary unit once, we can replicate it 20 times to produce 1 gigawatt and again many more times in future projects, thus avoiding the need for custom redesigns each time. This standardization facilitates manufacturing economies (e.g., bulk ordering of turbines, prefabricating skid-mounted components in factories). Modular construction also reduces on-site build time, which lowers labor costs and scheduling risk. We estimate that a standardized Organic Rankine Cycle plant design could decrease the surface equipment cost by between 10% and 15%. For instance, if the initial surface engineering, procurement, and construction cost is $5 billion, standardization might lower it to around $4.3 billion in subsequent units (which would save around $7 per megawatt-hour). Additionally, a well-tested design will operate more reliably, potentially enhancing uptime and capacity factor. Data centers value reliability, so a standardized geothermal plant with known performance would create a significant advantage. Essentially, we aim to turn geothermal power stations into something more akin to "LEGO blocks" rather than one-off constructions, much like combined-cycle gas plants became standardized in the 1990s. Factory-built components and repeat designs will drive costs down and improve quality.

Drilling Cost Reductions (Learning Curve)

Drilling represents a significant portion of FOAK costs, so improvements in this area will yield substantial benefits. As the project progresses, crews will drill hundreds of wells, providing an invaluable opportunity to enhance the learning process. We anticipate a standardization of drilling practices, improved training, and iterative optimization (e.g., refining drill bit choices for hard granite, optimizing mud programs). Additionally, contractors are likely to invest in specialized geothermal drilling rigs and equipment once they observe a consistent pipeline of work. All of these improvements can help reduce costs. Enhancements in drilling knowledge will also reduce the risk of cost overruns so that by the time Well #300 is drilled, we will have a much tighter grasp on time and materials than we did when drilling Well #1.

Flow Rate and Lateral Well Optimization

Flow rate and lateral well optimization offer substantial opportunities to reduce geothermal LCOE. Increasing lateral lengths and optimizing fracture permeability can increase fluid flow rates by approximately 20% to 40%, which can translate directly into fewer required wells and lower drilling costs to achieve 1 gigawatt of capacity. We estimate that such optimization could reduce overall wellfield capital expenditures by approximately 10%, resulting in a decrease in LCOE of between roughly $8 and $12 per megawatt-hour. Moreover, improved lateral efficiency reduces surface land requirements and environmental impacts, which can contribute to streamlined permitting processes.

Larger-Diameter and Longer Wells

Drilling larger-diameter and longer wells significantly enhances per-well productivity by allowing higher volumetric flow rates and increased fracture surface areas. Current standard geothermal wells typically have diameters of around 8.5 inches; increasing this to between 10 inches and 12 inches can substantially elevate fluid flow rates, thereby improving thermal exchange and net energy output per well. For instance, increasing average well diameter by 25% can boost flow capacity by between 30% and 50%, thus requiring fewer wells for the same power output.

Increasing average well diameter by 25% can boost flow capacity by between 30% and 50%, thus requiring fewer wells for the same power output.

Similarly, deeper wells that can access higher temperatures can dramatically improve per-well production. Combined, these improvements could potentially reduce total drilling costs by 15% to 20%, resulting in a decrease in LCOE of $10 to $15 per megawatt-hour. As drilling techniques advance, economies of scale in tooling and equipment will further amplify these benefits.

Investment Tax Credit and Policy Incentives

As of the first quarter in 2025, the current U.S. policy offers a 30% investment tax credit (ITC) for geothermal projects under the Inflation Reduction Act, in addition to potential production tax credits.

For a FOAK project that costs $8.9 billion to complete, this 30% ITC translates to approximately $2.7 billion, which significantly decreases the effective capital cost to about $6.2 billion.

