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Energy Transition

Beneath the Surface: Geothermal's Role in the New Energy Order

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Last year we published a report examining the potential of geothermal energy. Our interest was driven by the fact that besides nuclear energy there remains a short supply of clean baseload energy solutions. The simplicity and potential of geothermal was attractive, beneath the surface exists limitless energy. The past few years have seen a succession of innovations in the sector emerge, all focused on harnessing and scaling geothermal energy efficiently, removing the existing geographic barriers.

Innovation in the sector has been driven both by rising demand for clean, baseload power and by the transfer of skills from the oil and gas industry, as experienced engineers apply decades of subsurface expertise to a new frontier. Fervo, Eavor, and Quaise have emerged as leading innovators, each developing proprietary technologies now progressing from pilot to project stage and working rapidly down the FOAK cost curve. More recently, Solution Energy has advanced Forced Geothermal Circuit technology, a shallow, closed-loop subsurface heat exchanger deployable in new or existing wells, cutting drilling activity, cost, and timelines while expanding geothermal's geographic and commercial reach.

Hyperscalers such as Google and Microsoft were among the first to secure geothermal PPAs. The promise of a small-footprint, modular, behind-the-meter, green baseload energy source is too good to ignore for power-hungry data-centre operators facing a squeeze on electrons at a time when the success of their AI ambitions depends on assured access to energy.

The purpose of this report is to reinforce our conviction in this theme. We showcase the developments of the past 12 months from the perspective of policy, innovation, investment, and ultimately conclude that geothermal will play an outsized role within the future global energy mix.

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Energy

2024 saw a 4.3% increase in global electricity demand, that compares to 2.5% growth in 2023. Moreover, global energy demand grew by 2.2% in 2024, a notably faster rate than the annual average of 1.3% seen between 2013 and 2023.[1] 80% of the growth in global electricity generation last year was provided by renewable sources and nuclear power, emphasising the shift to clean energy. However, the profile of that energy matters. While solar and wind have been deployed at scale and their nth-of-a-kind costs have fallen sharply, they do not provide the firm, dispatchable power required to stabilise the grid or support energy-intensive industries.

A consequence of rising private-sector demand for electricity has been an increasingly constrained grid, with consumers and corporations now competing for limited capacity. This imbalance naturally drives prices higher, and the impact is being felt most acutely by households rather than by industrial users with deep balance sheets. In Ireland, for example, data centres accounted for 21% of national electricity consumption in 2024, compared with 18% for all households combined.

Data centres were a major driver of global electricity growth in 2024, with installed capacity rising by an estimated 20%, around 15 gigawatts, led by expansion in the US and China. Rising demand from the data centre sector added to broader pressures from cooling needs amid extreme temperatures, increased industrial consumption, and the electrification of transport.[2]

This surge in electricity use is exposing a critical weakness in existing infrastructure. Grid reliability is emerging as a central bottleneck in the energy transition, with transmission congestion and limited interconnection capacity preventing new generation from reaching end users. In many regions, the grid, not generation, is now the limiting factor for decarbonisation. As a result, firm, 24/7 clean power that can operate independently of weather and grid constraints is commanding a premium in power markets and long-term procurement contracts.[3]

Developers capable of providing uninterrupted power are commanding significantly higher prices in power purchase agreements (PPAs).

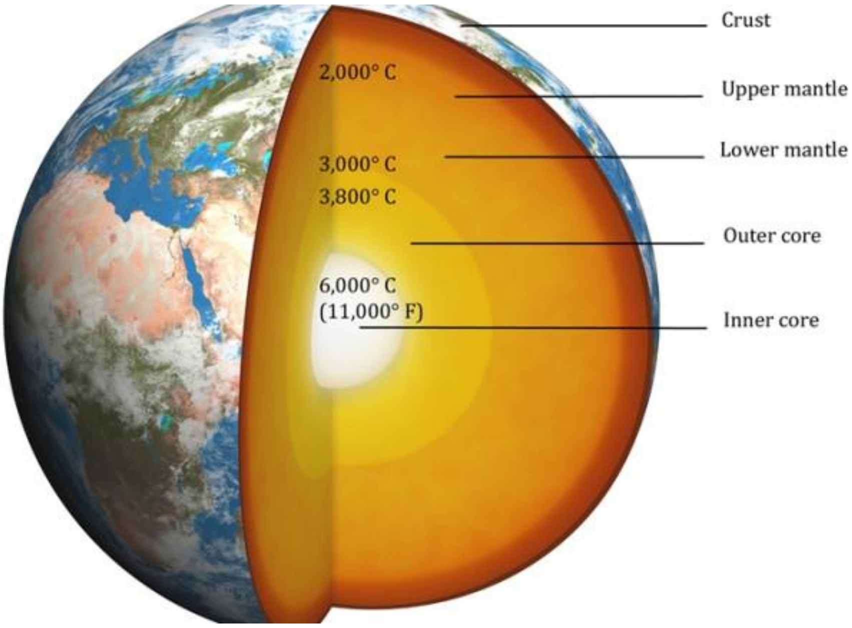
Geothermal energy is a renewable resource that harnesses the Earth's internal heat, which originates from both the planet's mantle and the natural radioactive decay of elements such as uranium, thorium, and potassium. According to the World Energy Council, the average heat flow at the Earth's surface is approximately 82 milliwatts per square meter, equivalent to an immense 42,000 gigawatts of total heat content, making it a virtually inexhaustible source of energy.

Geothermal power plants emit roughly 99% less carbon dioxide than fossil fuel facilities of comparable capacity.[4] This exceptionally low-emission profile, combined with its renewable nature, positions geothermal energy as an attractive solution for economies striving toward net-zero targets. Moreover, geothermal systems

[1] https://iea.blob.core.windows.net/assets/5b169aa1-bc88-4c96-b828-aaa50406ba80/GlobalEnergyReview2025.pdf
[2] https://iea.blob.core.windows.net/assets/5b169aa1-bc88-4c96-b828-aaa50406ba80/GlobalEnergyReview2025.pdf
[3] https://www.iea.org/commentaries/grid-congestion-is-posing-challenges-for-energy-security-and-transitions
[4] https://www.eia.gov/energyexplained/geothermal/geothermal-energy-and-the-environment.php

deliver steady baseload power and achieve some of the highest capacity factors among renewable technologies, making them one of the most reliable sources of carbon-free electricity available today.

Figure 1: Temperature of the Earth's Core[5]



Source: Discover

Recent geothermal contracts have been executed at $65 to $75 per megawatt hour, considerably above solar and wind deals, which often fall below $40. This price difference underscores the market's growing appreciation for firm renewable energy, electricity that is continuously available without the need for storage or backup. As data centre operations and industrial demand intensify, the premium for such reliable, carbon free generation is expected to increase, reinforcing geothermal's role as a vital source of stable green capacity.

A study commissioned by Ormat Technologies supports this trend. The analysis found that geothermal power in California is worth about $25 more per megawatt-hour than stand-alone solar, and more than $30 when the avoided cost of building new capacity is included. The analysis highlights how continuous output and dispatchability translate directly into higher system value as renewable penetration increases. In markets saturated with intermittent supply, every megawatt of firm, weather-independent power offsets multiple megawatts of solar and storage, strengthening the economic case for geothermal in long-term procurement.[6] Ormat is now negotiating new PPAs above $100/MWh, driven by strong demand for reliable renewable power from utilities and major corporate buyers.

