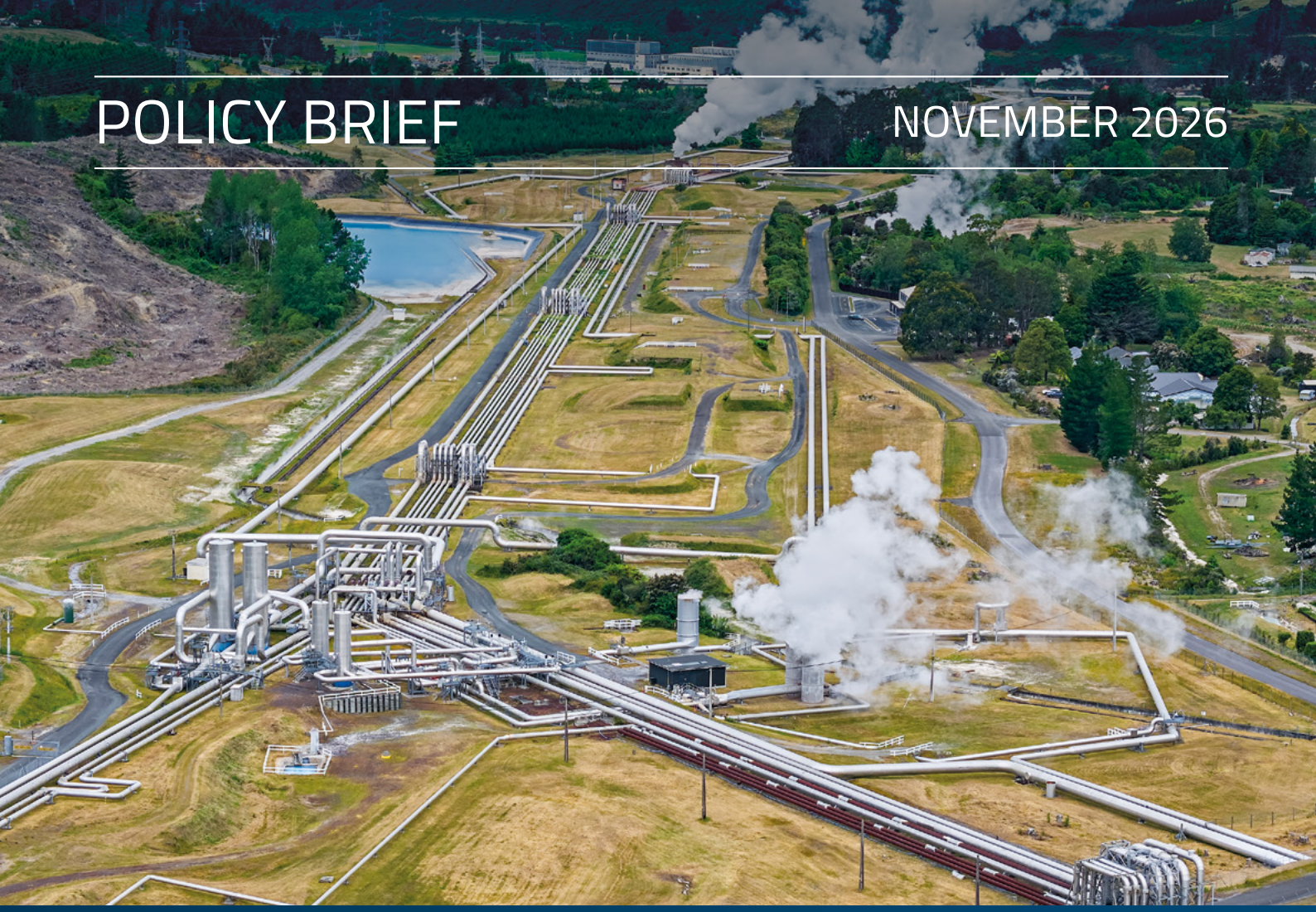
POLICY BRIEF

NOVEMBER 2026



Powering and Heating Europe: The Case for Next-Generation Geothermal

EU Policy Brief
by Future Cleantech Architects

FCA Future Cleantech Architects

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Executive Summary

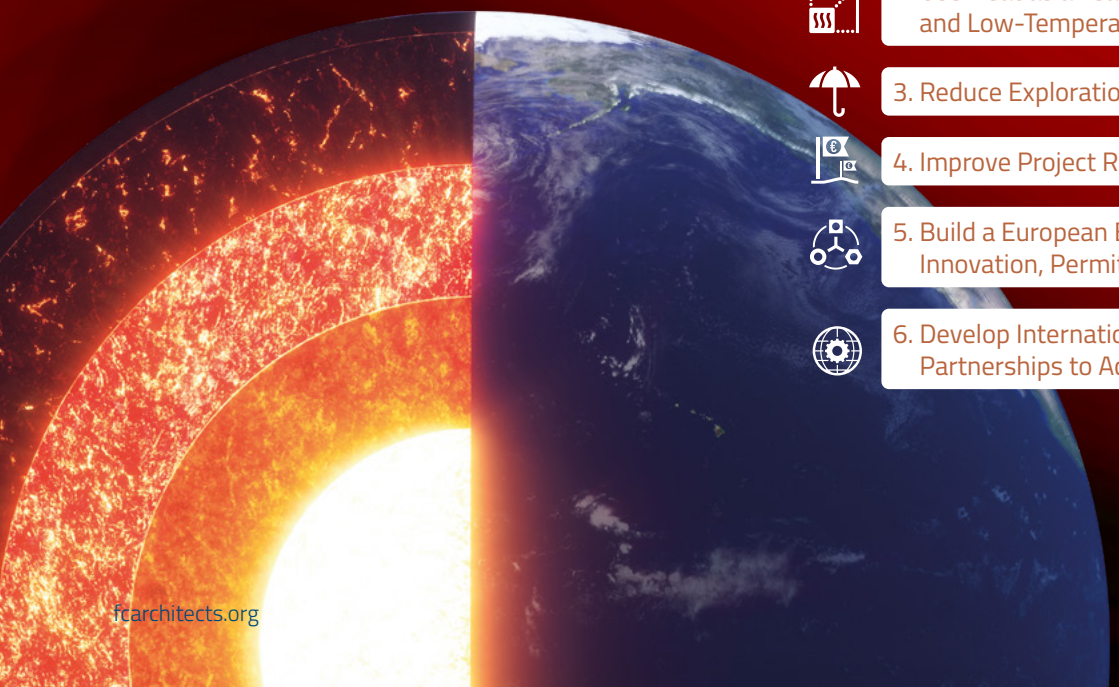
Geothermal energy is entering a new era. For more than a century, conventional geothermal has been limited to the relatively rare regions where heat, underground water, and permeable rock naturally occur together. As a result, outside of those locations, it contributes virtually nothing to the world's energy supply. Next-generation technologies, notably Enhanced Geothermal Systems (EGS), closed-loop geothermal and, further ahead, superhot-rock resources which would increase the economic and geological potential, are beginning to relax these geological constraints thanks to improved engineering techniques, thus expanding the potential resource. Geothermal can deliver much-needed round-the-clock clean energy in multiple ways, whether as a source of heat or power, cooling and seasonal storage, enhancing Europe's energy security and supporting the decarbonization of its economy. These approaches are at different stages of maturity, and their commercial prospects vary. Together, they offer a potential source of domestic heat and, where temperatures and project economics allow, clean firm electricity.

