

Greenwheel Insights

Heat beneath our feet: unlocking geothermal's untapped potential



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Executive Summary

- **Growing electricity demand and security of supply concerns put geothermal energy in the solutions spotlight.** Geothermal provides near-zero-emissions baseload and flexible power plus direct heat at stable operating costs, with minimal land footprint and no fuel inputs.
- **Conventional geothermal technologies are highly geographically constrained** with resources concentrated along tectonic margins. Globally, its contribution to power and heat demand is negligible.
- **Enhanced Geothermal Systems (EGS) transform the scale of the opportunity.** EGS significantly loosens geographic constraints, with technical potential far exceeding global power demand and potential cost trajectories that could make it competitive with hydro, nuclear and renewables plus storage over the next decade.
- **US policy support creates a leading deployment corridor.** Geothermal retains tax credits over other renewables, aligns with the administration's 'energy dominance' agenda, and benefits from emerging state-level frameworks in Western states that combine subsurface data, permitting clarity, targeted incentives and transmission access.
- **Hyperscalers are driving early demand.** Under favourable conditions, geothermal could meet a substantial share of US hyperscaler firm power demand growth in the 2030s. So far, hyperscalers dominate announced offtake deals.
- **Remaining headwinds centre on geology, execution and governance.** Deep drilling and reservoir engineering remain capex-heavy and geologically uncertain: induced seismicity is a risk, permitting processes are complex and fragmented in the US and EU, and local opposition can emerge around water, seismicity and cultural impacts.
- **Advanced Geothermal Systems (AGS) further extend both potential and uncertainty.** Closed-loop and superhot rock concepts could further relax geographic constraints and reduce some seismic and exploration risks, but they are nascent and require more drilling, higher capital intensity, specialist materials and currently show uncertain performance.

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Preface: The Investor Need

"We see companies investing in geothermal, and next-generation systems as a way to own critical 'always-on' carbon-free infrastructure at the heart of an increasingly electrified economy. For us, the opportunity lies where deep engineering expertise, disciplined development, and long-dated offtakes intersect – creating assets that can compound value over decades, delivering secure, firm, low-carbon power in a world of rising volatility."



Michel Sznajer

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Drilling down: the basics of geothermal energy

Geothermal energy is a vast, largely untapped, renewable and always-available heat resource beneath our feet. Technological constraints have prevented widespread use, but **new technologies are set to unlock exploitation** at much greater scale.

Geothermal resources vary by temperature, which determines potential application. Low temperature resources can be used directly or upgraded with heat pumps for space and water heating. Medium temperature resources can be used for different forms of industrial heat demand, while medium, high to super high temperatures can be used for power generation (Figure 1). This paper focuses on power generation applications.

Geothermal energy has several potential uses

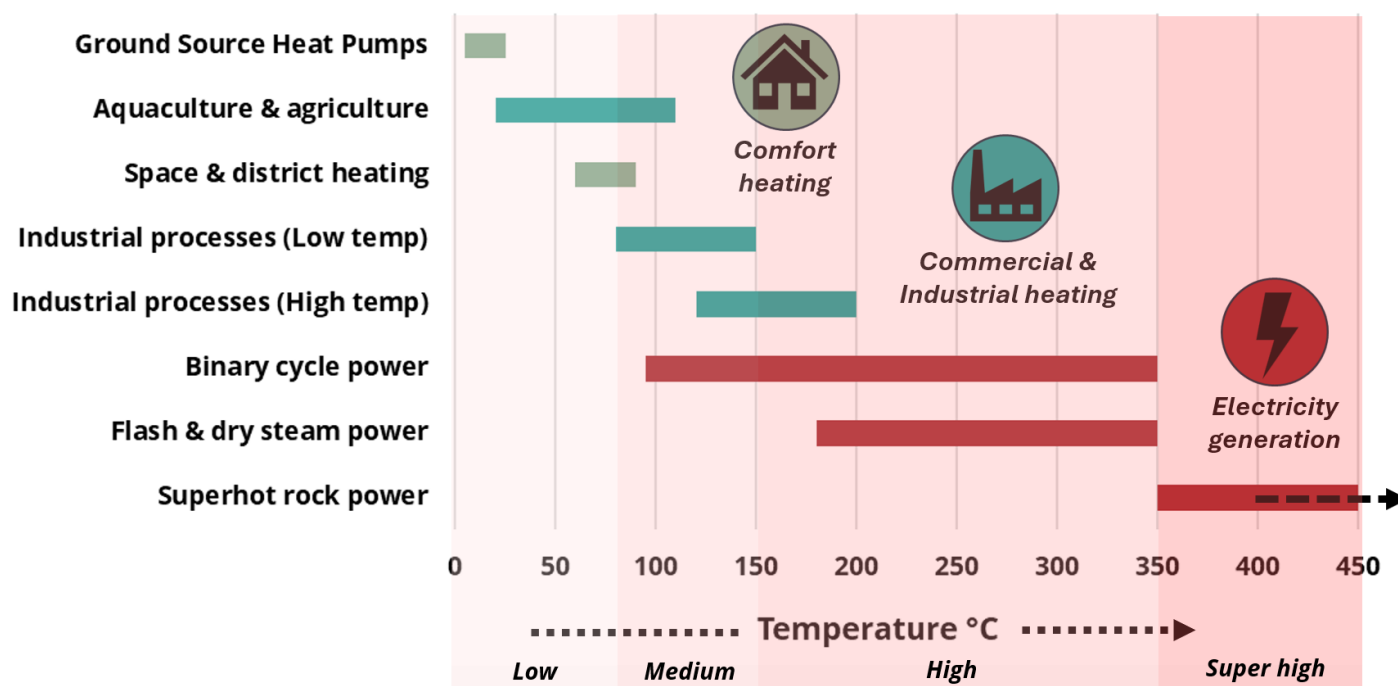


Figure 1 – Geothermal energy applications by approximate geothermal resource temperature. Various sources, including: [IEA \(2024\)](#), [Williams et al \(2011\)](#), [Lindal \(1992\)](#). Graphic created by Greenwheel.