"This is an exciting time for Ormat, and we foresee strong growth for our geothermal and storage business in 2025 and beyond, driven by favourable regulatory developments, increased exploration activity, rising demand for baseload renewable energy, and higher PPA pricing. Recent policy support for both geothermal and energy storage, coupled with the accelerating demand for carbon-free baseload power driven in part by the energy needs of AI data centres, highlight our critical role in the energy transition." – Doron Blachar, CEO, Ormat Technologies, Second Quarter 2025 Financial Results

[5] https://www.discovermagazine.com/planet-earth/taking-the-temperature-of-earths-core
[6] https://www.ormat.com/Warehouse/userUploadFiles/Image/Geothermal%20in%20the%20West%20239%20Thomsen.pdf

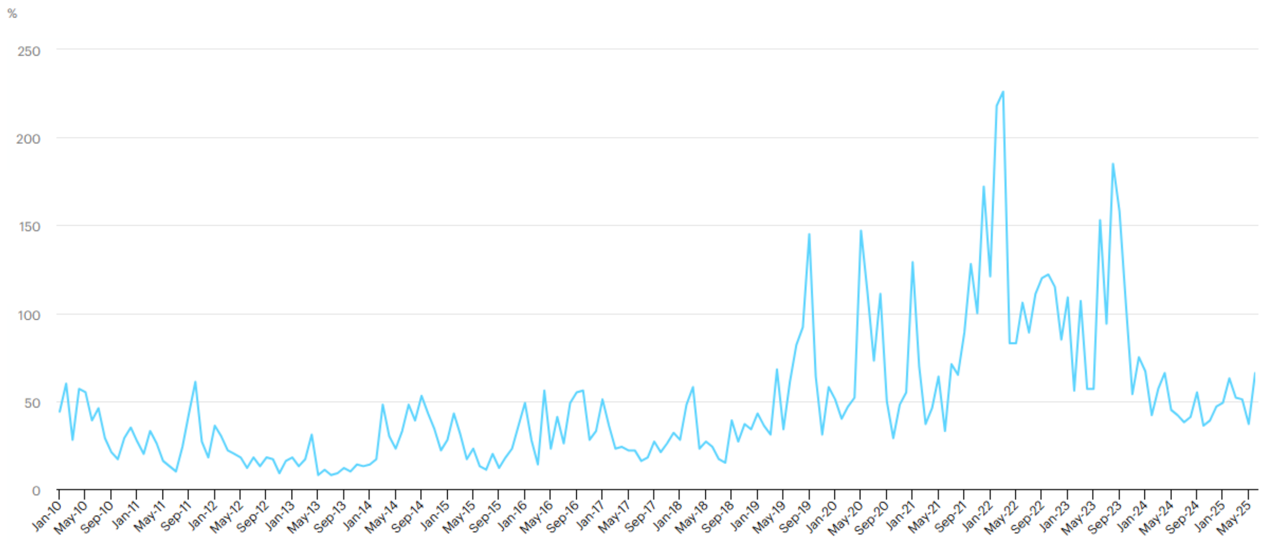
While it may appear niche today, geothermal has the capacity to play a foundational role in delivering clean, dependable grid energy. The EIA report that with continued technology improvements and reductions in project costs, geothermal could meet up to 15% of global electricity demand growth to 2050.[7] Technology is transforming geothermal from a resource limited to a few regions into one that can be harnessed globally, essentially a greener replay of the shale revolution.

Importantly, this innovation is coming at a pivotal time for energy more generally, with the world navigating the twin challenges of reducing emissions and ensuring secure, affordable power supply.

Baseload Supply Is Tightening

The global supply of baseload power is tightening. Traditional baseloads sources are faltering due to a combination of nuclear project delays, hydroelectric shortfalls, and volatile natural gas markets. Nuclear capacity additions are lagging as projects around the world face persistent delays and overruns. Hinkley Point C, for example, is three years behind schedule and has doubled in budget.[8] Hydropower has suffered from climate-driven droughts most recently plunging 8.5% in the first half of 2023.[9] Meanwhile, natural gas, the US's largest source of power, has seen extreme price volatility since 2022 amid the supply shock induced by the steep decline in Russian piped gas deliveries. Price volatility for gas spiked to 226%, a record high, and although they eased, volatility remains well above historical levels in key markets.[10] In 2024, gas market volatility was around 50% higher than the 2010–2019 average, while in Asia, spot LNG price swings were roughly 90% greater than the typical levels seen over that same period.[11]

Figure 2: Historical Monthly Volatility on the Benchmark Dutch TTF Month-Ahead Natural Gas Futures, 2010-2025



Source: IEA

7 https://www.iea.org/reports/the-future-of-geothermal-energy/executive-summary
8 https://www.businessenergydeals.co.uk/blog/hinkley-point-c
9 https://www.weforum.org/stories/2023/11/hydroelectricity-generation-falls-droughts-climate-change/
10 https://www.iea.org/data-and-statistics/charts/historical-monthly-volatility-on-the-benchmark-ttf-month-ahead-contract-2010-2025
11 https://www.iea.org/commentaries/what-drives-natural-gas-price-volatility-in-europe-and-beyond

In many regions, firm capacity reserves have dwindled to precariously low margins. The US Department of Energy (DOE) recently warned that continued retirements of coal and nuclear units without equivalent replacement could increase blackout risks 100-fold by 2030,[12] underscoring the need for new firm capacity. The DOE found that 104 GW of dispatchable plants are slated to retire by 2030, yet only 22 GW of the new generation in the pipeline is firm baseload, leaving a *"dependable-capacity deficit"* that intermittent renewables alone cannot close.[13] Similarly, grid operators are sounding the alarm: the Midcontinent Independent System Operator (MISO) in the US projected a 14 GW capacity shortfall by 2029 if planned plant closures proceed, prompting its CEO to warn *"we've got a lot of work to do to slow down the retirements and speed up the additions"*.[14] Such signals highlight a structural scarcity of reliable 24/7 power.

Geothermal energy stands out as a clear beneficiary of this trend. Unlike solar and wind, geothermal provides continuous output, independent of weather or time of day, effectively a renewable baseload solution. In a world where nuclear projects are delayed and hydro is weather-constrained, geothermal's baseload profile offers a timely substitute for retiring power plants. Policymakers and utilities are increasingly recognising this value. For example, in the US an estimated 700–900 GW of new clean firm capacity will be needed by 2050, and the DOE projects geothermal could supply up to 300 GW of that need.[15]

More immediately, capital is flowing into geothermal from both governments and private markets, underscoring its emergence as a credible baseload asset class. In 2023, the US DOE awarded $74 million for up to seven pilot projects.[16] In 2024, the US Department of Energy awarded $60 million under its *Enhanced Geothermal Systems (EGS) Pilot Demonstrations* programme to multiple commercial-scale projects, including Fervo Energy's Utah site and Chevron New Energies' project in California.[17] in the private side, Fervo Energy raised $244 million in early 2024, to accelerate deployment of its EGS technology following the success of *Project Red*.[18] Later that year, it secured an additional $255 million, to scale operations further.[19] Today, Fervo is raising its Series E at an estimated valuation of $3 billion. Elsewhere, Eavor Technologies received a €91.6 million grant from the EU Innovation Fund,[20] and since November 2023 the Canada Growth Fund has invested $188m.[21] These commitments highlight a clear trend: institutional, corporate, and public investors are increasingly allocating capital to geothermal as a scalable, firm, zero-carbon replacement for declining baseload power.

Every delay in a new nuclear reactor, every hydro dam constrained by drought, and every spike in gas prices all reinforce the value proposition of geothermal. This confluence of factors is turning geothermal energy into an increasingly attractive asset class: a 24/7 clean power source poised to fill the firm capacity gap and support

[12] https://www.energy.gov/articles/department-energy-releases-report-evaluating-us-grid-reliability-and-security
[13] https://www.energy.gov/sites/default/files/2025-07/DOE_Fact_Sheet_Grid_Report_July_2025.pdf
[14] https://www.countoncoal.org/2025/05/a-grid-emergency-in-miso/
[15] https://www.baseloadcap.com/why-invest-in-geothermal/
[16] https://content.govdelivery.com/accounts/USEERE/bulletins/3479cd4?utm
[17] https://www.energy.gov/eere/geothermal/enhanced-geothermal-systems-egs-pilot-demonstrations
[18] https://fervoenergy.com/fervo-energy-raises-244-million-to-accelerate-deployment-of-next-generation-geothermal/
[19] https://fervoenergy.com/fervo-energy-secures-additional-255-million-funding/
[20] https://eavor.com/press-releases/eavors-next-generation-geothermal-project-awarded-916-million-grant-from-the-european-innovation-fund/
[21] https://eavor.com/press-releases/canada-growth-fund-announces-additional-investment-in-eavor-technologies-a-calgary-based-advanced-geothermal-technology-company/

the world's electrification goals. The scarcity of conventional baseload isn't just a challenge, it's a catalyst accelerating geothermal's rise in the global energy mix, providing a long-term tailwind for the sector.

Why Geothermal?

The US DOE projects that geothermal capacity could grow more than twentyfold by 2050, reaching around 90 GW of power generation across the US. While geothermal energy currently produces around 15GW of power globally, it has only functioned in specific locations where the Earth's heat occurs near the surface, like the Geysers geothermal field in California or Iceland's volcanic active landscape.