The scale of the opportunity is significant, with some estimates that Europe has up to 40 TW of technical potential for EGS power generation within 8 km of depth; this is equivalent to around 35 times Europe's current total installed electricity capacity. The central question for Europe is therefore not whether the geothermal resource exists. It is whether the technologies, supply chains, business models, and financial instruments needed to access it can be developed at a competitive cost. The policy objective should be to use public intervention to move geothermal projects from geological potential to commercial certainty, identifying projects with credible economics, reducing the cost and risk of accessing the subsurface, and generating enough deployment and operational evidence to determine where next-generation geothermal can compete.

Recommendations

To unlock the potential of next-generation geothermal in Europe, this policy brief sets out the following recommendations:

1. Create Markets and Recognize the Value of Next-Generation Geothermal for the Energy System
2. Use Heat as a Learning Market for District Heating and Low-Temperature Industrial Heat Below 200 °C
3. Reduce Exploration Risk and the Cost of Drilling
4. Improve Project Revenue Certainty
5. Build a European Ecosystem: Innovation, Permitting, Deployment
6. Develop International Geothermal Innovation Partnerships to Accelerate Learning



Why Next-Generation Geothermal Matters for Europe's Energy Transition

The rationale for developing this resource is not to replace solar and wind, which are likely to be the backbone of Europe's low-cost electricity system. Rather, geothermal can complement variable renewables by providing clean firm power, i.e. a low-carbon, domestic, and dispatchable backbone to help achieve a reliable, increasingly carbon-free power grid. The value of that contribution will depend on location and system needs. It is part of a wider portfolio of solutions to manage intermittency on short and long timescales, which becomes more and more important as the penetration of variable renewables increases: demand response, storage (battery and others), stronger grids for geographic smoothing, and dispatchable generation from firm low-carbon resources. Geothermal can contribute to this portfolio because its output is not dependent on weather conditions. Its system value is therefore reliability and predictability, and even a certain degree of flexibility, in addition to its contribution to energy security as a home-grown source.

Geothermal can also supply heat directly to industrial sites and district heating networks. Where the temperature, depth, geology and distance to demand are suitable, direct use avoids the conversion losses and power generation equipment required to turn heat into electricity. It can also reduce the need for additional electricity network capacity compared with some electrified alternatives, although the comparison is site-specific. Lower-temperature resources may serve buildings and a range of industrial processes; deeper and hotter resources may support electricity generation or higher-temperature heat but generally require greater upfront investment. Geothermal heat beats geothermal power both in terms of efficiency (~10-20% for the latter compared to 90% for the former) and capital expenditure (CAPEX) (dispensing with power generation equipment). While geothermal heating is limited to low temperatures below 200°C, this range covers district heating and many industrial processes, and thus already represents a substantial fraction of Europe's total energy demand.

This policy brief draws on Future Cleantech Architects (FCA)'s own previous standpoint on geothermal for heating, as well as a round of structured interviews conducted with private sector experts, from investors to technology developers (see acknowledgment section below). The interviews provide practical insight into project risks and market barriers, but are not an exhaustive survey of the sector. The brief is intended to equip the European Union (EU) and its member states with an up-to-date, evidence-based view of where next-generation geothermal stands today, what is actually holding it back in Europe, and which policy levers would work best to unlock it. It covers both direct heat and electricity generation, since the two markets share the same subsurface data, drilling capabilities and early-stage risk. Even if their economics and routes to market differ, they share the same cost drivers, and, therefore, many of the same policy solutions.

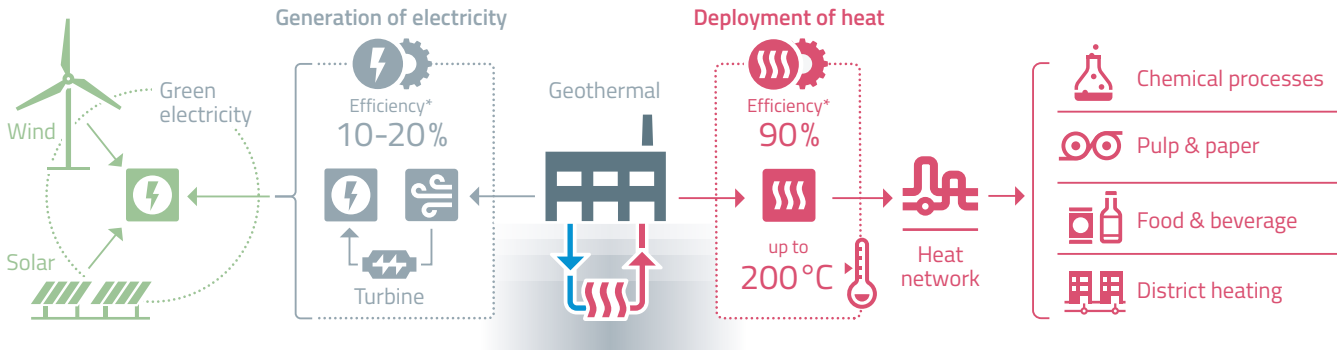


Figure 1: Geothermal's current efficiency for electricity generation and heat deployment. | * Depending on temperature

From Conventional to Next-Generation Geothermal

Geothermal plants extract heat naturally present underground. Temperature rises with depth, on average by around 30°C per kilometer, though this varies by location. The temperature of the heat directly determines its energy content, the possible direct heating applications, as well as the efficiency for converting it to electricity. In some places, the hot rocks are closer to the surface than in others, but geothermal energy is in principle available everywhere, if one drills deep enough. Therefore, the deeper and hotter a well is, the more valuable the tapped resource becomes, and the project economics improve accordingly. Higher temperature resources can provide more valuable applications, including electricity generation and high-temperature industrial heat. The tradeoff lies in the higher upfront cost of deeper wells.

Historically, geothermal power and heat have been concentrated in a small number of geologically favorable regions, such as Iceland and parts of Italy. Next-generation geothermal (EGS and closed-loop systems) overcomes this geographic constraint by artificially creating a reservoir to extract heat from dry rock, unlocking significantly more viable regions for geothermal exploitation. In addition to this, next-generation geothermal technologies are steadily progressing to ever deeper and faster (and therefore cheaper) drilling.

