Briefing

Unlocking the energy below our surface: improving affordability and resilience in heat through ground source heat pumps

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Background

Europe's continued reliance on fossil fuels undermines the security, affordability, and sustainability of its energy system; the Commission's Action Plan for Affordable Energy points out that it increases price volatility and costs as well as vulnerability to external pressure and global market uncertainty. While the electricity sector has made significant progress in the transition to renewable energy, the decarbonisation of the heating sector remains relatively slow. Around 75% of European final heat consumption still comes from fossil fuels.

Ground source heat pumps (GSHP) powered by shallow geothermal energy offer a significant opportunity to accelerate the transition to fossil-free heating. They are secure because their operation is independent of global trade or short-term weather fluctuations; affordable because they are economically competitive in the long term; and sustainable because they generate minimal emissions and regional impacts. Yet, due to distrust and low recognition among consumers and policymakers, their contribution to the heating sector remains low.

This policy briefing explains how GSHP work, and outlines their current and potential use in Europe, as well as their key benefits. It also identifies the main challenges limiting their wider deployment and analyses how policy can support their wide and socially just use.

Functioning and use cases

Heat pumps function like fridges, transferring heat from one space to another. More specifically, they transfer environmental heat into buildings to heat them up, or extract heat from buildings to cool them down. They can provide several kWh of heat for each kWh of electricity they require. However, their efficiency considerably depends on the environmental conditions; the greater the temperature difference they must bridge, the more electricity they consume (Figueira et al, 2024).

Most heat pumps installed today use outside air as their heat source. As Figueira et al. (2024) point out, the seasonal temperatures work against the heat pumps in these configurations: in the summer, the pumps must cool using warm air, and in the winter, they must heat using cold air.

This is where shallow geothermic energy (SGE) comes in. SGE refers to heat extracted from (hydro-) geological formations of up to a few hundred meters depth. The formations maintain stable temperatures of typically up to 25°C, regardless of the season. Additionally, they transfer heat more effectively than air. So, they allow for more efficient heat pump systems (Menberg et al, 2025).

Importantly, SGE differs from deep geothermic energy (DGE), which comes from geothermic sources that are so hot that they allow for direct use of heat without heat pumps and for electricity generation. Accessing sufficiently hot geological formations normally requires drilling around 3,000 metres deep, which makes this method economically unviable in many cases (IEA, 2024). The highest installed capacities can be found in regions where heat is closer to the surface due to geological anomalies, such as Iceland, West Anatolia (Turkey), or Tuscany (Italy) (IPCC, 2011; Dulian, 2022).

A heat pump system that uses SGE is called a ground sourced heat pump (GSHP). It comprises a ground loop, which extracts heat from the ground, and a heat pump. Ground loops can be so-called closed-loop or open systems. Closed-loop systems are pipes through which water or a coolant flows to exchange heat with the ground. These systems can be installed both horizontally or vertically. Open systems consist of vertical tubes which extract and inject water from aquifers directly (Menberg et al., 2025).

In regions requiring both heating during winter and cooling during summer, GSHP are particularly effective. During winter, they consistently extract heat from the ground and during summer, they reject heat back into it. Therefore, their heating is based on formations that have been warmed up during summer, *vice versa* (Menberg et al., 2025). This principle has been applied in the Schiphol Airport in Amsterdam, for example, reducing the total gas consumption of the airport in 2022 by 90% (AMS Schiphol, n.d.).

GSHP systems are highly adaptable to specific environmental and urban requirements. They can be designed as standalone units for individual users, or as large-scale suppliers for district energy grids. A large-scale system, the Mijnwater project, which uses former coal mines as collective shallow geothermal sources for an entire city district, has been employed in Heerlen, Netherlands, for example. The heating network applied in this project makes use of the district's diverse thermal needs. Data centres require cooling and homes require heating. The grid connects these different demands to increase the overall efficiency (Mijnwater, n.d.).

As with the mines in the Mijnwater project, SGE can be integrated into existing subsurface infrastructure such as tunnels, building foundations, or sewage pipes, to share and decrease up-front construction costs. However, this approach is technically challenging (Figueira et al., 2024).