However, this geographical barrier is dissolving. Technological advances from adjacent industries like oil and gas are opening previously untapped regions. Continued innovation, supported by independent developers and initiatives such as the US DOE Enhanced Geothermal Shot Program, is driving progress in drilling techniques, manufacturing, and regulation. These developments are expected to reduce costs significantly and unlock geothermal's full potential.

We believe geothermal energy is reaching a pivotal moment in the global energy transition. For over a decade, wind and solar have dominated the renewable landscape, driven by dramatic levelised cost of energy (LCOE) reductions of 83% for solar PV and 63% for onshore wind between 2009 and 2023 making them competitive with fossil fuels. While geothermal's current LCOE remains roughly double that of wind and solar, it is already on par with natural gas and coal, offering a clean and reliable baseload alternative.

Yet, LCOE alone does not tell the whole story. It fails to capture geothermal's distinct advantages in reliability, flexibility, revenue generation and land use intensity.

The Nesjavellir Geothermal Power Station, Iceland

> Revenue Potential

Electricity's value fluctuates with demand and market conditions, and intermittent generators like wind and solar cannot align output with these shifts as their output is dependent on the weather. Geothermal, however, can deliver power precisely when it's needed most. This dispatchable capability allows energy system operators (ESOs) to match generation with consumption, another advantage not reflected in LCOE metrics and enhances geothermal's long-term revenue potential.

> Capacity Payments

With capacity factors often exceeding 85-95%, geothermal plants operate far more consistently than the 18-25% capacity factor of intermittent renewables[22]. Their reliability commands higher fees paid to generators known as capacity generators that guarantee energy delivery when required. For example, a 100-MW geothermal plant earning $5/kW-month would generate about $6 million annually in capacity payments whereas a similar sized wind or solar farm would make 5-15% of that.

> Grid Stability

With the highest capacity factors among renewables, geothermal plants provide dependable baseload power that supports resource adequacy and frequency stability. Their continuously rotating turbines supply system inertia, buffering the grid against sudden changes in demand or supply. They can also assist with frequency regulation, provide black start capability during blackouts, and operate for 30–50 years ensuring long-term reliability.

This stability is particularly important for data centres, which require constant baseload power rather than intermittent supply. With global data centre energy demand expected to triple by 2030[23], geothermal reliability will become an increasingly valuable asset.

> Land Use Efficiency

Geothermal energy also offers a remarkably low land footprint using just 10% of the land required for wind farms and 20% of that needed for solar farms. As the second-lowest land-use intensity among baseload sources, it presents a quiet, compact, and community-friendly option for developers and investors. Land availability is a growing constraint in many countries: for instance, McKinsey estimates that in Germany, while 51% of the land is potentially suitable for wind, only 9% remains viable after regulatory and environmental restrictions. Similar challenges exist in France, where less than half the potential area can be utilised[24].

> Emissions and Environmental Benefits

Since the Paris Agreement in 2015, renewable deployment has surged, but wind and solar alone cannot meet global energy needs. Geothermal energy offers a critical complement producing around 97% less sulphur

[22] https://www.slb.com/resource-library/insights-articles/beyond-lcoe-what's-the-true-value-of-geothermal-energy
[23] https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/ai-power-expanding-data-center-capacity-to-meet-growing-demand
[24] https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/renewable-energy-development-in-a-net-zero-world-land-permits-and-grids

emissions and 99% less CO_2 than fossil fuel plants of similar capacity. As a clean, dispatchable source of baseload power, it strengthens both decarbonisation goals and system resilience.

> Energy Security

Finally, in a world where energy security has re-emerged as a strategic priority after the Russian invasion of Ukraine exposed the vulnerabilities of import dependence. In the face of this, geothermal stands out as a secure, domestic solution. It provides steady, homegrown baseload power, supports heating and cooling applications, complements intermittent renewables, and avoids reliance on critical minerals, mitigating supply chain risks.

Technology

Although conventional geothermal is a mature technology, it currently supplies only about 3 GW in the US which is less than 0.1% of total energy because hydrothermal reservoirs are geographically constrained largely to tectonic fault lines. Even with better exploration, capacity potential is capped at ~40 GW. However, the DOE's report from 2024 concluded that next-generation systems leveraging advanced drilling, subsurface imaging, and oil-and-gas expertise could unlock up to 5,500 GW, transforming geothermal into a scalable baseload solution[25]. As Bill Gates notes, geothermal could become the 'hidden giant' of clean energy eventually supplying up to 20 % of the world's electricity[26].

Extract from Bill Gates' Blog, *Gates Notes*

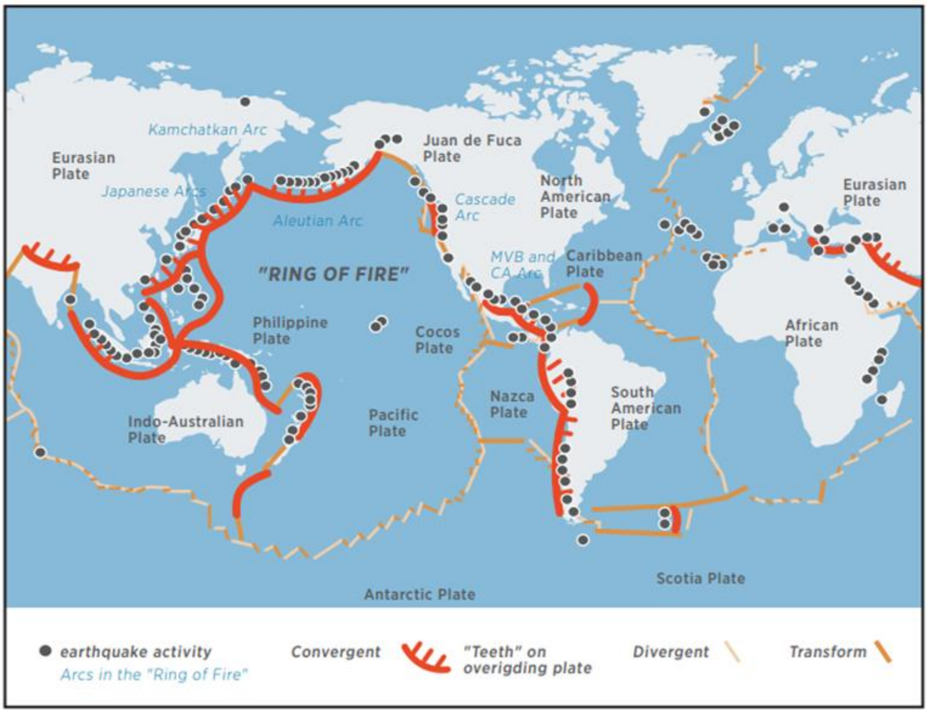
> This is the kind of effort that will help our country remain a leader in energy innovation worldwide. I used to think that geothermal would never be more than 5 percent of the global energy mix. But now I believe it could eventually supply up to 20 percent of the world's electricity. Geothermal power will have a big role to play in our clean energy future, and it's exciting to see companies like Fervo push the technology to new depths.

> Hydrothermal System

A hydrothermal geothermal system occurs where three components are present: heat, water and permeability. Wells are drilled to bring this heat to the surface, where it's used to generate electricity or provide direct heating, and then the cooled water is pumped back underground to be reheated and reused. It accounts for nearly all of todays global geothermal electricity generation with 95-98% of total generation[27]. However, the specific conditions required for hydrothermal systems to function are rare and occur mainly along tectonic boundaries. This limits largescale deployment. This has given rise to newer, more advanced systems being developed which can overcome these geographical limitations and scale beyond volcanic regions.