The foundation: Conventional Geothermal

How does it work?

Resources vary by rock permeability and fluid conditions. The most easily and widely exploited resources using conventional technologies are 'hydrothermal', where in-situ water passes through naturally porous or fractured rocks to carry medium or high temperature geothermal heat toward the surface (Figure 2).

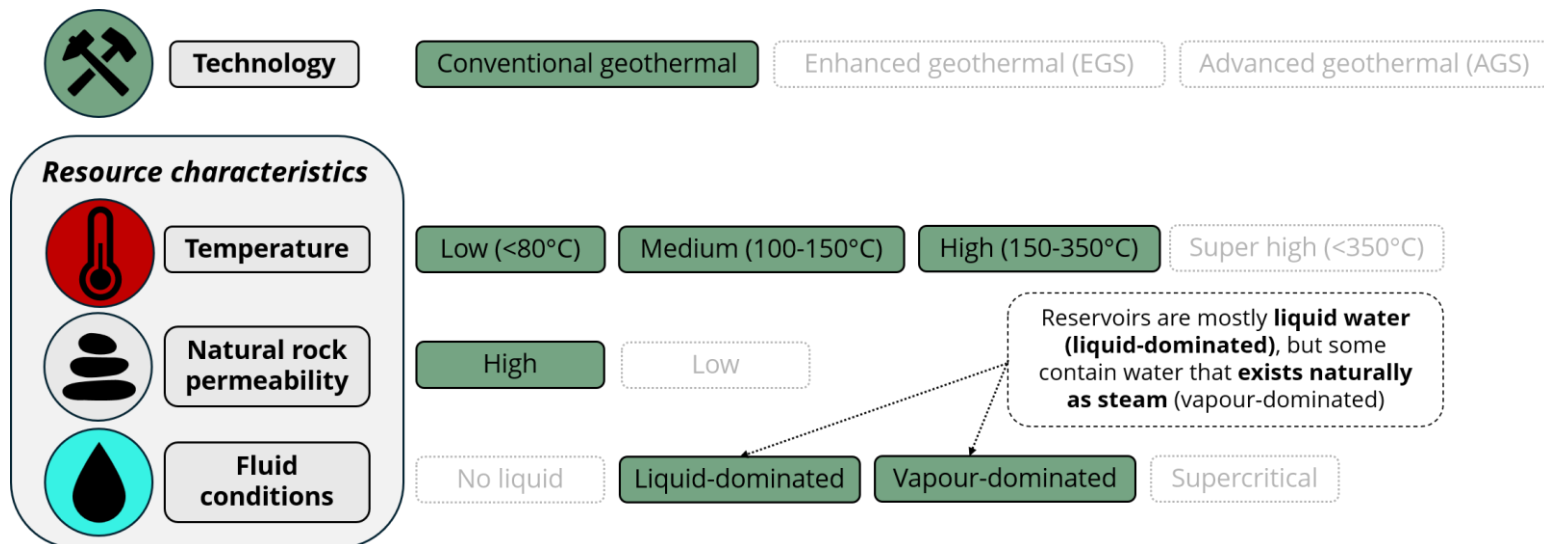


Figure 2 – Geothermal resources unlocked by different technology categories. Created by Greenwheel.

Around two-thirds of installed conventional geothermal capacity is used for direct heating.ⁱ Production wells are drilled through caprock into hydrothermal reservoirs of **low to medium temperatures**, at depths of a few hundred meters to a few kilometres. This **draws fluid** - water or brine – to the surface, **which is then piped directly to buildings, industry or other infrastructure to deliver space, water or industrial heating**. If the liquid is brine or otherwise corrosive, heat exchangers can transfer heat to a closed-loop liquid. Once used, liquid is typically reinjected to the reservoir.

Around one-third of conventional geothermal capacity is used to produce electricity.ⁱ These systems are similar but **require the use or production of steam to drive a turbine** with three key variations. The most common are 'flash steam' plants, where high pressure medium-temperature, liquid-dominated resources are rapidly depressurised ('flashed') into steam, driving the turbine.

Next are binary cycle plants, where lower temperature fluid passes through a heat exchanger that vaporises a secondary working fluid (with a low boiling point), whose vapour then drives the turbine. The final type are rare dry steam plants, where naturally occurring steam (vapour-dominated resources) feeds directly from the wellhead to drive the turbine.

Ground source heat pumps (GSHPs) supply similar volumes of low temperature (mostly comfort) **heat as conventional geothermal** but instead operate by transferring low temperature but consistent heat from the ground at very shallow depths.ⁱ Despite their large untapped global potential they are a different category of geothermal technology, so aren't discussed further here.

Conventional geothermal can have several advantages...