Conventional Geothermal

Conventional geothermal, more specifically known as hydrothermal, is a mature technology that started in the early 20th century in Italy. It requires three conditions: elevated ground temperatures at a depth reachable by conventional drilling; the presence of water in the ground as a heat transfer medium; and sufficiently permeable rock so water can flow through the reservoir to pick up the heat. This specific set of geological conditions is limited to only a few areas globally, such as Kenya, Indonesia, or Iceland, where 30% of electricity is produced by geothermal. However, these conditions are rare and unlikely to scale[1] to meet a noticeable fraction of global energy demand, despite being a commercially mature technology. In 2024, the new geothermal capacity added worldwide was equivalent to less than a single utility-scale gas power plant.

[1] To FCA's knowledge, only one startup, Zanskar Geothermal, is challenging this view, believing that the potential for conventional geothermal in the US has been underestimated by a factor of 10-100 (from possible sites as well as the power potential of those sites). Their AI-driven geoscience and field and drilling methods have been successful so far in repowering sites that were previously deemed tapped out. Whether this thesis applies to Europe is less clear.

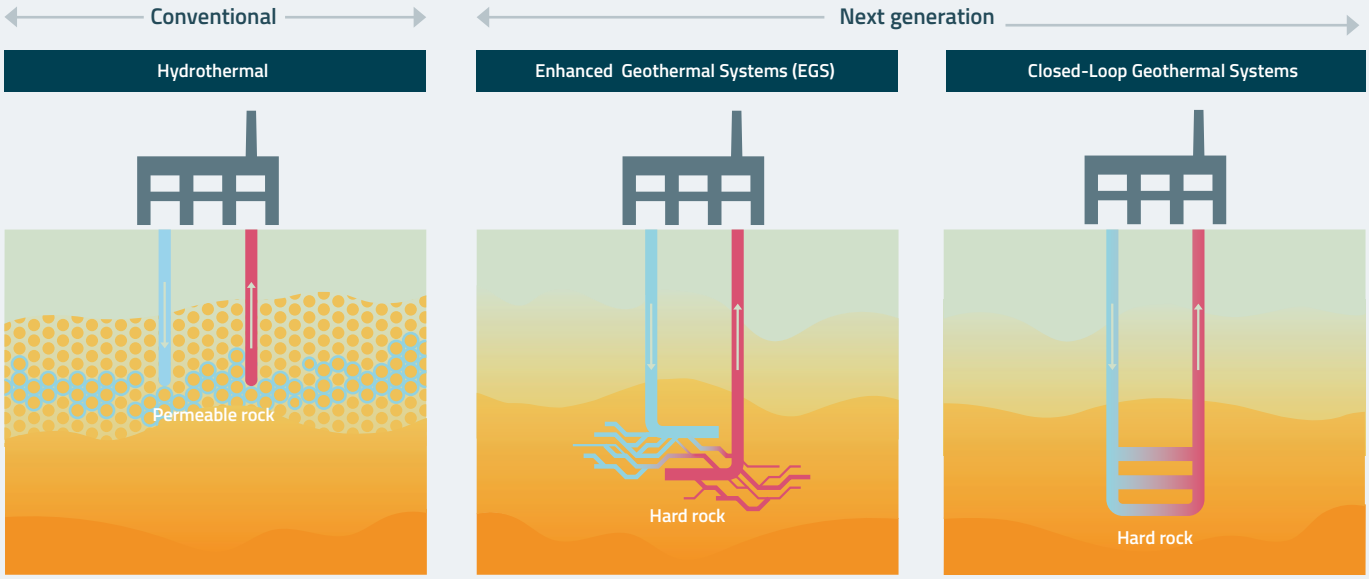


Figure 2: The different types of geothermal systems

Enhanced Geothermal Systems (EGS)

Next-generation geothermal technologies seek to overcome these limitations by artificially creating the conditions for geothermal energy generation, such that only the prerequisite of heat remains. This drastically unlocks and expands the resource potential globally: the International Energy Agency (IEA) estimates that the global technical potential of EGS below a levelized cost of electricity (LCOE) of 300 USD/MWh (an arguably high threshold) exceeds that of conventional geothermal by a factor of 2,000. This is equivalent to 140 times current global annual electricity demand.

EGS borrows from the extensive experience of the shale oil and gas industry in the United States with horizontal drilling – steering the well sideways through the rock layer – and hydraulic fracturing which injects high-pressure fluid to artificially create cracks in the rock. Water can then be injected into one well and circulated through the cracks in the hot rocks, picking up thermal energy via heat transfer, until it reaches an extraction well that returns it to the power plant at the surface, ready to generate electricity[2]. The main benefit of hydraulic fracturing is that these cracks provide a large surface area for the water to efficiently and cost-effectively pick up the heat present in the rock. In contrast to the shale industry, however, EGS requires fewer additives[3] to fracture rocks and the industry has developed protocols specifically to mitigate the risk of induced seismicity, following experience from the US Department of Energy. By borrowing from the shale industry, EGS has progressed very quickly and leading projects have reached commercial demonstration, with the first offtake agreements signed in 2024-2025 and first power generation on the grid in Q4 2026. The existence of a workforce trained in these techniques, as well as a supply chain for the equipment involved, is a significant boost. The US Department of Energy is also a strong (bipartisan) supporter, with an Enhanced Geothermal Shot initiative that aims to reduce the cost of EGS by 90% to 45 USD/MWh by 2035, and $99 million for 21 projects were just announced in September 2026.

Closed-Loop Geothermal

In contrast to EGS, closed-loop systems do not involve any fracturing, which allays residual concerns on seismicity and water use. Instead, a series of hermetic pipes are drilled, through which fluid circulates to pick up heat without ever leaving the pipe (hence the name). The absence of fracturing also reduces any potential seismicity concerns from local communities and stakeholders. However, closed-loop systems do require more drilling than EGS to construct the subsurface piping system with enough surface area to pick up heat between the injection and production wells. Accordingly, they are likely to cost more than EGS. In terms of maturity, they are also being commercially demonstrated, for example in the United States with XGS Energy and in Europe with Green Therma and with Eavor's first-of-a-kind commercial-scale plant in Bavaria, Germany.

Superhot Rock as the Future Frontier

Above 374°C and 220 bar of pressure, water becomes a so-called supercritical fluid, a particular thermodynamic state that can absorb much more heat per kilogram of water. With such an increased energy density, a geothermal plant can produce much more power with the same flow rate of water. As a result, if drilling technologies can go deep enough to reach these conditions, then a "superhot" well could produce 5-10 times more electricity than a typical one operating at slightly lower temperature or pressure. Conventional drilling technologies and materials are not yet suitable for the extreme physical conditions found at these depths, nor cost-effective, since drilling cost tends to increase exponentially with depth for conventional technologies. New research and startups are emerging to address this, such as high-pulsed-power drilling, thermal-shock drilling, millimeter-wave drilling, laser drilling, percussive drilling, high-pressure water jet drilling, directional steel-shot drilling, plasma drilling, and electric impulse drilling. However, these technologies are less mature, so the long-term pursuit of this "holy grail" of geothermal must not distract from more immediately achievable gains at less ambitious depths, where these technologies can also play an important role in any case.