[25] https://cdn.catf.us/wp-content/uploads/2025/06/09154348/doe-liftoff-nextgen-geothermal.pdf
[26] https://www.gatesnotes.com/utahs-hottest-new-power-source-is-below-the-ground
[27] https://globalenergymonitor.org/projects/global-geothermal-power-tracker/

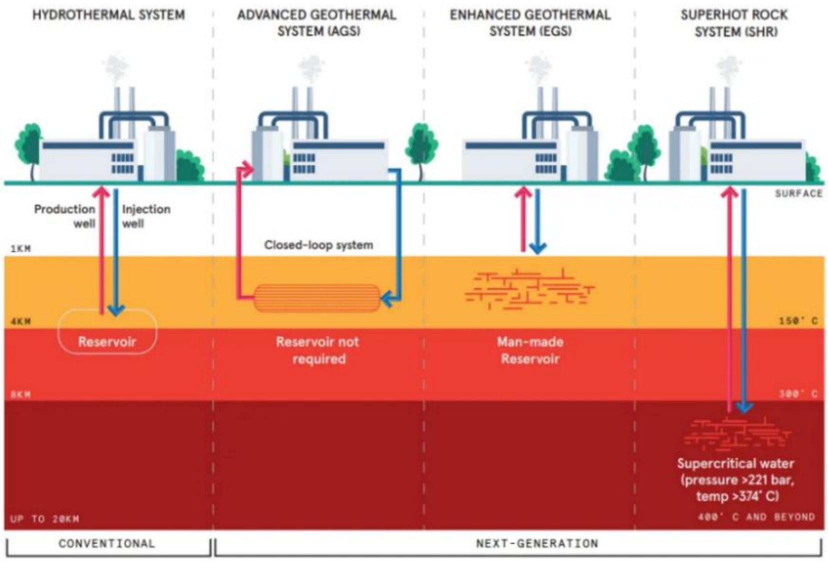
Figure 3: Geothermal Ring of Fire[28]



Source: IRENA

Due to its proven technology and the long lifespans of existing fields like the Geysers (North America) and Hellisheiði (Iceland) hydrothermal will continue to dominate the geothermal electricity generation mix for some time. However, the rise of next generation geothermal systems will begin to take market share from traditional hydrothermal processes.

Figure 4: Types of Geothermal System[29]



Source: S&P Global

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[28] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2017/Aug/IRENA_Geothermal_Power_2017.pdf

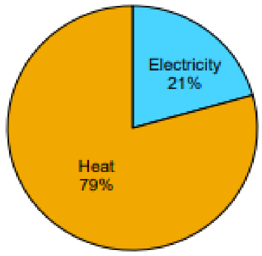
[29] https://www.spglobal.com/commodity-insights/en/news-research/latest-news/energy-transition/011124-infographic-next-generation-technologies-set-the-scene-for-accelerated-geothermal-growth-energy-transition

> Advanced Geothermal Systems (AGS)

Advanced Geothermal Systems, sometimes referred to as closed-loop geothermal, functions like a radiator. A working fluid travels four to eight kilometres down before absorbing heat from the surrounding rock and rising back to the surface through the other side of the loop. At the surface, this heat is transferred to a secondary fluid which vaporises and spins a turbine to generate electricity. Once cooled, the primary fluid is pumped back underground to repeat the process creating a continuous closed-loop cycle.

Current generation costs for AGS of $105–$321/MWh remain higher than alternative geothermal technologies due to required drilling depths but closed-loop designs could reach $64–$160/MWh assuming drilling costs continue to fall.[30] Their high heat efficiency (~90% for direct use) makes them particularly competitive for district heating potentially 30–50% cheaper than turbine-based systems like hydrothermal and EGS[31]. Danish firm Green Therma is pushing this frontier with its Heat4Ever™ closed-loop AGS system for district heating, already backed by public funding and planned for demonstration in Aalborg, Denmark. Considering that 79% of geothermal energy consumption is used for heat, AGS could prove incredibly useful.

Figure 5: Total final geothermal energy consumption by application, world (left), and top 10 consuming countries (right), 2023



Source: DESNZ[32]

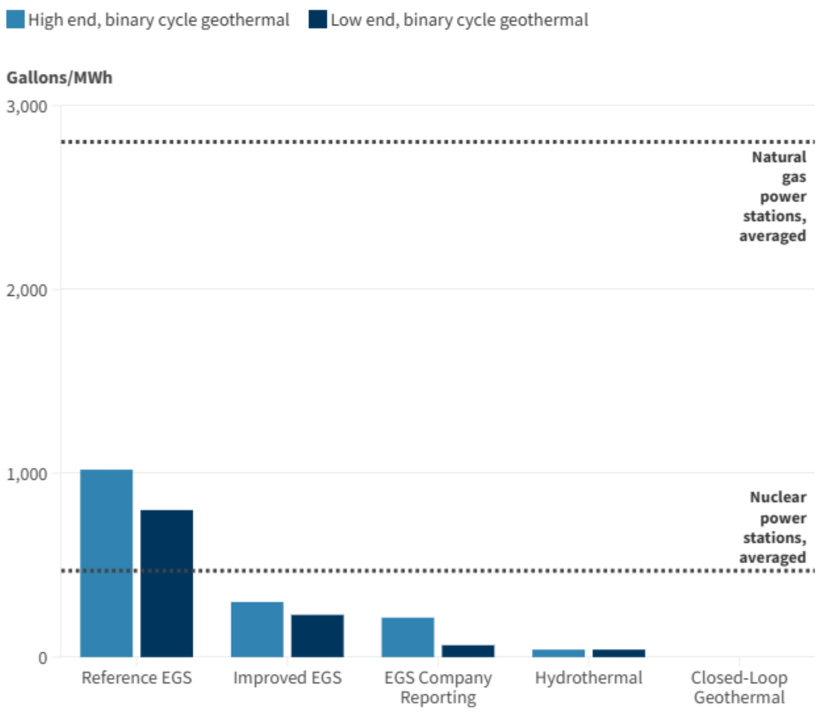
AGS combines high efficiency, scalability, and minimal water use, making it an effective geothermal solution as costs decline. In regions like Europe, where water-intensive fracturing faces public and regulatory resistance, closed-loop systems could gain a competitive edge. As global water scarcity intensifies, AGS's low water requirements may also yield a "water premium," enhancing its long-term value. Although AGS remains more expensive than EGS, in areas constrained by limited water resources or restrictions on hydraulic fracturing, AGS systems could nevertheless offer a more attractive solution.

[30] https://research-hub.nrel.gov/en/publications/techno-economic-performance-of-eavor-loop-20

[31] https://www.iea.org/reports/the-future-of-geothermal-energy

[32] https://assets.publishing.service.gov.uk/media/664c827ff34f9b5a56adcb5d/UK_Energy_in_Brief_2023.pdf#:~:text=(1)%20Excludes%20non%2Denergy%20use.%20(2)%20Includes%20agriculture%2C,to%20higher%20energy%20prices%20and%20warmer%20temperatures.

Figure 6: **Water Demand for Next-Generation Geothermal Systems**[33]



Source: Carnegie[34]

> Enhanced Geothermal System (EGS)

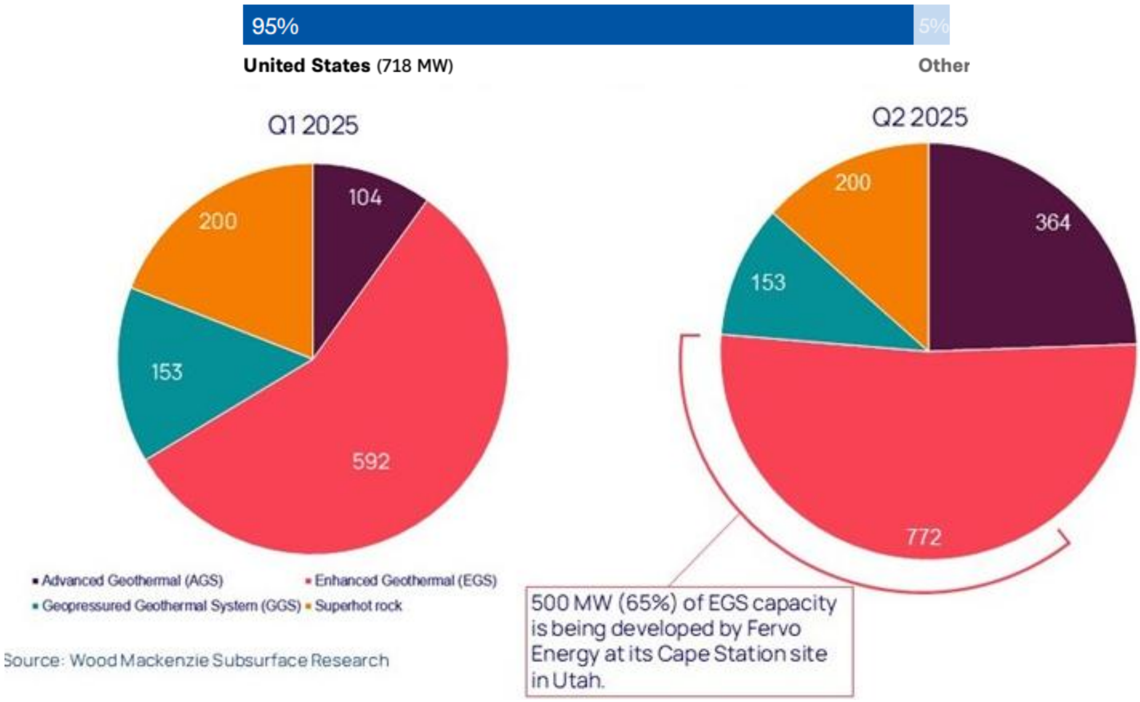
Enhanced Geothermal Systems (EGS) are designed to unlock geothermal energy in areas where natural conditions such as underground water or rock permeability are insufficient for conventional hydrothermal production. Engineers drill deep wells into hot, dry rock three to five kilometres below the surface and then inject water at high pressure to create or enhance fractures in the rock. This allows the injected water to circulate through the heated fractures and absorb thermal energy. The heated water is then pumped back to the surface, where the water vaporises and spins a turbine which generates electricity. The loops are shallower in the ground at three to five kilometres potentially decreasing costs relative to AGS.