Using this benefit could lower the LCOE from $119 to around $88 per megawatt-hour. We have not included this amount in the base economics, so applying such credits represents additional potential. The initial 1 gigawatt project will likely take advantage of the ITC while it is still accessible. Furthermore, if the project is eligible for bonus credits (e.g., for being in an "energy community" or utilizing domestic content), the project's economic feasibility could be further enhanced. The ITC effectively lowers the costs to help bridge the funding gap for FOAK projects; by the time the credit is phased down, we anticipate that other cost reductions will have been achieved. In a favorable policy environment for geothermal energy, often fostered by a supportive Secretary of the U.S. Department of Energy, these incentives are not seen as subsidies but instead as essential initial support for a new industry that can enhance American energy independence.

Permitting Reforms (State and Federal)

Geothermal projects often face protracted permitting processes, including environmental reviews and land leases, which can add delays and costs. A concerted effort by state regulators, policymakers, and federal agencies, such as the U.S. Bureau of Land Management, to streamline geothermal permitting could yield significant time and cost savings. For example, establishing categorical exclusions for certain low-impact exploration activities or creating a single coordinated permit process would cut down the current multiyear permitting timeline. If the FOAK project can be designated as a priority (perhaps under an "Energy Park" concept or via executive action), the preconstruction period could be shortened from approximately three years to about one year. Faster permitting processes reduce development overhead and financing costs because the project spends less time in limbo accruing interest. Quantitatively, if the timeline is shortened by two years, the project could avoid more than $100 million in capitalized interest and will start generating revenue sooner. This might translate to an LCOE that is about $5 less per megawatt-hour and improve NPV. Beyond dollars, speeding up the issuing of permits is crucial to meet the urgency of AI data center demand. On the federal side, the Department of Energy under Secretary Chris Wright has signaled support for removing barriers and enabling faster approvals for energy infrastructure. The Department of the Interior also recently announced that it would implement an emergency energy permitting process to reduce federal permitting review timelines from several years to a maximum period of 28 days.[41]

Accelerated Exploration and Resource Targeting

A part of FOAK costs is allocated to determining drilling locations, which may sometimes lead to unproductive wells. By utilizing modern geological data and tools such as Project InnerSpace's GeoMap, we can target high-temperature resources more effectively. The additional subsurface information gathered through this project—including temperature gradients, well logs, and flow tests—will better inform future explorations. We anticipate that we can increase the success rate and reduce exploratory drilling for later expansions by concentrating on the most promising sites.

Economically, if we lower the exploration budget from $500 million to approximately $200 million in a subsequent project by using FOAK insights, that $300 million in savings can translate to a decrease of about $3 to $4 per megawatt-hour in LCOE for a 1 gigawatt project. Additionally, speeding up exploration allows for quicker capacity expansion; for example, we might be able to deploy multiple wells

simultaneously once we gain confidence in the field's characteristics. Moreover, targeting known favorable regions—such as sites near existing hydrothermal areas in Nevada for the upcoming projects—would eliminate some uncertainties that this FOAK project encountered. In summary, improved data and knowledge lead to a higher success rate and lower costs.

Advanced Drilling Fluids (Supercritical CO_2 and Other Fluids)

Using supercritical carbon dioxide (CO_2) or other advanced drilling and heat-transfer fluids can greatly enhance geothermal system efficiency. Compared with traditional water-based fluids, supercritical CO_2 possesses superior heat-extraction properties, lower viscosity, and higher buoyancy, enabling significantly higher heat-transfer rates from the subsurface reservoir to the surface plant.

Initial modeling and pilot studies suggest that supercritical CO_2 can increase energy extraction efficiency by between 20% and 30% compared with traditional fluids. This increased efficiency means fewer wells are needed for the same energy output, directly reducing drilling costs and overall capital requirements. Using these advanced fluids could lead to reductions in LCOE of approximately \$10 to \$20 per megawatt-hour due to lower operational pressures, fewer pumping requirements, and enhanced thermal efficiency. Moreover, supercritical CO_2 systems offer environmental advantages such as reduced water usage and the potential use of captured carbon dioxide, both of which further enhance geothermal's sustainability profile.

SENSITIVITY ANALYSIS

As part of our technoeconomic model, we conducted a sensitivity analysis on key parameters to understand their impact on LCOE and capital costs.