[2] The water is then re-injected and the loop begins anew, so there is very little wastewater produced by this process.

[3] These additives adjust the fracking fluid's properties and effectiveness, for example, guar gum is added as a thickener, while sand acts as a so-called proppant, preventing the closing of newly generated cracks.

One Resource, Multiple Markets

The geothermal resource can serve both heat and electricity markets. This matters because different applications can be developed at different depths and temperatures, while sharing the same cost drivers and equipment. While site selection is the first step that determines costs, since the geothermal gradient varies geographically, beyond that, the economics of geothermal are dominated by CAPEX (around 75%[4] of LCOE), which is heavily influenced by drilling cost, itself depending in large part on drilling speed. Encouragingly, the learning rates of next-generation geothermal have been high so far.

Heating: The Near-Term Opportunity for Europe

District heating and low- and medium-temperature industrial heat offer some of the most immediate opportunities for geothermal deployment in Europe. These applications generally require shallower depths than electricity generation, resulting in lower costs and therefore a lower barrier to commercial entry. Industrial processes and district heating networks can also provide relatively steady demand. However, the opportunity is geographically specific: Temperature, drilling depth, heat demand, network distance and the cost of competing heat sources determine whether a project is viable. Further advantages compound this: Using the heat directly avoids both the efficiency losses and extra capital costs associated with otherwise converting the heat into electricity, strengthening the commercial viability; industrial applications also typically run at a constant, 24/7 load, which is well-suited to the baseload profile of geothermal. As a result, next-generation geothermal could reach a levelized cost of heat (LCOH) of 20-70 €/MWh$_{th}$[5] in the 2030s, where it would be competitive with Europe's high cost of natural gas.

Europe should use these relatively lower-risk applications as a learning market: Deployment can build drilling capacity, develop supply chains, improve resource characterization, generate operational data, and provide experience that can progressively reduce the cost and risk of deeper geothermal projects in a self-sustaining fashion. Nevertheless, this does not mean that geothermal should be confined to heat, but rather that the early heat market can help create the industrial capabilities needed to unlock further opportunities for expansion into electricity markets. This is one of geothermal's distinctive characteristics: It is not an all-or-nothing technology requiring a single breakthrough before deployment can begin. It is a continuous innovation pathway, in which progressively better drilling, reservoir engineering, and project development can open increasingly valuable applications.

Ground-Source Heat Pumps

Info box

Ground-source heat pumps (GSHP), sometimes also called geothermal heat pumps, operate at shallow depths (up to around 100-200 m) to extract very low-temperature heat from the ground, which is then boosted to a more useful higher temperature using electricity in a heat pump. While ground-source heat pumps are usually considered a form of geothermal energy, the need for topping up electrically excludes them from the present brief, which focuses purely on the extraction and direct use of deeper, hotter geothermal heat.

Nevertheless, ground-source heat pumps could deliver substantial benefits to European power grids in a context of widespread electrification of building heating. Because GSHPs leverage more stable ground temperatures year-round compared to air-source heat pumps (ASHP) which are subjected to ambient temperatures, the efficiency (known as "coefficient of performance", COP) of a GSHP would be around 4.6 on a 0°C October day compared to 2.8 for the ASHP. In other words, the required electrical load on the grid would be around 40% lower with the GSHP. This difference is especially notable in winter, since the efficiency of air-source heat pumps is lowest precisely when heating demand is highest. When scaled up to country-wide deployment levels of heat pumps, the difference between ground-source and air-source has profound implications for electricity demand and particularly peak loads, which define the size and therefore cost of the grid.



Due to their higher upfront cost compared to air-source heat pumps, ground-source heat pumps currently represent a minor share of the market. Increasing this can be done through technical improvements (e.g. more standardized, modular, compact, faster, and cheaper drilling from startups such as Dandelion Energy, Bedrock Energy, Dig Energy, and Borobotics), economies of scale (e.g. mass manufacturing of appliances, labor costs falling as installation time decreases with experience), and innovative business models (e.g. leasing programs, shared ground arrays and heat networks).

[4] Calculated using data from the United States National Laboratory of the Rockies.

[5] The original values are expressed in 2024 USD and so have been converted here.

Electricity Generation: The Mid-Term Opportunity for Europe

Electricity generation requires higher-temperature resources and therefore generally deeper, more expensive wells. The technical potential for EGS in Europe[6] below a cost of 260 €/MWh[7] is 3,000 GW between 3-5 km and 20,000 GW between 5-7 km of depth; by comparison, Europe's average power demand over the year is closer to 300 GW. For prices more in line with coal- and gas-fired power generation, the potential is 43 GW below 100 €/MWh and an extra 100 GW at 100-200 €/MWh.

The economics of each project depend on the site's temperature, depth, drilling costs, reservoir performance, financing conditions, permitting, and the value received for the electricity produced. The progression from heat to power should not be construed as a prescriptive and rigid sequence. These markets will develop in parallel and reinforce each other.

Co-Benefits and Additional Revenue Streams for Geothermal Technologies

A geothermal project can potentially generate additional value in addition to direct heat and electricity, through services and products such as thermal storage for cooling data centers or lithium production. These opportunities are site-specific and depend on resource chemistry, technology performance, market prices, and additional processing costs. Six geothermal areas across Italy, Germany, France, and the United



Kingdom have high lithium concentrations in their geothermal brines; the Upper Rhine Valley between France and Germany has the potential to produce 4-6 kt/year of lithium by 2030, enough to make 1.2 million electric vehicle (EV) battery packs.

These additional revenues should not be treated as a substitute for sound geothermal economics. However, they can improve the sector's prospects by providing further value and revenue streams.

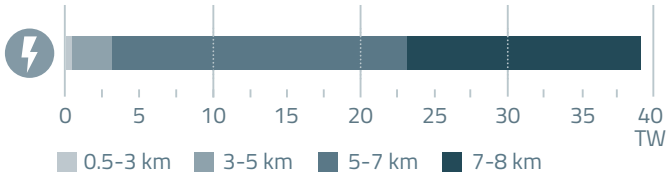


Figure 3: Total technical potential in TW for EGS electricity capacity by depth in Europe. Source: Project InnerSpace in IEA report on geothermal 2024.