It can provide **continuous heat or electricity with stable operating costs**, with no fuel inputs and long asset lifetimes with modest maintenance requirements. **Electricity generation can ramp flexibly**, allowing for both baseload and peaking roles with **near-zero emissions**.¹ It also has a **very small surface footprint relative to its heat or electricity output**, particularly compared to other renewable technologies, but also fossil fuels.ⁱ

Geothermal is strongly supportive of energy security and sovereignty. As with other renewable technologies, it doesn't require (often imported) fuel inputs. Although plant designs are highly site-specific, much of the equipment for conventional geothermal is standardised and mass-manufactured, with broad supply chains overlapping with the oil and gas industry, particularly for sub-surface hardware.ⁱ

Conventional hydrothermal systems have recently been paired with lithium production through Direct Lithium Extraction (DLE) technologies, where lithium-rich brines are the heat-bearing fluid. Such dual-purpose plants are operating in California, the Upper Rhine Valley in Germany and France, and in Cornwall in the UK.ⁱⁱ **Other potential plants are at different stages of development.** If all such projects materialise, they could produce around 5% of global demand in 2035 even under a relatively ambitious lithium demand trajectory.ⁱ

...but substantial limitations

Suitable hydrothermal resources are concentrated along tectonic margins, where geothermal energy is close to the surface and geology is favourable.ⁱ This **heavily restricts where geothermal plants can be sited. For direct heat use in particular, demand must also be local** as unlike electricity, heat can't be viably transported beyond short distances.

Conventional geothermal **has high capital costs**, and due to site-specific requirements and limited build out has **not been subject to the dramatic learning curves experienced by some other renewables**, like solar PV.ⁱⁱⁱ This means the average levelised cost of electricity (LCOE) of conventional geothermal has remained stable for

¹ Geothermal reservoirs can contain small volumes dissolved greenhouse gases that may be vented.

years. In the early 2010s, geothermal power was significantly cheaper than wind and solar on a global average basis, but **onshore wind has been cheaper since 2016, and solar PV since 2018** (Figure 3).

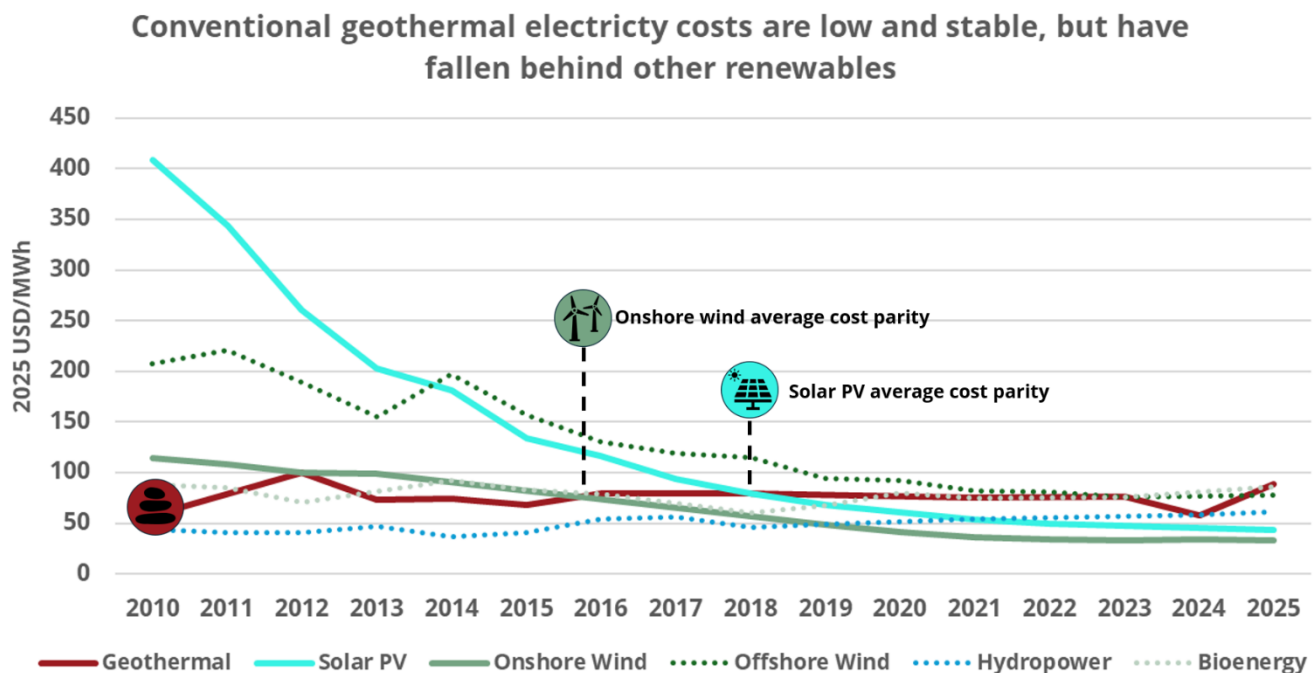


Figure 3 – Global average levelised cost of electricity evolution. Source: [IRENA \(2026\)](#). Graphic created by Greenwheel.

Development timelines are significantly longer than most other power generation options, except nuclear. Timelines can be a decade or more, with much of the time and uncertainty surrounding subsurface exploration, drilling and permitting.ⁱ