Next, we summarize results for six key variables analyzed: drilling and completion costs, flow rates, reservoir temperatures, exploration and construction time, operations and maintenance costs, and cost of capital. Each parameter was independently varied to quantify its impact on the LCOE. (**Figures 11** and **12** show the sensitivity analysis of LCOE and capital expenditures, respectively, across scenarios.)

Drilling and Completion Costs

Drilling and completion costs account for nearly half of the total initial capital expenditures. A 20% reduction (from \$12 million to \$9.6 million per well) lowers the LCOE by

SENSITIVITY ANALYSIS OF LCOE ACROSS SCENARIOS

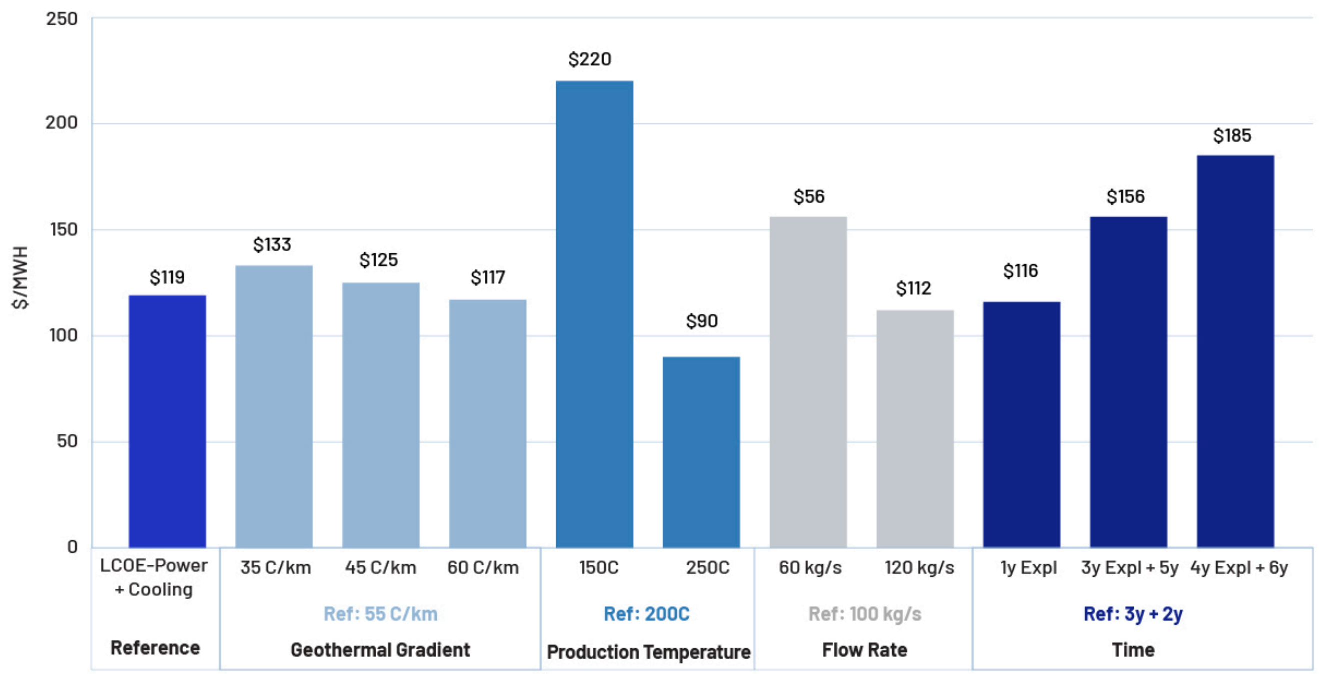


Figure 11. Sensitivity analysis of LCOE across different scenarios. Source: the authors.