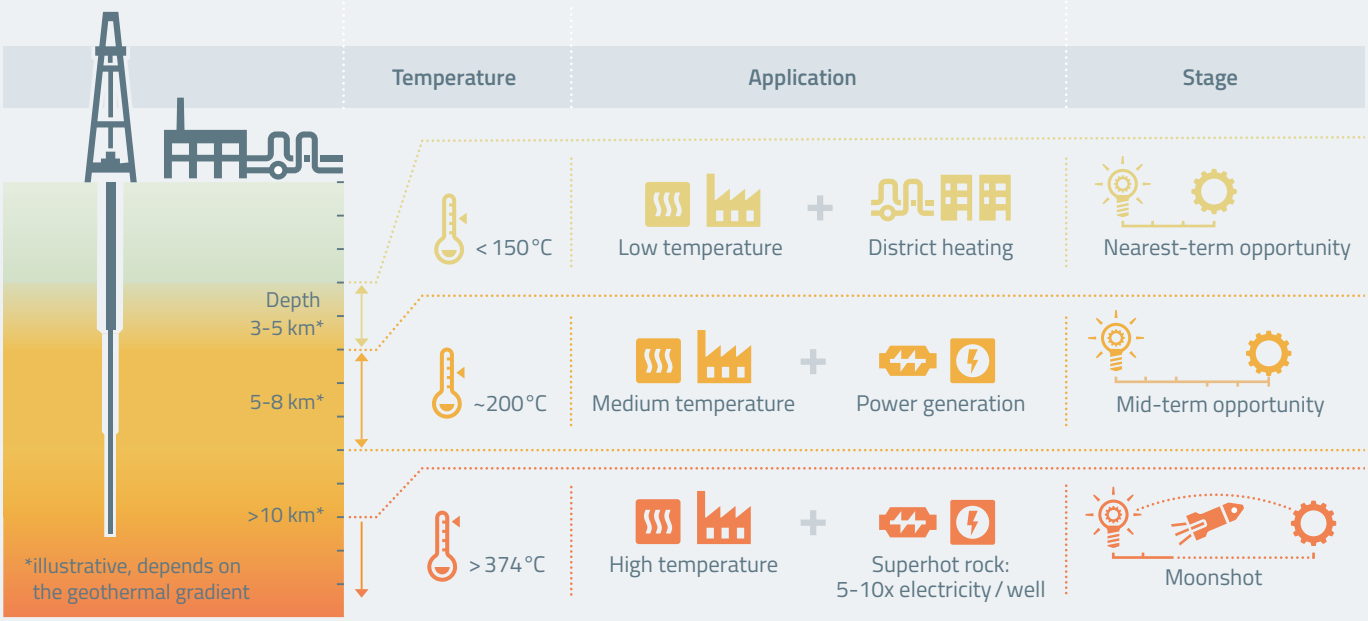


Figure 4: Geothermal's potential: Depth and temperature ranges, possible applications, and stages.

[6] Top markets in Europe include Germany, France, Italy, Spain, Hungary, and Romania.

[7] The original value is 300 USD/MWh and has been converted.

A Strong European Potential

As seen in Figure 3, at less than 3 km, the potential is very limited. It starts to become significant at 5 km, and from 7 km onwards, the physical potential is almost everywhere, although the economics will still differ depending on the quality of the resource. The potential is particularly high in France, Germany, Italy, and the Pannonian Basin in southeastern Europe, almost everywhere, as can be seen in Figure 5, although Europe's current installed base remains small relative to this potential. Geothermal power capacity is concentrated in Türkiye, Italy, and Iceland, representing a mere 2-3% of total generation for the first two. Most of the rest of Europe has negligible installed capacity today, around 1 GWe total. The policy challenge is therefore to improve the economics of the marginal project, rather than simply to maximize the number of identified geothermal resources.

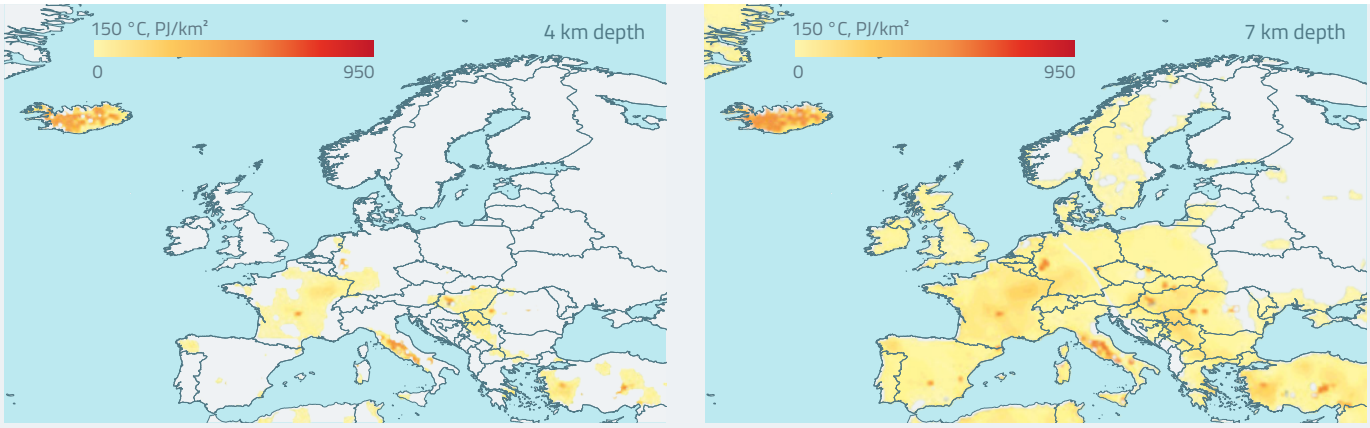


Figure 5: Map of geothermal potential for electricity generation with EGS, at 4 km and 7 km depths respectively. Source: Project InnerSpace in IEA report on geothermal 2024.

FCA's tracking of national energy and climate plans (NECPs) also shows an uneven but growing landscape for innovative renewables such as next-generation geothermal: Several Member States (including Italy and Slovenia) are actively planning for deployment, while others remain at an early or exploratory stage, and virtually none have yet developed a clear policy framework for ultra-deep geothermal. Austria, Croatia, France, Hungary, Ireland and Poland have developed national geothermal roadmaps setting out measures to support subsurface investment, demonstration projects, and the development of domestic supply chains, with some countries also providing dedicated funding and setting deployment targets.

Finally, encouragingly, public opinion polls across Europe have found geothermal energy to be the least politically polarized technology across political parties, a notably different pattern from nuclear and gas. This opens up an opportunity to create policy and societal support for this technology. Public acceptance will depend not only on general attitudes toward geothermal, but also on how individual projects manage local concerns, including induced seismicity, water use, noise and transparency. Early engagement and credible monitoring should be part of project development, not an afterthought once permits are sought.

Drilling Dominates the Cost Structure and the Risk

Drilling is the central cost driver[8], which depends heavily on the geology at the digging site. According to the companies FCA interviewed, drilling time can account for around 75% of well cost depending on the site. Every stakeholder interviewed identified drilling, not the surface plant, nor the resource itself, as the primary cost driver and the primary source of project risk. Costs rise steeply, and in a non-linear fashion, with depth and temperature because of longer drilling times, higher-specification equipment, and greater downtime from harder or more abrasive rock. Better drilling technologies, such as progress in current polycrystalline diamond compact drill bits and non-contact technologies in the near future, can yield substantial cost reductions.