Steady growth is expected, within constrained potential

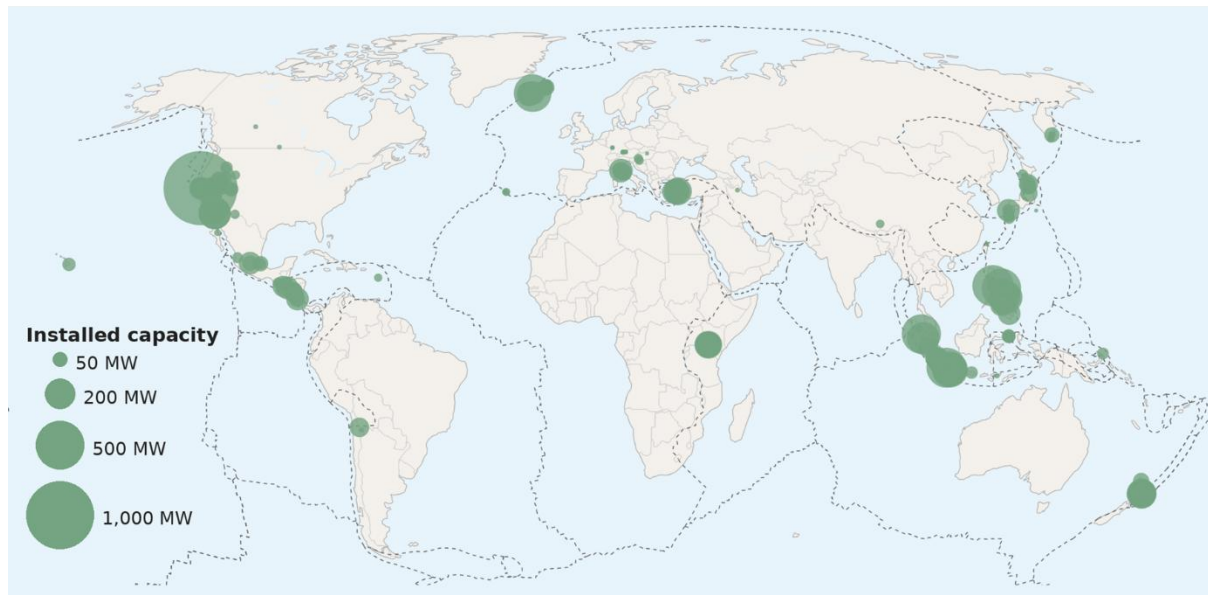
Excluding heat pumps, **geothermal for direct heating accounts for just half of 1% of global heat demand. District heating accounts for over two-thirds of this** – almost entirely in China and Iceland. The remainder, for direct comfort and industrial heating, is concentrated in Türkiye, Japan and New Zealand.ⁱ

Similarly, geothermal power is <1% of global electricity generation,ⁱ despite renewables now accounting for more than a third of global power.^{iv} In the more than fifty years since commercial plants began operation, capacity growth has been slow and linear, reaching **around 16GW operational capacity in around 30 countries, but with around 70% in just five** – the United States, Indonesia, the Philippines, Türkiye and New Zealand (Figure 4).^v

Globally, **a further 2GW of conventional geothermal power capacity is under construction, with nearly 6GW in pre-construction, and nearly 4GW of further announcements.** Investment in conventional geothermal power reached nearly \$5

billion in 2025 - a 4x increase from 2018 (but lower than for geothermal for direct heat, at \$11.5 billion).^{vi}

Operational geothermal power capacity is highly concentrated in five countries sitting over tectonic margins



Projects in construction and pre-construction phase would grow conventional capacity by 50%, concentrated in the same lead countries

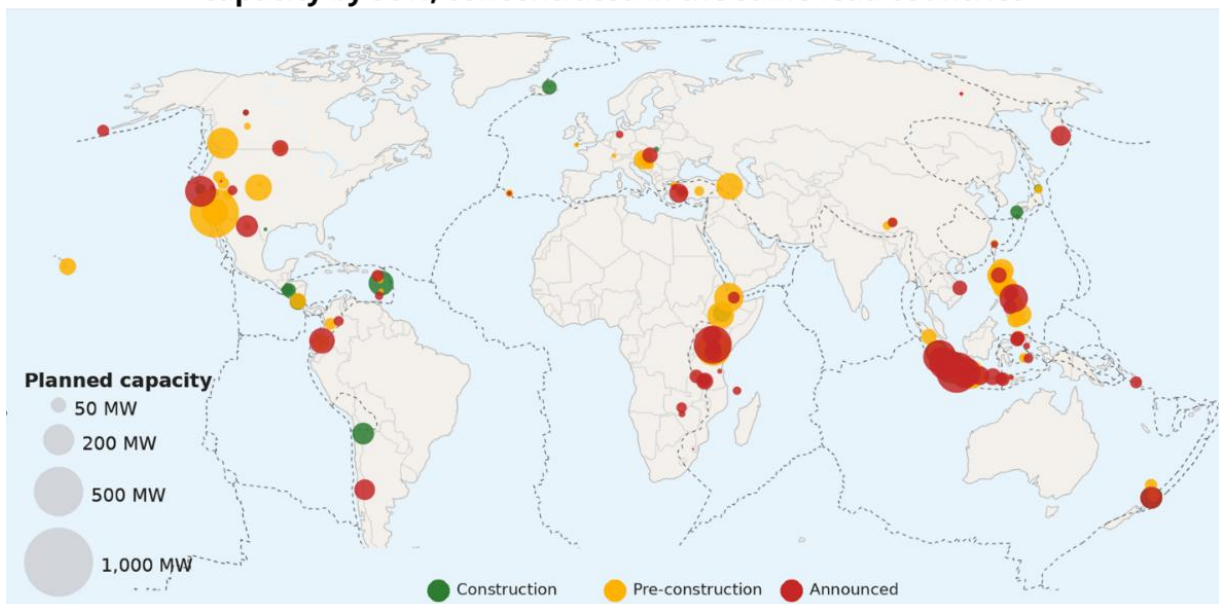


Figure 4 – Conventional geothermal capacity: Installed and pipeline. Data Source: [Global Energy Monitor \(2026\)](#). Assumes any planned or existing capacity without an explicit technology label are conventional installations. Data as of July 2026. Graphic created by Greenwheel.

The IEA estimate that **with support to drive knowledge transfer and supply chain scale from the oil and gas sector**, conventional geothermal **costs could halve**.ⁱ However, this is highly contingent, and fundamental geographic constraints remain.

The key to unlocking scale: Enhanced Geothermal Systems (EGS)

How does it work?