The first commercial-scale plants, such as Fervo Energy's 500 MW Cape Station in Utah due to phase in production between now and 2030 (backed by Bill Gates' Breakthrough Energy) signal EGS's entry into early deployment, with pilots in Nevada, Oregon, and the U.K. proving feasibility.

[33] https://carnegieendowment.org/research/2025/07/unlocking-global-geothermal-energy-pathways-to-scaling-international-deployment-of-next-generation-geothermal?lang=en

[34] https://carnegieendowment.org/research/2025/07/unlocking-global-geothermal-energy-pathways-to-scaling-international-deployment-of-next-generation-geothermal?lang=en

Figure 7: Total Next-Generation Capacity (MW) Operating and Under Development, by Technology and Country



Source: Wood MacKenzie[35]

The sector has received strong policy support from the US government, including research funding, tax incentives, and inclusion in major clean energy initiatives. EGS has benefited from advanced drilling and reservoir engineering the oil and gas industry, with much of its workforce transitioning from that sector to drive innovation. Forecasts from McKinsey and the US DOE forecast state EGS could reach about 85 GW of installed capacity by 2050 with capacity rising sharply after 2030 if cost and drilling advancements continue[36].

At present, EGS generation costs are estimated between $100 and $240/ MWh roughly comparable to the cost of new nuclear power. However, recent analyses project that with continued innovation and scaling, EGS costs could decline to around $80/ MWh by 2030 and as low as $50 by 2035. If achieved, this would place EGS within the same cost range as onshore to offshore wind.

[35] https://www.woodmac.com/news/opinion/hot-rocks-geothermal-momentum-continues-to-build/

[36] https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/is-geothermal-energy-ready-to-make-its-mark-in-the-us-power-mix

Figure 8: **Mapping Next-Generation Geothermal Sites**

Source: Mapping Next-Generation Geothermal Sites[37]

> Superhot Rock System (SHR)

Superhot Rock (SHR) systems inject cold water deep underground, drilling as far as necessary to reach rock heated beyond 400°C. The depth required to reach these temperatures varies significantly around the world: in some regions the ~400°C isotherm occurs at less than 10 km, while in many others it lies 10-15 km below the surface. At these extreme depths, pressure and temperature conditions cause the injected water to enter a supercritical phase, enabling it to absorb and transport vastly more thermal energy to the surface. The resulting superhot, high-pressure fluid is then brought back up to generate steam for electricity production or to supply industrial heat. Once cooled, the same water is reinjected underground, completing a continuous high-efficiency cycle.

SHR systems are still in the early stages of research and development. Although some supercritical resources exist closer to the surface in unique geological settings, most lie much deeper underground and are beyond the reach of current oil and gas drilling technology. Accessing these high-temperature zones will require next-generation drilling techniques capable of reaching depths far greater than today's conventional wells. Although SHR systems could yield up to 10x the power of conventional wells, commercial viability depends on breakthroughs in ultra-deep drilling and high-temperature materials capable of withstanding >400°C condition.

> Forced Geothermal Circuit (FGC)

Forced Geothermal Circuit (FGC) systems offer a compelling alternative to other geothermal technologies because they eliminate the need for deep drilling, which can represent up to 50% of total project costs. Unlike hydrothermal systems constrained by specific geological settings, or EGS and AGS, which still rely on expensive subsurface drilling, FGCs use shallow, closed-loop heat exchange circuits that can be deployed anywhere that non-productive or abandoned geothermal, oil or gas wells exists. This approach reduces

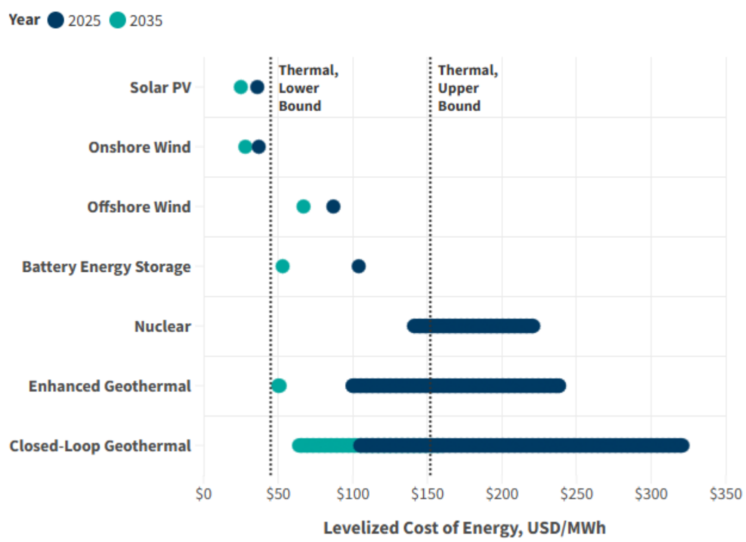
[37] https://carnegieendowment.org/research/2025/07/unlocking-global-geothermal-energy-pathways-to-scaling-international-deployment-of-next-generation-geothermal?lang=en

capital costs, shortens development timelines, and repurposes end-of-life wells into productive clean energy assets.

Solution Energy are the pioneers of this technology and have a proprietary downhole system (FGC) that can produce commercially viable baseload power from existing or new wells with temperatures as low as 120C. This technology is completing production testing later this year and if proven has the potential to reduce geothermal power costs and make geothermal viable in many locations other that the more limited 'ring of fire' regions that produce most of the world's geothermal power today.

The other aspect of FGC technology is its potential to deliver a new approach to data centre cooling that requires less power than current systems and zero water consumption. With innovations like FGC and the AI capex boom, the geothermal sector might be on the cusp of a major inflection point.

Figure 9: Cost of Energy Types vs. Next-Generation Geothermal



Source: Carnegie Analysis[38]

Geographic Spread

Globally, more than 18,000 geothermal wells have been drilled, and analysts estimate that over 35,000 additional wells will be needed by 2050 to meet growing clean energy demand and net-zero goals. Most drilling today is concentrated in proven geothermal regions such as the United States, Iceland, Indonesia, and Turkiye, where geological data and experience reduce exploration risks. Europe is also emerging as a major centre of geothermal expansion particularly Germany, France, Poland, and Croatia.

However, next-generation systems like EGS, AGS, and FGC can unlock heat resources in areas once considered unsuitable. The US continues to lead in deployment helped by its oil and gas expertise while Saudi

[38] https://carnegieendowment.org/research/2025/07/unlocking-global-geothermal-energy-pathways-to-scaling-international-deployment-of-next-generation-geothermal?lang=en

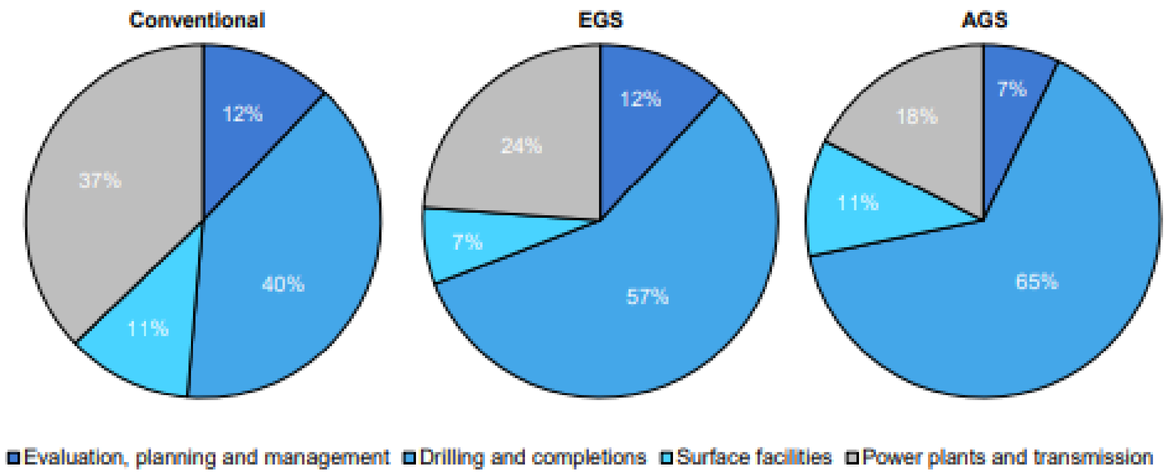
Arabia, Australia, and parts of Africa are beginning to explore shallow and enhanced systems for power and district heating.