SENSITIVITY ANALYSIS OF CAPITAL EXPENDITURES ACROSS SCENARIOS

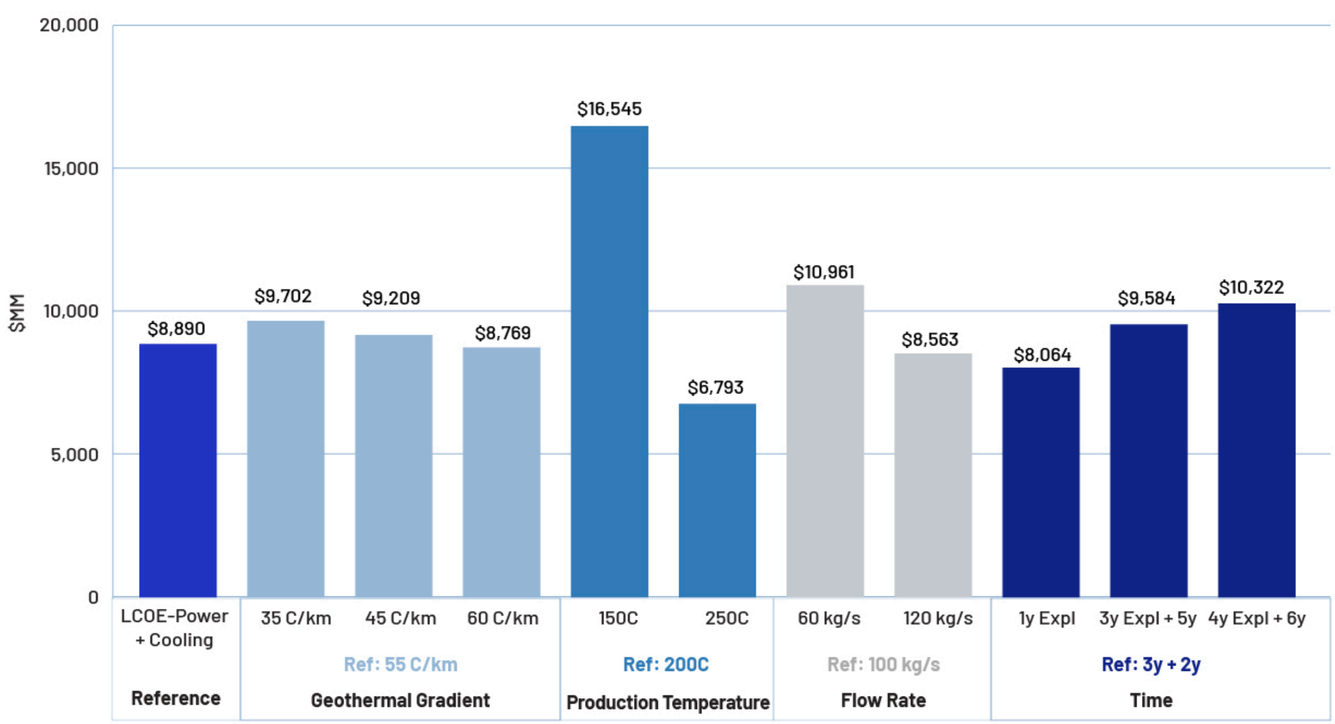


Figure 12. Sensitivity analysis of total capital expenditures across different scenarios. Source: the authors.

approximately $15 to $20 per megawatt-hour, potentially reducing baseline costs from around $120 per megawatt-hour to between about $100 and $105 per megawatt-hour. Conversely, a 20% increase (to $14.4 million per well) raises LCOE by about $20 to $25 per megawatt hour, increasing overall costs to roughly $140 to $145 per megawatt-hour. Therefore, effective drilling management, a focus on initial projects in areas with strong temperature gradients (for shallower wells), and cost control are essential.

Flow Rates

Flow rate directly affects well productivity. An increase in flow rate by 20% (from 100 kilograms per second to 120 kilograms per second) reduces the number of required wells to achieve a project's goals, resulting in a decrease in LCOE of approximately $15 to $20 per megawatt-hour. Conversely, a 40% decrease in flow rate (down to 60 kilograms per second) significantly increases both the number of wells needed and drilling costs, raising LCOE by about $25 to $30 per megawatt-hour to $145 to $150 per megawatt-hour. It is worth noting that our model does not account for a steeper thermal decline at higher rates. Optimizing flow rates through reservoir stimulation and lateral enhancements can significantly impact project economics.