Enhanced geothermal systems (EGS) draw on horizontal drilling and hydraulic fracturing (fracking) techniques to inject fluid under pressure to create artificial fractures in rock and create or expand hydrothermal reservoirs. **This creates newly exploitable geothermal resources** where rock is naturally impermeable, and fluid is naturally absent (Figure 5). Surface-level plant designs and applications are the same as conventional geothermal.

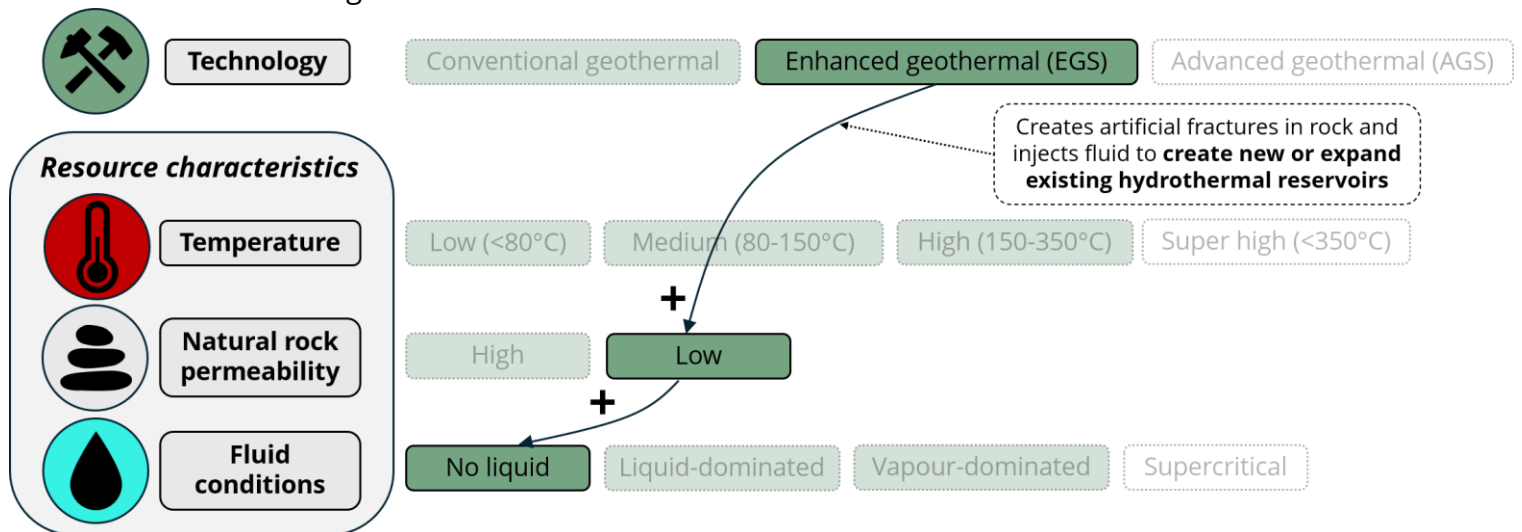


Figure 5 – Geothermal resources unlocked by different technology categories. Created by Greenwheel.

The technical potential far exceeds our needs

As subsurface temperatures generally increase with depth, **EGS can create technically exploitable geothermal resources almost anywhere** by drilling deep enough.ⁱ

At depths of up to 8km and with a power generation cost ceiling of \$300/MWh, **the global power capacity potential unlocked by EGS is double that of onshore wind, and second only to solar PV**. Given the high capacity factors of geothermal, **this translates to electricity generation potential at 150x current global electricity demand**.ⁱ

At the country level, **the USA has the world's largest technical potential** - several times more than all its current power capacity combined. China has the second largest. **Europe has just over half the potential of the USA, but this still represents over 30x its current capacity across all generation technologies**. Together, Africa and ASEAN countries account for over a third of global technical potential.ⁱ

With EGS, technically exploitable geothermal resources can be found almost everywhere