Industrial & Strategic Partnerships

> Oil & Gas Industry Partnerships

The oil and gas sector is becoming a cornerstone of next-generation geothermal commercialisation. Decades of expertise and technology transfer directly support geothermal development, with IEA analysis showing that around two-thirds of investment in conventional geothermal and over three-quarters in next-generation systems overlap with oil and gas skills and supply chains. Partnerships such as Chevron's collaboration with Baseload Capital, BP's investment in Eavor Technologies, and Equinor's emerging geothermal pilots highlight growing industrial alignment between the two industries. This provides the geothermal industry with a ready-made foundation to drive down costs, accelerate deployment, and offers energy companies a natural pathway to diversify portfolios and redeploy assets as the global energy transition accelerates.

Figure 10: Shares of Conventional and Next-Generation Geothermal Technology Investments that Overlap with Oil and Gas Industry Skills and Expertise



Source: IEA[39]

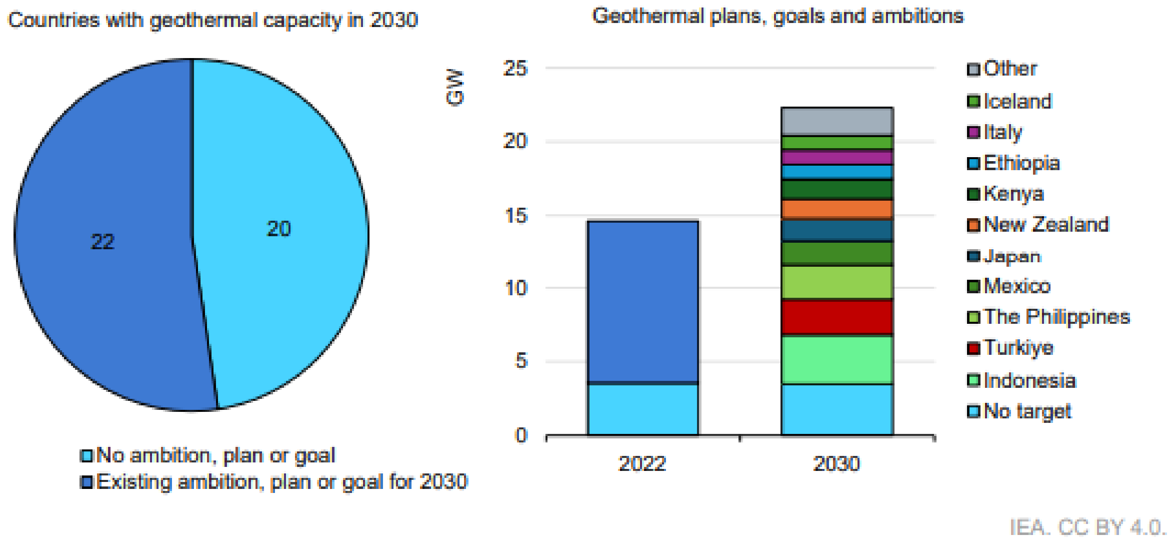
Currently, oil and gas companies account for only a small share of global geothermal capacity, operating roughly 15% through affiliated subsidiaries, minority stakes, or joint ventures[40]. The bulk of geothermal assets, however, are held by integrated energy utilities that have broadened their natural gas and electricity portfolios to include geothermal generation.

39 https://iea.blob.core.windows.net/assets/cbe6ad3a-eb3e-463f-8b2a-5d1fa4ce39bf/TheFutureofGeothermal.pdf

40 https://iea.blob.core.windows.net/assets/cbe6ad3a-eb3e-463f-8b2a-5d1fa4ce39bf/TheFutureofGeothermal.pdf

> Government Policy and Public–Private Collaboration

Figure 11: **Government Plans, Goals and Ambitions for Geothermal Power Capacity in 2030**



Source: IEA[41]

Currently, while over 100 countries have established policy frameworks to support and subsidise renewable energy development, fewer than 30 have comparable policies for geothermal[42]. This must change to attract investment and lower the cost of next-generation geothermal technologies. The US has been particularly influential in shaping geothermal's investment landscape. Early-stage public funding has helped to de-risk the sector and accelerate cost reduction. The Department of Energy (DOE) committed $300 million to the FORGE initiative which helped developers like Fervo Energy become commercial viability. The DOE's GEODE programme also provided $10 million in seed funding and has made $155 million available in competitive grants.

Across Europe, national policies are aligning around geothermal as a secure and scalable clean-energy source. Germany has introduced targeted public funding and fast-track permitting[43]; the Netherlands has mobilised more than €1 billion[44] in geothermal heat projects through subsidies and public–private partnerships; and France's Geothermal Development Action Plan provides a structured framework for scaling district heating and industrial heat use. The IEA believe an uptick in government support combined with skills and expertise transfer from oil and gas could cut project costs by as much as 80% by 2035, reducing generation costs to around USD 50/MWh[45]. At this level, geothermal would rival or undercut other clean, baseload power sources such as hydro, nuclear, and bioenergy and compete directly with wind and solar.

> Private Investment and Emerging Partnerships

Private capital is now responding to these signals. Specialist investors such as Baseload Capital and Breakthrough Energy continue to fund early-stage geothermal ventures, while technology companies are entering long-term power purchase agreements to secure clean baseload power. Notable recent deals

[41] https://iea.blob.core.windows.net/assets/cbe6ad3a-eb3e-463f-8b2a-5d1fa4ce39bf/TheFutureofGeothermal.pdf
[42] https://iea.blob.core.windows.net/assets/cbe6ad3a-eb3e-463f-8b2a-5d1fa4ce39bf/TheFutureofGeothermal.pdf
[43] https://www.reuters.com/sustainability/climate-energy/germany-moves-fast-track-geothermal-energy-projects-2025-08-06/
[44] https://www.world-energy.org/article/42990.html
[45] https://iea.blob.core.windows.net/assets/cbe6ad3a-eb3e-463f-8b2a-5d1fa4ce39bf/TheFutureofGeothermal.pdf

include Exceed Geo Energy's 110 MW AGS project in Texas and XGS's 150 MW facility in New Mexico, which will supply Meta's data-centre operations[46].

2024–2025 Milestones

After decades of slow, steady progress, geothermal energy is now scaling at pace. The number of next-generation projects has climbed sharply over the past 18 months, with global activity rising by around 40% between Q1 2024 and Q2 2025.[47] Growth has been particularly strong across North America and Europe, with the United States alone announcing 260 MW of new Advanced Geothermal Systems (AGS) capacity in Q2 2025. At the same time, early-stage activity is emerging in the Middle East and Africa, where pilot drilling programmes are beginning to establish a foothold for future geothermal development.[48]

Figure 12: Next-Generation Geothermal Project Tracker

Source: Wood Mackenzie

This momentum reflects a step change in technology and investor appetite. Enhanced and closed-loop geothermal systems are expanding beyond traditional hydrothermal zones, supported by a surge in public and private capital. Global investment in geothermal tripled between 2021 and 2024, exceeding US $2 billion,[49] and advanced systems now represent a significant share of new capacity.

Policy frameworks and funding are catching up fast. The US, EU, Japan, and Indonesia have all introduced geothermal-specific incentives or pilot programmes, while public funding for geothermal jumped 57% quarter-on-quarter in early 2025 to reach US $400 million.[50] Venture and corporate investors have followed suit, with next-generation developers such as Fervo, Eavor, and XGS raising US $319 million in Q2 alone. Drilling activity is also accelerating, 88 wells were drilled globally in Q2 2025, nearly double the previous quarter, signalling that projects are moving decisively from concept to execution.