Finally, what matters most is not so much today's costs, but rather future costs, which depend on the particular learning rates of the technology (i.e. how much cheaper it gets over time the more you build it). Recent data from EGS is promising in this respect and shows learning curves of 35% for drilling time.

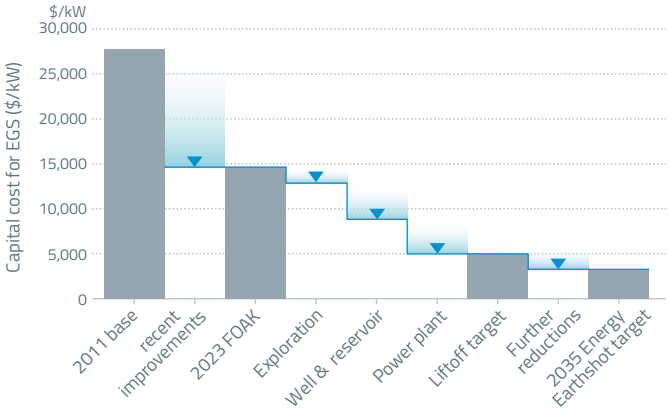


Figure 6: Capital cost reduction waterfall for enhanced geothermal systems. Source: US Department of Energy's 2024 Liftoff report.

The most effective geothermal policy is unlikely to be a policy that subsidizes the final megawatt-hour. The policy opportunity is to support innovation and deployment that generate measurable reductions in drilling time, cost, and failure rates, and address the barriers that keep promising projects from reaching the point where performance can be demonstrated: incomplete subsurface information, expensive early wells, limited drilling capacity, and uncertain routes to market.

[8] As drilling costs fall over time, the balance will shift towards also lowering the cost of the surface power plant.

Geological Uncertainty Creates a Financing Valley of Death

Before the first well is drilled, developers may have incomplete information about temperature, permeability, geological structure, reservoir productivity, drilling conditions, and long-term well performance. Developers may therefore need to spend significant amounts of money acquiring or reconstructing information that could potentially be treated as public geological infrastructure. This information gap creates an early-stage financing problem: since the highest-risk expenditure occurs before the project can generate revenue, private commercial lenders and institutional investors are least willing to provide capital precisely when the project needs it most. The result is a financing valley of death.

Public policy can address this market failure. Better public data can reduce duplication, improve project screening, and lower exploration risk. The appropriate objective is to share or insure risks that private markets cannot efficiently absorb, allowing projects to reach the stage where conventional private finance becomes available once uncertainty has been reduced.

Europe's Disadvantage Compared to the United States is Not Primarily Geological

Interviewees consistently drew a sharp contrast between Europe and North America. Permitting timelines are the most frequently cited barrier: Obtaining a drilling permit can take years in most of Europe, with the process often handled by mining authorities with limited geothermal-specific expertise and sometimes treated by default and out of caution as equivalent to oil-and-gas fracking. By comparison, timelines can be as short as 3-4 weeks in parts of the United States such as Texas, even though these vary significantly from one state to another. Germany's Geothermal Acceleration Act (*Geothermie-Beschleunigungsgesetz*) is a big step in the right direction.

A second gap is the overall capacity: Interviewees estimated the US has on the order of a thousand or more drilling rigs[9], compared to roughly 100 in Europe, so the learning curve is less steep for Europe and the cost of renting a rig in the first place is twice as high. Nevertheless, skills transfer from oil and gas engineers is repeatedly cited as one of the fastest ways to build a European geothermal workforce.

According to the EU's Joint Research Centre report on geothermal, the EU is underrepresented in drilling services, but has a strong manufacturing base for above- and below-ground equipment.

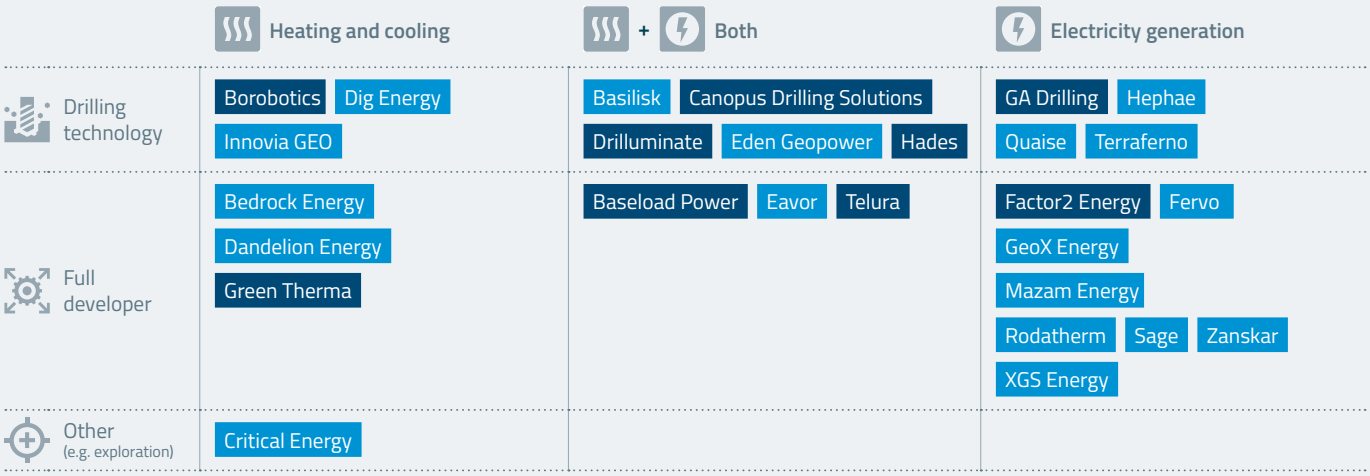


Figure 7: Non-exhaustive mapping by FCA of geothermal startups in Europe / North America

Regulation Can Become an Unnecessary Barrier

Induced seismicity is a particular perceived challenge for EGS, even though fracking for geothermal is very different from oil and gas fracking. The issue is regulatory fragmentation across EU countries and how geothermal is regulated through frameworks designed for other activities, particularly oil and gas fracking. The policy window is important because EGS remains relatively small. Europe can establish risk-based rules before the sector reaches significant scale.

Experience differs across countries, with various approaches to permitting (decentralized to cantons in Switzerland for example) and seismicity (e.g. the Netherlands). Inspiration from the US Department of Energy's protocol could be very useful for Europe to mitigate potential incidents. The objective should therefore be appropriate regulation of actual geothermal risks, not automatic application of rules designed for fossil-fuel extraction.

Business Models Are Converging on Long-Term, Stable Offtake

Across both heat and power, interviewees pointed to power purchase agreements (PPAs) and Contracts for Difference as very important instruments for making geothermal projects financeable, as the vast majority of project cost takes place upfront in drilling while operating costs and price risk over a 30+ year asset lifetime are comparatively low. More wells also create more experience, which improves productivity and lowers costs, which makes more projects financeable. Costs are high because the sector has little deployment experience, but deployment remains limited because costs are high; long-term offtake contracts can help break this cycle and make geothermal projects financeable by giving lenders confidence in future revenue. For electricity, 24/7 clean power PPAs can provide the revenue certainty required to finance capital-intensive projects.