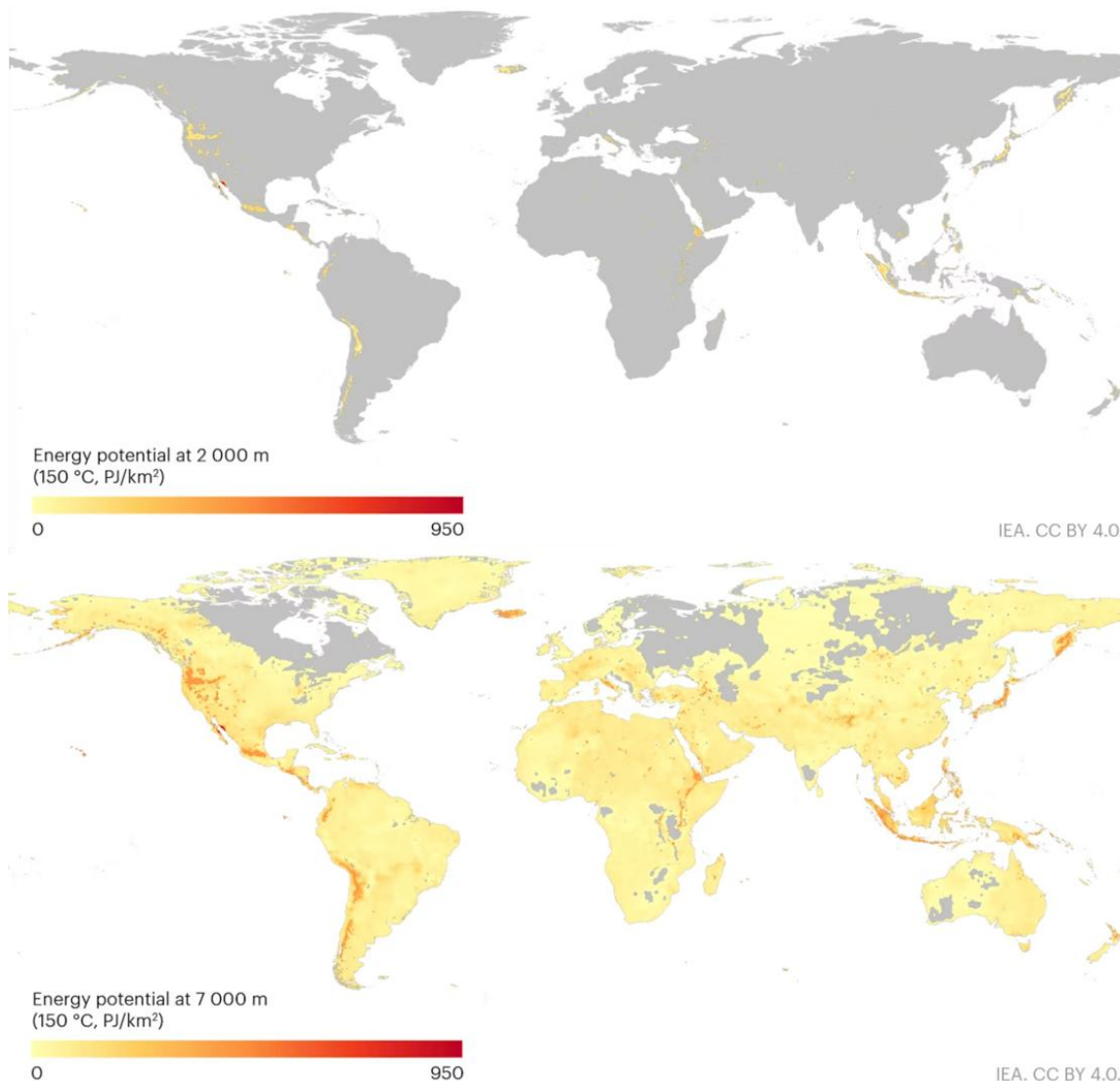


Figure 6 – Global geothermal technical potential for power generation at different resource depths (temperature and regional concentration), with a cost ceiling of \$300/MWh. Graphic sourced from [IEA \(2026\)](#) under Creative Commons licence.

EGS is finding its feet

To date, **EGS capacity is small and experimental**. Of the more than 100 projects completed (concentrated in Europe and the USA), only a handful deliver notional volumes of commercial electricity or heat production.^{vii}

However, **developments by these R&D plants** – across drilling speeds and depths, flow rates, and production temperatures– **have pushed the technology to the cusp of commercial viability and scale**.^{vii} Around **2.5 GW of EGS is under development** for power generation, almost entirely in the USA.^v **Financing for EGS jumped from \$22 million in 2018 to \$2.2 billion in 2025**.^{vi}

The IEA estimate electricity generation **costs from early commercial units to be around \$230/MWh, but rapid learning by doing** through cumulative deployment **could bring down costs to \$50-120/MWh in 2035** – comparable to current conventional geothermal - **and \$30-70/MWh by 2050**, depending on the rate of innovation and knowledge transfer from the oil and gas industry.ⁱ

At the lower end of these estimates, and when adjusting for the value of dispatchability, the IEA estimate that **EGS would be competitive with hydropower, nuclear and solar and wind**, both standalone and paired with battery storage, **by 2035** – in at least the USA, Europe and China. This could lead to **investment of up to €2.5 trillion by 2050, and generation sufficient to cover 15% of global electricity demand growth over this time** – equivalent to current electricity demand of the USA and India combined.ⁱ

Actual costs may be nearly a decade ahead of this projection. For example, reported construction costs for Fervo's 100 MW plant due for commissioning by the end of 2026 implies electricity generation costs around the top end of the IEA's 2035 range,² and Ember estimates that **43GW could be built in the EU today, at below €100/MWh**.^{viii} – capable of satisfying >10% of EU power demand.

Tailwinds are combining to open the opportunity space....

Beyond driving low-emissions power and heat generation and supporting energy sovereignty, EGS has three key tailwinds:

Data centres are driving near-term demand

Data centres require large volumes of firm power and currently face grid interconnection queues of several years in the US and many markets. One study concludes that behind-the-meter **EGS could, using optimistic assumptions, cost-effectively meet two-thirds of expected US hyperscaler demand growth by the early 2030s, and up to 100% in 13 of the 15 largest US markets**.^{ix} Virtually all near-term EGS offtake deals are with hyperscalers.^x

Different forms of flexibility are needed to balance variable renewables

Like conventional geothermal, EGS's ability to provide load-following generation makes it **highly complementary to electricity systems with growing variable renewables**. However, **EGS is also able to provide long-duration energy storage** by acting as a thermal battery. Fluid can be pumped into the reservoir and at periods of low electricity demand to let pressure and heat build, which can be stored for several days and released to generate power when power demand and prices are high. Operating EGS flexibly as a load-following thermal battery rather than baseload may significantly increase project returns, system value, and deployment potential.^{xi}

² Fervo reports construction costs of around \$7,000/kW ([McCarthy, 2026](#)); about the low cost-reduction trajectory estimate for 2030 by the [IEA \(2026\)](#).