Reservoir Temperatures

Higher reservoir temperatures significantly enhance per-well power output. Raising temperatures from 200°C to 250°C reduces the number of wells required by nearly half, cutting LCOE by around $25 to $30 per megawatt-hour, which then lowers project costs to about $90 to $95 per megawatt-hour. Conversely, a 10% temperature reduction (from 200°C down to 180°C) greatly reduces output, increasing LCOE by approximately $25 to $30 per megawatt-hour to $145 to $150 per megawatt-hour. Accurate resource characterization to ensure high temperatures is essential.

Exploration and Construction Time

The model is very sensitive to the amount of time needed for the exploration and construction phases. Any delays have a significant impact on both capital expenditures and overall LCOE of the project. Conversely, the accelerated timelines improve the project economics. This component emphasizes the importance of pace, the formation of a strong supply chain, and policy support.

Operations and Maintenance Costs

Annual operations and maintenance costs directly impact long-term economics.

A 25% reduction through automation or economies of scale could lower the LCOE by roughly between $5 and $10 per megawatt-hour, reducing project costs to around $110 to $115 per megawatt-hour.

Conversely, a 25% increase due to unexpected maintenance needs could push the LCOE up by $5 to $10 per megawatt-hour so it would reach approximately $125 to $130 per megawatt-hour. Effective operations and maintenance planning significantly impacts a project's lifetime economics.

Cost of Capital

Financing terms strongly influence geothermal economics. Reducing the weighted average cost of capital (WACC) from 8% to 6% decreases LCOE by around $15 to $20 per megawatt-hour, bringing costs down to about $100 to $105 per megawatt-hour overall. An increase in WACC to 10% raises LCOE similarly, by approximately $20 to $25 per megawatt-hour, increasing project costs to roughly $140 to $145 per megawatt-hour. Favorable financing conditions and policies are essential to achieving competitive economics.

Key Takeaways From the Sensitivity Analysis

Our sensitivity analysis provided us with several key takeaways:

- Reservoir temperature and flow rate significantly affect LCOE. Even small deviations in these parameters greatly alter project economics, underscoring the importance of precise reservoir engineering and accurate site assessment.

- Drilling cost management is critical, as even minor cost overruns notably increase LCOE. Thus, operational efficiency and innovation are critical.

- Financing terms affect project viability considerably. Policymaker and stakeholder support for securing favorable financing terms is essential to achieving target economics.

- Operations and maintenance expenses, though less sensitive than the other aspects assessed, still meaningfully affect project economics and highlight the need for reliable, cost-effective operational planning.

- Project development timelines are critical levers that can make or break the project.

This sensitivity analysis identifies critical areas for targeted investment and policy intervention, ensuring competitive and stable geothermal economics throughout the project's lifetime.

CONCLUSION

Engineered geothermal systems represent a transformative energy solution and are uniquely positioned to address the rapidly escalating power demands of AI-driven data centers. Our detailed techno-economic analysis clearly demonstrates that a FOAK 1 gigawatt geothermal facility can competitively provide baseload power at an initial LCOE that is cheaper than nuclear. This LCOE is close to the median equivalent LCOE of a combined-cycle natural gas plant and is much lower than current estimates for nuclear power.

The key innovations outlined—powering cooling with waste heat and geothermal energy, improving drilling, optimizing lateral and flow rates, using larger well diameters, and incorporating advanced drilling fluids such as supercritical CO_2—chart a clear path toward significantly reduced future costs. Each technological advancement further compounds to decrease costs, making geothermal not only a viable baseload power source over the next decade but also a highly competitive one, with potential future LCOEs as low as $50 per megawatt-hour.

Given current trends, policy support, and technological advancements, geothermal energy stands ready to become the cornerstone of sustainable, reliable, and economically competitive power generation for America's data centers. Policymakers, industry leaders, and developers now have a clear blueprint to harness the immense geothermal potential beneath our feet, securing a resilient, domestically fueled energy future that will power the next generation of technological and economic leadership.

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