[9] EGS and horizontal wellpads for closed-loop require special types of rigs for fracking that Europe does not have. Also, access to the tubular supply chain is essential and Europe's lack of upstream oil and gas makes this a challenge too.

Potential early offtakers that are less price-sensitive and less risk-averse than average could be data centers, technology companies, industrial sites, utilities, and large corporate consumers with strong creditworthiness. This is already happening in the US, where leading geothermal startups have secured their first contracts (e.g. Meta will buy 150 MW from Sage Geosystems, Google will buy 115 MW from Fervo) and should be emulated in Europe. For heat, long-term heat purchase agreements and heat-as-a-service models could play a similar role, particularly where customers are reluctant or unable to finance drilling themselves. They can be relevant for district heating operators and industrial consumers replacing fossil fuel boilers for instance.

Over the medium to long term, the more we build geothermal, the better our understanding of the challenges and how to overcome them will be, and the deeper we will be able to go, unlocking new resources. The technology can gradually improve and expand its market reach. Some models estimate that even a small number of commercial and industrial customers (order of magnitude[10] 3%) procuring clean firm power sources can kickstart the virtuous cycle of making these technologies more affordable and accessible.



Policy Recommendations to Decrease Project Costs and Accelerate the Learning Curve

FCA sees six actions to scale next-generation geothermal and address market and policy failures that currently prevent a potentially valuable clean technology from reaching commercial scale: the lack of recognition of clean firm power, geological risk, the cost of drilling, weak market signals, and Europe's fragmented innovation ecosystem. Therefore, the three connected priorities are: reducing the cost and risk of accessing the subsurface, creating markets that generate learning and provide credible revenue, and building the regulatory and industrial ecosystem needed to deploy projects at scale.

The EU has already adopted a target in the Renewable Energy Directive (REDIII) for 5% of innovative renewables by 2030 and Future Cleantech Architects estimates that this could result in 3-45 GW[11] of deployment of various new technologies. Next-generation geothermal fits this goal particularly well and should be encouraged accordingly within the context of this target.

1. Create Markets and Recognize the Value of Next-Generation Geothermal for the Energy System

The EU's energy framework increasingly recognizes the need for flexibility, yet system planning insufficiently factors clean firm power in the mix, i.e. clean generation capable of providing reliable and predictable generation with high capacity factors, complementing variable renewables when these are unavailable for extended periods. Geothermal competes poorly if it is assessed only through the lens of current LCOE versus more mature wind and solar. Its value proposition is different: predictable generation, high utilization, direct heat provision, and combined heat and power.

The EU and member states should:

- Recognize clean firm power technologies, including next-generation geothermal, in the post-2030 energy framework (REDIV).
- Extend the REDIII innovative renewable technologies target into the post-2030 framework with clear implementation measures and reporting on actual deployment.
- Allow eligible geothermal projects to participate in capacity mechanisms where they can demonstrate that they provide the relevant service and integrate next-generation geothermal explicitly into member states' long-term capacity planning and national energy and climate plans (NECPs).
- Assess technologies and geothermal projects according to their actual contribution to reliability, emission reduction, and system value.

2. Use Heat as a Learning Market for District Heating and Low-Temperature Industrial Heat Below 200 °C

District heating and low-temperature industrial heat offer the nearest-term, strongest business case for geothermal in Europe, given the large addressable market (700 TWh/year of industrial heat demand below 200 °C) and the lower upfront cost compared to hotter, deeper power generation wells. These projects can provide an earlier commercial opportunity than deep electricity projects and help develop critical capabilities for the overall sector, from drilling and subsurface characterization to project development and financing. Our recent report with Project InnerSpace preliminarily scores and maps which industrial clusters could run on geothermal heat by analyzing factors such as subsurface conditions, aquifer stress, seismicity, and heating demand. Medium-temperature industrial heat above 200 °C[12] represents the next tier of opportunity as drilling reaches greater depths.

[10] By their own admission, the Riepen et al. model is more of a back-of-the-envelope calculation to give insight into the magnitude of the dynamics at play; it is not supposed to be a detailed model offering precise numbers.

[11] Extrapolating from various assumptions on the growth rates of new renewable capacity, from +5%/year in the pessimistic case (the lowest growth rates of wind and solar from 2013 to 2022), to +11%/year in the base case (the historical global average from 2015 to 2022), and +25%/year in the optimistic case (maximum growth rate from solar in the EU, in 2022).

[12] Note that it is unlikely that geothermal will ever provide more than 500 °C for even the most favorable conditions.

The EU and member states should:

- Develop standardized heat purchase agreements (HPA) for municipalities and industrial consumers and encourage business models such as heat-as-a-service (HaaS), in which a geothermal developer finances, owns and operates the geothermal system while the customer pays a fixed price per unit of delivered heat with zero CAPEX burden. This can help overcome the upfront CAPEX barrier faced by industrial consumers and it allocates project risk to the most appropriate stakeholders.
- In addition to the 2025 and 2026 output-based auctions for renewable heat, which should advertise geothermal eligibility more vocally to attract more proposals, create specific grant calls for next-generation geothermal under the Innovation Fund as it is difficult to compete only on the basis of €/tCO_2 cost of abatement with heat pumps and e-boilers.
- Target industrial heat clusters and suitable industrial sites to aggregate and concentrate demand in order to share and reduce project development costs.

3. Reduce Exploration Risk and the Cost of Drilling

The largest risks in next-generation geothermal are concentrated at the beginning of the project, before the project generates revenue: Developers have to spend substantial amounts of capital exploring and drilling before knowing definitively whether the resource will perform as expected. Public intervention should therefore focus on early-stage risk.

The EU and member states should:

- Rapidly establish a centralized, open-access European geothermal subsurface database as was announced in the AccelerateEU Communication, with high-quality public data characterizing geothermal resources across Europe (e.g. geological maps of temperature, depth, seismicity, and other subsurface characteristics). This should build on existing EU geological data initiatives and ensure data collected with public support becomes publicly available after appropriate confidentiality periods.
- Establish or expand exploration insurance and guarantee schemes covering a proportion of the risk of unsuccessful or underperforming first wells, drawing on national experience including Germany recently.
- Encourage national promotional banks and the European Investment Bank (EIB) to provide risk-sharing instruments for early exploration and even provide partial coverage against unsuccessful or underperforming exploration wells. Geothermal is a CAPEX-heavy technology, so the cost of financing has a major impact on the LCOE. An EU facility to national, regional, or local banks should target the gap before the resource performance is proven.