Policy support in the USA is firm and bipartisan

Geothermal retained Inflation Reduction Act (IRA) era tax credits that were cut for solar and wind projects under the 2025 'One Big Beautiful Bill Act' and is explicitly cited as **contributing to the current administration's 'energy dominance' agenda**. The administration is also seeking to **streamline Federal permitting** for geothermal.^{xii}

State-level policy is a key driver, led by California and Nevada – states with among the highest EGS potential.^{xiii} California requires procurement of multiple gigawatts of "clean, firm" resources and long-duration storage by 2035, including geothermal. Nevada's 'clean transition tariff' altered regulatory obligations to allow large offtakers to procure electricity from a relatively expensive, emerging technology, which facilitated an offtake agreement between Fervo and Google.^{xiv} Combined with Federal support, California, Nevada and other Western states now offer a combination of subsurface data, clear permitting, targeted incentives, transmission access and R&D support that makes the region the most commercially attractive for EGS deployment.^{xiii}

In the longer-term, EGS may also be used to expand lithium extraction by creating artificial brines, with lithium leached from surrounding rock. However, lithium concentrations would be lower than natural brines, and no lithium production projects have been clearly announced.

...but headwinds and contingencies remain

Aside from easing fundamental siting constraints, EGS remains subject to the general challenges faced by conventional geothermal projects, and **four broad headwinds**:

Site needs for geothermal projects and demand-side infrastructure may differ

While EGS significantly eases geographic constraints, they don't disappear. Emerging EGS technologies still require sufficient heat within 1-3km depth to be economically (and in some cases, technically) viable.^{xv} In the USA, the best sites sit in the Western States, while data centres have tended to concentrate in areas with dense fibre optic infrastructure, such as in Northern Virginia.^{xvi}

Many hyperscalers also value 'speed to power', which the relatively long lead times for geothermal can't deliver. Together, these factors **may challenge the near-term scale of behind-the-meter geothermal for data centres** as a deployment driver.

As an early commercial technology, execution risks remain significant

Deep drilling can be complex and geologically uncertain. As drilling typically accounts for more than half of all project capex,ⁱ this can introduce significant cost and schedule risks. This also **challenges cost reduction potential**, expected to be driven by declining

drilling costs.ⁱ **Engineering artificial reservoirs**, including creation and maintaining flow and pressure also **remains technically challenging, with induced seismicity risk.**^{xvii}

Policy frameworks remain difficult to navigate

In the US, efforts to streamline permitting remain stuck in Congress, meaning that geothermal projects on Federal land can be subject to several different Federal reviews. **In many states and regions, developers must also navigate a stack of state, local and sometimes tribal approvals that may collectively take several years.**^{xii} **In the EU**, geothermal is promoted through renewables targets and mechanisms, but **projects are stymied by incentive and regulatory patchworks, complex, lengthy and highly fragmented permitting** (including different legality of hydraulic fracturing, for any purpose or geothermal energy specifically), **and limited access to subsurface data.**^{xviii}

Public opposition may curtail opportunities in some regions

Public support for both conventional and enhanced geothermal energy **in the US is generally high** despite limited familiarity,^{xix} **although local resistance can be strong** due to concerns around water supply and quality, induced seismicity and in some cases, impacts on tribal cultures.^{xx} **In Europe, opposition is more generalised.** Although familiarity with geothermal is also low, risk perceptions associated with fracking for the same reasons are more prominent,^{xxi} and may impact EGS development.^{xxii}

Future systems: Advanced Geothermal

How does it work?

Advanced geothermal systems (AGS) fall into two categories, which may be applied together. The first are **'closed-loop' systems**, which pump fluid in closed circuits acting as underground heat exchangers: the fluid is heated by hot rocks before returning to the surface – avoiding hydrothermal reservoir use or creation. The second are **'superhot rock' systems**, which use advanced techniques to drill deeper to reach hotter resources. These systems use or produce 'supercritical' fluids – i.e. water at temperatures higher than 374°C that exists in neither ordinary liquid nor gaseous form (Figure 7).

Closed-loop systems are also beginning to enter niche commercial application, with the first system coming online in Germany in December 2025.^{xxiii} Other demonstration projects are scattered around the world, and a few other small-scale commercial projects have been announced.^v **Superhot rock systems are not yet commercial** and remain limited to research and demonstration sites.ⁱ

Even broader potential than Enhanced Geothermal....

- **Superhot systems could almost eliminate geographic constraints...** Techniques and materials for deeper drilling open resources several kilometres deep, where significant resources are available almost anywhere (Figure 6).