46 https://www.esgtoday.com/meta-xgs-sign-deal-to-power-data-centers-with-geothermal-energy/
47 https://www.woodmac.com/news/opinion/hot-rocks-geothermal-momentum-continues-to-build/
48 https://www.woodmac.com/news/opinion/hot-rocks-geothermal-momentum-continues-to-build/
49 https://www.woodmac.com/news/opinion/hot-rocks-geothermal-momentum-continues-to-build/
50 https://www.woodmac.com/news/opinion/hot-rocks-geothermal-momentum-continues-to-build/

Collectively, this growth marks geothermal's evolution from a niche renewable to a mainstream clean-firm energy solution, capable of providing the 24/7 baseload power needed to stabilise renewables-heavy grids.

> Q1 2024

- The US Department of Energy awarded $60 million for commercial scale *Enhanced Geothermal Systems (EGS)* demonstrations, including Fervo Energy's Utah project and Chevron New Energies' California project, to validate 24/7 geothermal power generation.[51]
- Fervo Energy raises $244 million in a Series D round led by Devon Energy, accelerating its next-generation EGS deployment following Project Red[52]
- Menengai II (Kenya) reaches financial close with US$117 million backing from AfDB, FinnFund, and TDB, strengthening East Africa's geothermal leadership.[53]
- Quaise Energy raises $21 million Series A1 to advance deep-drilling technology for "superhot rock" geothermal.[54]

> Q2 2024

- Google signs long-term geothermal PPA with NV Energy and Fervo Energy to supply up to 115 MW of geothermal power to Nevada data centres.[55]
- Fervo Energy Announces 320 MW Power Purchase Agreements with Southern California Edison[56]

> Q4 2024

- European Union pushes for faster geothermal rollout: The European Council issues a joint call to action urging member states to remove barriers and support financing for geothermal development.[57]
- Japan gov't to support companies boosting geothermal power plants[58]
- Fervo Energy secures an additional $255 million (equity and debt) to scale its US EGS portfolio, with Capricorn Investment Group leading the $135 million equity portion.[59]
- Wood Mackenzie estimates $2 billion in geothermal commitments globally in 2024, signalling a structural re-rating of the sector.[60]
- UK establishes National Geothermal Centre to accelerate research, deployment, and private investment.[61]

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[51] https://content.govdelivery.com/accounts/USEERE/bulletins/38a490c
[52] https://fervoenergy.com/fervo-energy-raises-244-million-to-accelerate-deployment-of-next-generation-geothermal/
[53] https://energynews.pro/en/kenya-financial-close-for-menengai-geothermal-project/
[54] https://www.quaise.com/news/quaise-energy-raises-21-million-to-accelerate-terawatt-scale-deep-geothermal-energy
[55] https://www.reuters.com/business/energy/google-partners-with-nevada-utility-geothermal-power-data-centers-2024-06-13/
[56] https://fervoenergy.com/fervo-energy-announces-320-mw-power-purchase-agreements-with-southern-california-edison/
[57] https://www.consilium.europa.eu/en/press/press-releases/2024/12/16/geothermal-energy-council-calls-for-faster-deployment/
[58] https://english.kyodonews.net/articles/-/51029
[59] https://fervoenergy.com/fervo-energy-secures-additional-255-million-funding/
[60] https://www.woodmac.com/news/opinion/2024-the-promise-of-geothermal/
[61] https://ukngc.com/first-national-centre-launched-to-advance-geothermal-energy-in-the-uk/

> YTD 2025

- Fervo–Shell Energy offtake deal: Fervo signs a 5-year power purchase agreement with Shell Energy North America (US) for 31 MW[62]
- The Ministry of Economy, Trade, and Industry (METI) of Japan has announced a subsidy round for projects for promoting the understanding of geothermal power generation.[63]
- Canada Growth Fund announces additional investment in Eavor Technologies. Commitment by CGF of up to ~C$138 million[64]
- Fervo Energy Secures $206 million In new financing to accelerate cape station development[65]
- Indonesia opens tender for 21 geothermal sites for exploration and development[66]
- Kenya's Olkaria VII (80 MW) progresses through regulatory approval, expanding one of the world's largest geothermal fields.[67]
- UK Geothermal Energy Review & Cost Estimations (Aug 2025) published, first major update since 2016, confirming declining levelised costs and system-value potential.[68]
- IEA renews policy push for geothermal integration into national strategies and recommends expanded risk-mitigation financing.[69]

Cost and Pricing Signals

A major hurdle for geothermal energy has long been its high upfront capital requirements. Unlike wind or solar, geothermal projects demand significant initial investment in infrastructure, which drives up their LCOE.

Between 2009 and 2023, the costs of generating electricity from solar and wind power dropped dramatically, by 83% for solar photovoltaic systems and 63% for onshore wind. This decline in LCOE was primarily driven by a combination of technological advances, manufacturing efficiencies, and economies of scale. Improvements in solar cell efficiency, turbine design, and system integration meant that each unit of equipment produced more energy over its lifetime. At the same time, global manufacturing expanded and matured, leading to lower unit costs through mass production, process optimisation, and learning-by-doing. As installation volumes grew, developers became more efficient, financing costs fell, and supportive policies created a virtuous cycle of lower costs and higher deployment. Together, these factors made wind and solar energy cost-competitive with fossil fuels and fundamentally reshaped the global power sector.

A similar trajectory could be achievable for geothermal energy, though its challenges and cost structures differ. Like wind and solar, geothermal projects stand to benefit from learning effects and technological innovation. As more wells are drilled and developers refine their methods, drilling speed increases and costs decline, evident in recent examples such as Fervo Energy's rapid improvements. Advances in drilling technologies,

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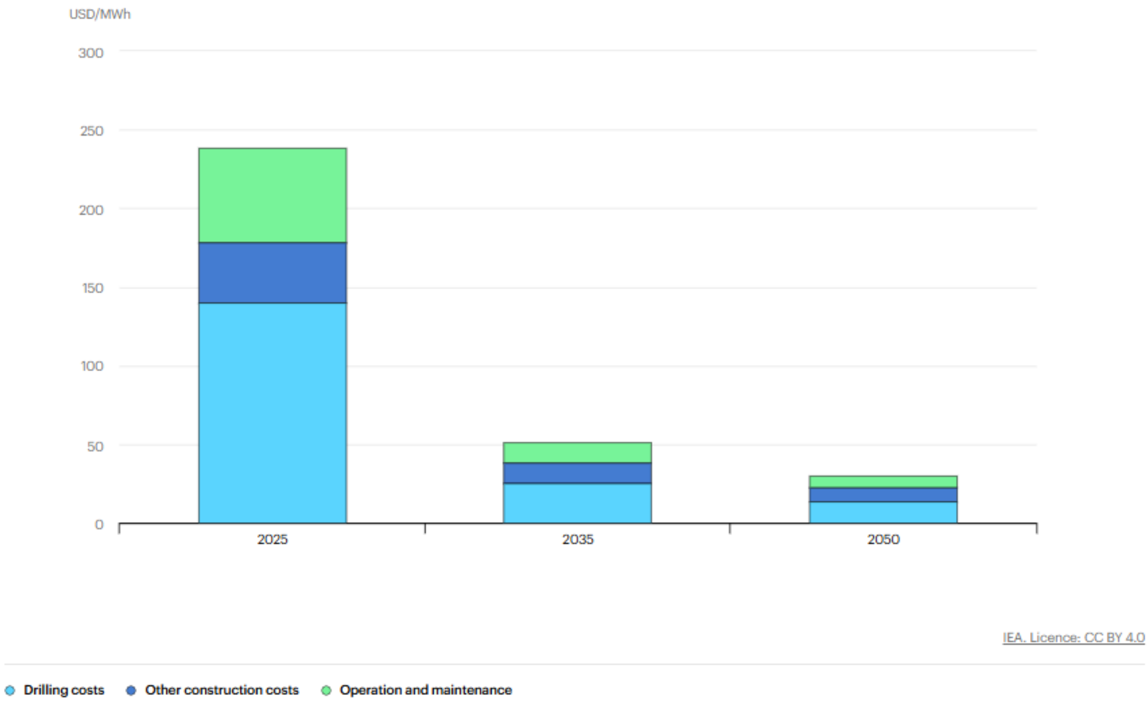
[62] https://fervoenergy.com/fervo-energy-announces-31-mw-power-purchase-agreement-with-shell-energy/
[63] https://www.thinkgeoenergy.com/japans-meti-offers-subsidy-for-geothermal-information-and-education-projects/
[64] https://eavor.com/press-releases/canada-growth-fund-announces-additional-investment-in-eavor-technologies-a-calgary-based-advanced-geothermal-technology-company/
[65] https://fervoenergy.com/fervo-secures-new-financing-to-accelerate-development/
[66] https://www.thinkgeoenergy.com/indonesia-opens-tender-for-21-geothermal-sites-for-exploration-and-development/
[67] https://www.thinkgeoenergy.com/kengen-receives-cabinet-approval-for-olkaria-vii-geothermal-power-plant-kenya/
[68] https://www.gov.uk/government/publications/uk-geothermal-energy-review-and-cost-estimations
[69] https://www.iea.org/reports/the-future-of-geothermal-energy/policy-recommendations

reservoir modelling, and real-time data monitoring are also enhancing project predictability and efficiency, while the transfer of expertise and technology from the oil and gas sector offers additional opportunities to accelerate progress.