4. Improve Project Revenue Certainty

Early projects need a credible route to revenue as well as lower exploration risk. Long-term contracts and appropriate market arrangements can help. Policy should also ensure that, when appropriate, markets can remunerate the services geothermal provides. Potential early offtakers include industrial consumers, utilities, data centers and large corporate customers willing to pay for reliable clean energy, whether electricity or heat.

The EU and member states should:

- Facilitate long-term power purchase agreements (PPAs) for geothermal power and heat plants, at least on non-flexible parts, and encourage business models like heat-as-a-service, decoupling infrastructure ownership and financing from energy use by customers under long-term contracts to address upfront investment barriers.
- Aggregate projects into portfolios to attract financing, by diversifying risks that are spread across various projects (some geothermal wells will perform better than expected, some worse, and some exploration wells may be unsuccessful).
- Take advantage of co-benefits: Geothermal can deliver heat as well as power, storage, and cooling for homes and industry. It also has the potential to co-extract valuable resources like lithium from geothermal brines.

5. Build a European Ecosystem: Innovation, Permitting, Deployment

The scale-up of geothermal ultimately depends on bringing down drilling costs and building the industrial capabilities to deploy wells at scale. Europe has a strong industrial base, but the current drilling ecosystem is too small to generate the learning rates required for rapid cost reduction. Policy should therefore support both technology innovation and deployment at scale.

The EU and member states should:

- Invest in research and development (R&D) into faster and deeper drilling technologies, which can have a powerful effect on project cost, and create regulatory sandboxes where appropriate for testing those novel geothermal technologies. This is also where Europe's industrial policy can become strategic.
- Use European innovation programs to support technologies moving from demonstration towards commercial deployment, and include innovators in the Geothermal Stakeholder Partnership announced in the Electrification Action Plan.
- Make permitting more predictable and standardized, reducing fragmentation both within member states (one-stop-shop) and across member states. Identify acceleration areas for next-generation geothermal where prior data and environmental assessments help to get faster decisions.
- Set proportionate risk-based rules for geothermal stimulation and induced seismicity. Require baseline studies, clear monitoring, public communication, mitigation plans and seismicity protocols for EGS projects involving hydraulic stimulation, based on the actual risk profile of geothermal projects. Clear risk-mitigation protocols for induced seismicity, particularly in jurisdictions with prior sensitivities, can ensure public acceptance and foster community engagement.
- Incentivize workforce and technology conversion from the oil and gas industry, given that a majority of geothermal technology investment overlaps with existing oil and gas drilling, evaluation, and surface expertise, and that Europe's oil and gas services sector still has a strong manufacturing base, workflows, capital and trained labor. Several of the world's largest oil and gas companies are European. This will help repurpose relevant industrial capabilities towards a growing cleantech market.

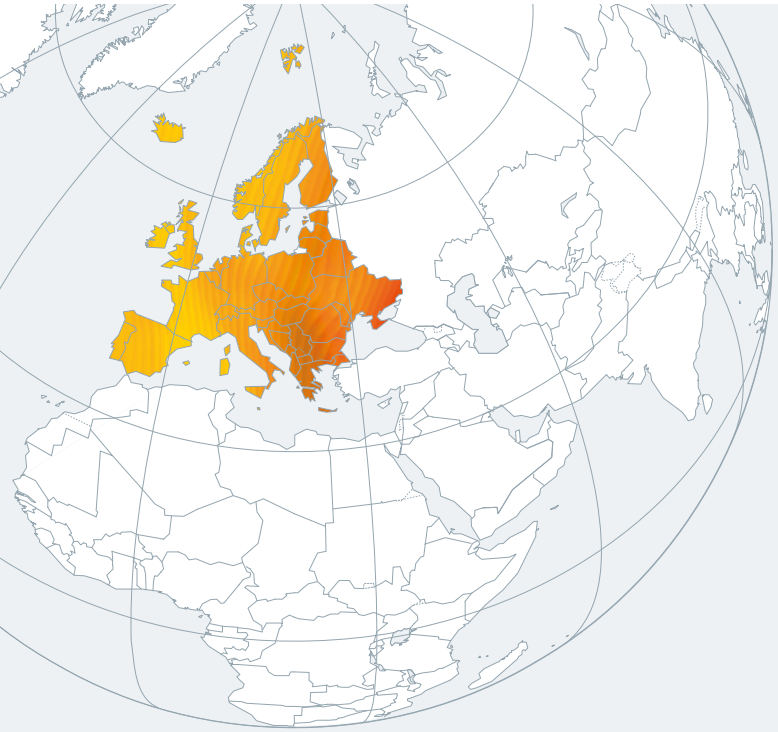
6. Develop International Geothermal Innovation Partnerships to Accelerate Learning

Geothermal is a technology with global potential. Not only does this increase the spillover impact for emissions reductions, it also represents an economic opportunity. The EU should strengthen its cooperation with countries at the forefront of next-generation geothermal. This would help scale up and accelerate learning on all key components of the sector, including drilling, subsurface characterization and reservoir engineering, as well as surface plant equipment. Geothermal is particularly well suited to international cooperation, as much of the learning is transferable across geologies.

The EU and member states should:

- Use EU international energy dialogues and partnerships, and Global Gateway as announced in AccelerateEU, to establish a dedicated geothermal cooperation track with leading and partner countries such as the United States, Japan, Iceland, Türkiye, and Kenya.
- Support joint R&D and demonstration projects, technical expertise exchanges, drilling know-how, risk mitigation protocols, and facilitate partnerships around first-of-a-kind projects and deployment.
- Help European startups access demonstration opportunities and different geologies outside Europe, allowing them to test technologies, build operational experience, and accelerate learning. At the same time, the EU should encourage foreign companies developing next-generation geothermal technologies to demonstrate and build plants in Europe, in partnership with European companies and research organizations. This can accelerate technology transfer and foster European know-how, industrial capacity, and supply chains, in line with the objectives of the Industrial Accelerator Act.





Conclusion

Geothermal offers Europe a homegrown, scalable, clean, reliable, and versatile energy source with a genuinely global technology-export opportunity, built substantially on capabilities and workforces that already exist in Europe's oil and gas services sector. Next-generation geothermal overcomes previous limitations and unlocks new resources at a meaningful scale. What stands between that unrealized technical potential and deployed capacity is a set of solvable barriers, mostly regulatory and financial: slow and fragmented permitting, an underdeveloped drilling supply chain, and a financing gap for the earliest, riskiest wells.

Now is the time when targeted and ambitious policy support could accelerate the sector's development to tangibly contribute to Europe's energy goals.

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About Future Cleantech Architects:
We are a climate innovation think tank. We exist to close the remaining innovation gaps to reach net-zero emissions by 2050. To reach this objective, we accelerate innovation in critical industries where sustainable solutions are still in very early stages.



FCA and Project InnerSpace joint report,
Unlocking Europe's Geothermal Industrial Heat Potential



FCA Standpoint
The Potential of Next-generation geothermal for heating in Europe

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