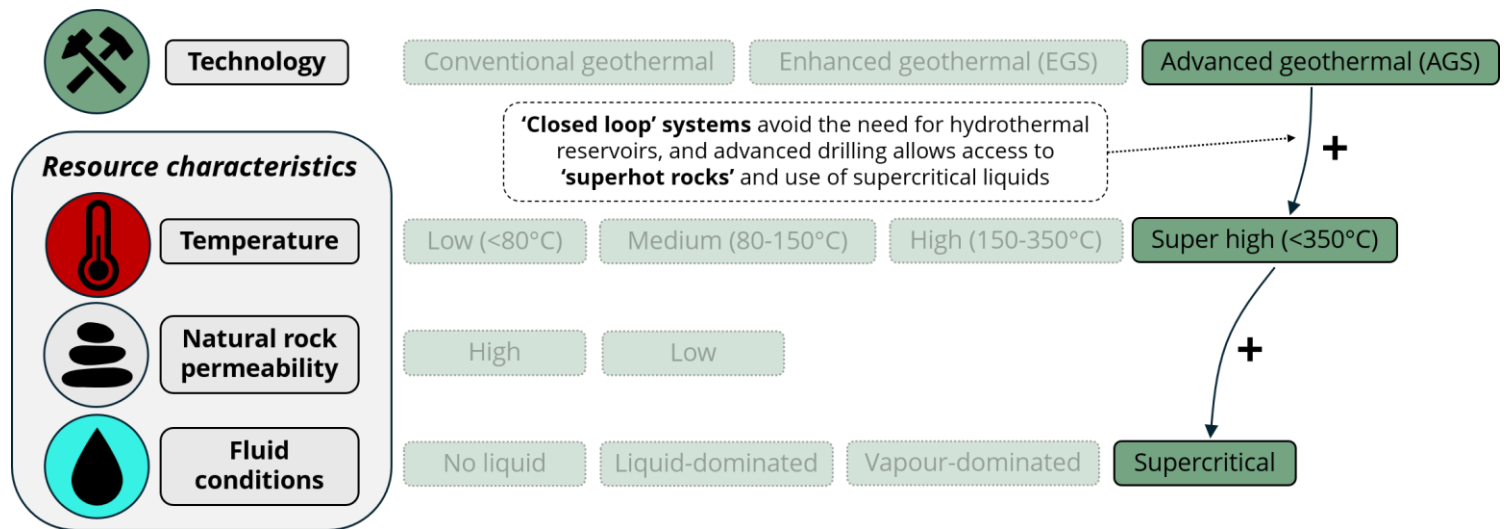


Figure 7 - Geothermal resources unlocked by different technology categories. Created by Greenwheel.

- **...and potentially deliver higher energy output with lower costs.** Higher temperatures allow higher energy output per well, reducing levelised cost through reduced capex per unit capacity.^{xxiv}
- **Closed-loops systems have fewer drilling-related risks.** Exploration risks are reduced and, by avoiding the creation or expansion of hydrothermal reservoirs, seismicity risks are removed.^{xxv}

...but uncertainties are more significant

- **Closed-loop systems require more drilling, higher capital expenditure and have uncertain performance.** Each well extracts less heat, meaning more drilling to achieve meaningful capacity, increasing capital intensity. Evidence suggests that closed-loop systems can struggle to maintain high and stable performance, with their behaviour not yet well understood.^{xxvi}
- **Superhot systems have very significant technical and cost risk and uncertainty, and maintain seismicity risk.** Drilling to and operating at extreme temperatures requires specialist materials and techniques that are only partially developed and demonstrated.^{xxvii}

Company Profiles



Michel Sznajer

Portfolio Manager,
Redwheel Next Generation
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"Below we present two companies with significant geothermal operations we have invested in – Ormat and Fervo. We also hold exposure through Constellation, which owns Calpine (the second-largest US geothermal power company). We find geothermal an exciting investment opportunity as it combines innovation, strong appeal for clients and pricing power. Despite being a currently niche segment in power generation, it has the potential to multiply manifold, yet with what we view as an oligopolistic competitive environment."

Ormat is a global leader in utility-scale geothermal power generation and equipment. It is the only vertically integrated designer, builder, owner and operator of geothermal plants in the world. The company derives over three-quarters of its revenues from geothermal activities, with the remainder coming from solar generation and batteries – offering multiple legs of growth and value creation.³

Ormat has a two-pronged approach for its geothermal business. On the one hand, Ormat continues to grow its conventional geothermal business with 50 sites under exploration and development in 6 countries.³ The business benefits from growing appetite for baseload carbon-free power and rising power purchase agreement (PPA) prices. On the other hand, the company is investing in EGS in 3 ways:⁴

- 1) a partnership with Schlumberger, the global leader in oil services with a long experience in hydraulic fracturing
- 2) an investment in Sage Geosystems, a Pressure Geothermal start-up
- 3) the development of surface equipment adapted to larger project sizes, notably the Ormega100, the largest binary unit available on the market with 100MW of output.

Fervo is an emerging company but a leader in EGS, with the first plant on track for completion by the end of 2026 and an agreement with Google to develop up to 3GW of capacity by 2033.⁵ The commissioning of the company's first plant and, if successful, its planned expansion in subsequent years could unleash an acceleration in interest and further contracts.

³ Ormat Earnings Presentation Q42025.

⁴ Ormat Earnings Presentation Q12026.

⁵ [Fervo Q12026 Results Release](#).

Endnotes

- ⁱ [IEA \(2024\)](#)
- ⁱⁱ [Morris \(2026\)](#)
- ⁱⁱⁱ [Muller et al \(2025\)](#)
- ^{iv} [Ember \(2026\)](#)
- ^v [Global Energy Monitor \(2026\)](#)
- ^{vi} [IEA \(2026\)](#)
- ^{vii} [Lipton et al \(2025\)](#)
- ^{viii} [Mindekova & Geneletti \(2026\)](#)
- ^{ix} [King et al \(2025\)](#)
- ^x [Garcia \(2026\)](#)
- ^{xi} [Ricks et al \(2025\)](#)
- ^{xii} [US DOE \(2026\)](#)
- ^{xiii} [Garth & West \(2026\)](#)
- ^{xiv} [Wu et al \(2024\)](#)
- ^{xv} [Aljubran & Horne \(2024\)](#)
- ^{xvi} [Allan \(2025\)](#)
- ^{xvii} [Boretti \(2025\)](#)
- ^{xviii} [European Commission \(2026\)](#)
- ^{xix} [Kaufman \(2025\)](#)
- ^{xx} [Rabe \(2026\)](#)
- ^{xxi} [Cox \(2023\)](#)
- ^{xxii} [Kassem & Moscariello \(2026\)](#)
- ^{xxiii} [Eavor \(2026\)](#)
- ^{xxiv} [Cladouhos \(2024\)](#)
- ^{xxv} [Liedekerke et al \(2026\)](#)
- ^{xxvi} [Zargartalebi et al \(2025\)](#)
- ^{xxvii} [Pearce & Pink \(2025\)](#)

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