Economies of scale and standardisation will play a major role as geothermal deployment expands. Replicable project designs, modular power systems, and a maturing supply chain could yield cost reductions similar to those that transformed solar and wind economics. Policy support is also critical: initiatives such as the US Department of Energy's Enhanced Geothermal Shot program aim to reduce geothermal's LCOE by 90% by 2035, mirroring the early-stage government backing that catalysed the rise of wind and solar.

In essence, while geothermal's path will differ from that of other renewables, the same fundamental forces, technological learning, industrial scaling, and strategic policy support, can drive comparable cost declines. With continued innovation and investment, geothermal energy has the potential to become both economically competitive and uniquely valuable as a source of clean, firm, baseload power.

Figure 13: Levelised Cost of Electricity of Next-Generation Geothermal in a Low-Cost Case, 2025-2050



Source: International Energy Agency[70]

> Financing

First-of-a-kind projects are expensive and can disincentivise private capital being allocated due to the perceived project risk. Geothermal, however, has benefitted from both federal and state support in the US which in turn

[70] https://www.iea.org/data-and-statistics/charts/levelised-cost-of-electricity-of-next-generation-geothermal-in-a-low-cost-case-2025-2050

has catalysed private investment. California, for example, has mandated that 1GW of new capacity must come from zero-emitting, renewable resources with at least an 80% capacity factor.[71][72]

At the end of 2024, Sightline Climate reported that cumulative fundraising in geothermal since 2020 surpassed $700 million representing a tenfold increase over the past three years.[73] More recently, Fervo raised $300m for its series E round at a valuation of $3bn – taking the total fundraising for geothermal over $1 billion.

"If deep cost reductions for next generation geothermal can be delivered, total investment in geothermal could reach USD 1 trillion cumulatively by 2035 and USD 2.5 trillion by 2050. At its peak, geothermal investment could reach USD 140 billion per year, which is higher than current investment in onshore wind power globally. As a dispatchable source of clean power, geothermal is also attracting interest from stakeholders beyond the energy industry, including technology companies looking to meet the fast-growing demand for electricity in data centres." – EIA [74]

Geothermal developers have moved rapidly down the learning curve. Fervo Energy, for example, has achieved a threefold increase in drilling speed while cutting per-well drilling costs from about $9 million to $4.5 million. This improvement, reflecting a 35% learning rate, was realised across the company's first eight wells.[75]

Continued development and learning will further reduce costs, making geothermal competitive on an LCOE basis with other energy sources. Its high-capacity factor and renewable baseload output, however, set it apart from alternatives at similar price points.

Supply Chain

The geothermal energy supply chain is complex and capital-intensive, spanning exploration, drilling, equipment manufacturing, permitting, and grid integration. While geothermal offers reliable, clean baseload power, its deployment pace is constrained by several supply-chain challenges. Recent industry highlight persistent bottlenecks in drilling capacity, ORC (Organic Rankine Cycle) equipment manufacturing, permitting processes, transmission access, and skilled labour availability, all of which limit how quickly new geothermal capacity can be brought online.

> Drilling & Well Services

Accessing geothermal resources remains a critical bottleneck because specialised high-temperature, corrosion-resistant drilling infrastructure is limited and costly. In recent industry supply-chain risk surveys, companies across renewables (including geothermal) cited scarcity of drilling equipment and long lead times as major constraints.[76] In the UK context, stakeholder evidence reports have flagged high day rates for drilling rigs and long stand-by times as a barrier for geothermal deployment.[77]

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[71] https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M528/K560/528560288.PDF
[72] https://www.jpmorgan.com/insights/banking/investment-banking/powering-geothermal-energy-investment
[73] https://www.jpmorgan.com/insights/banking/investment-banking/powering-geothermal-energy-investment
[74] https://iea.blob.core.windows.net/assets/cbe6ad3a-eb3e-463f-8b2a-5d1fa4ce39bf/TheFutureofGeothermal.pdf
[75] https://amplyfi.com/blog/geothermal-energy-emerges-as-viable-solution-for-ai-data-center-power-crisis/
[76] https://www.wtwco.com/en-gb/insights/2023/05/2023-renewable-energy-supply-chain-risk-report?
[77] https://nora.nerc.ac.uk/id/eprint/535567/1/report_OR23032.pdf?

> Manufacturing & ORC Equipment

The manufacturing of ORC systems, turbines, heat exchangers, and associated parts is another bottleneck. NREL's latest "Geothermal Manufacturing and Supply Chain Analysis" highlights supply-chain constraints for geothermal component manufacturing, including challenges in scaling up domestic capacity for critical parts.[78] ORC turbines are integral to next-generation geothermal plants, with production concentrated in Italy, Israel, China, and Türkiye. As deployment accelerates, this narrow supply base could create bottlenecks without expanded capacity.

> Permitting & Regulatory Risk

Above-ground regulatory processes present persistent delays. Engagement with regulatory and permitting stakeholders remains ongoing, with regulatory approvals and permitting continuing to pose significant challenges to the timely deployment of geothermal projects.[79] The US is attempting to implement emergency permitting procedures to speed up this process but the IEA's stress it remains a key hurdle to project realisation.[80]

> Grid & Transmission Interconnection

Grid access remains a critical barrier to geothermal development, as many high-quality resources are located in remote areas far from major demand centres. Limited transmission capacity and the high cost of new interconnections often delay project timelines and reduce economic viability. Expanding grid infrastructure and coordinating transmission planning are therefore essential to unlock geothermal potential at scale.

> Skilled Labor & Technical Capacity

Workforce development is an important focus area for the growing geothermal sector. While the industry requires specialized expertise in drilling, reservoir management, and power conversion systems, many of these skills already exist within adjacent industries such as oil and gas. By leveraging this transferable experience and expanding targeted training programs, the geothermal sector is well positioned to build the skilled workforce needed to support its next phase of growth.

Outlook

Global electricity demand is accelerating driven by the electrification of transport, industrial decarbonisation, and the exponential rise of AI and data centre power consumption. As grids strain under this surge, firm, carbon-free generation is becoming both scarce and valuable.

Against this backdrop, geothermal energy is emerging as the most scalable form of clean baseload power. The convergence of policy support, technological innovation, and private capital has transformed geothermal from a niche opportunity into a mainstream pillar of the energy transition. Enhanced and Advanced Geothermal Systems are now demonstrating the potential to unlock vast heat resources previously inaccessible, positioning

[78] https://www.nrel.gov/geothermal/manufacturing-supply-chain?
[79] https://docs.nrel.gov/docs/fy24osti/87423.pdf?
[80] https://www.iea.org/reports/the-future-of-geothermal-energy?

geothermal as a globally deployable solution. Over the next two years, we expect accelerated project deployment, declining drilling costs, and deeper integration with industrial power users.

Emerging technologies such as FGCs could further accelerate adoption, converting idle wells into low-cost, modular geothermal assets, dramatically reducing drilling costs and development timelines. FGCs can be deployed almost anywhere existing well infrastructure exists, turning stranded oil and gas assets into productive clean-energy resources. This is a truly scalable technology: low footprint, repeatable, and capable of expanding geothermal's reach far beyond conventional hotspots.

Technology companies and hyperscalers are likely to remain key early adopters of geothermal, seeking secure clean power for their expanding compute infrastructure. With continued cost declines, improved permitting frameworks, and expanded grid access, geothermal could become a cornerstone of clean energy portfolios, capable of meeting up to 15% of incremental global electricity demand by 2050.

In an era defined by rising energy intensity and constrained grid capacity, geothermal is emerging as the strategic bridge between net-zero ambition and energy security; a rediscovered resource ready to define the next phase of the transition.

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