GSHP in Europe

Potential

GSHP work most effectively where the subsurface transports heat. Europe's groundwater basins, particularly those in the north and west, are generally excellent heat conductors. Therefore, Menberg et al. (2025) calculated a great overall potential for the continent. However, the authors stress that the real local potential is dependent on several factors that continent-wide assessments do not consider.

For example, there are often space constrains. Horizontal heat collectors require much space, and the installation of vertical collectors requires space for a drilling rig. In general, there must be sufficient distance between collectors so that one does not interfere with the other. Also, if too many neighbours use open systems, the groundwater level could sink (groundwater drawdown). This must be prevented to secure fresh water supply and prevent that the ground moves down. Moreover, heat must be produced close to the user, as it is costly to transport it. Therefore, good geological conditions are only useful when they are close to households or industry (Menberg et al., 2025).

To account for these limitations, it is useful to consider local studies. Despite the named limitations, these studies indicate a great potential for SGE-powered heat pumps. For example, it was found that between 44% and 93% of all residential building blocks in the German state Baden-Württemberg could be heated with GSHP, depending on their renovation status (Miocic & Krecher, 2022). Another study identified that GSHP could supply around 60% of western Switzerland's heating and cooling needs. If applied as district heating, lower space constrains and more efficiency would allow for a supply of almost 90% (Walch et al., 2022).

Development

According to reports presented at the 2022 European Geothermal Congress (Sanner et al., 2022), SGE is the dominant geothermal energy sector in Europe. It has an overall installed capacity of 44 GW in Europe (EGEC, 2025a), and a higher market share in the geothermic sector than DGE. Most operational GSHP units are in Sweden, followed by Germany, France, and Finland. Most newly installed systems in 2021 were by far in Germany, followed by Sweden, Finland, and Poland. Germany had an exceptionally high extension rate for a country with an established market. After Sanner et al. (2022), this is because of favourable market conditions and supportive policy measures.

Benefits of GSHP

Cost efficiency and adaptability

In 2021, the International Energy Agency (IEA) assessed the heating costs of several technologies, including gas and pellet boilers, as well as different solar thermal and heat pump systems, in several European countries and Canada. They calculated the levelized costs of heating (LCOH), meaning the overall investment and operational costs divided by the overall heat generation.

Even though GSHP requires high initial investment, the IEA calculated a lower LCOH than for all other technologies they considered. So, over the lifetime, GSHP is the cheapest option for heating (IEA, 2021). This is because, once installed, the ground loop can operate for 50 years or more, providing a base for energy-efficient heating with little electricity and no fuel consumption.

The introduction of the carbon price on heating via the ETS2 starting from 2028 will make fossil fuels more expensive. This will further increase competitiveness of technologies based on electricity, like GSHP. The German consumer organization (*Verbraucherzentrale*) calculated that a typical household gas boiler in a single home could accumulate up to €9,500 in carbon costs in its 20 years life time. Every increase in fossil fuel costs, and any decrease in electricity costs, increases the competitiveness of GSHP (Bäumer, 2025).

The systems are even more cost-effective when connected via energy grids. If several heat pumps are connected to one collector, or if one heat pump supplies multiple users, the investment costs can be shared and reduced through economies of scale. This could generate opportunities for a variety of business models and community-based approaches.

In addition to reducing costs, grid-based systems increase resilience by distributing individual demand variations across a large system. They also allow for effective supply in high-density areas where there is not sufficient space for individual systems (Figueira et al, 2024).

Geopolitical resilience and grid stabilization

Oil and gas are mostly imported from non-EU countries. Other than these energy carriers, SGE is independent from international trade and geo-political instabilities. GSHP also contribute to the stability of energy systems as the proportion of renewable energy sources increases. Since buildings retain heat for some time, it does not need to be generated constantly. Smart GSHP can be turned on when solar and wind plants are generating a lot of energy and turned off when they are not (Marijanovic et al., 2022; Smart Energy Europe & DNV, 2022). This flexibilization of the electricity use contributes to grid stability.

Environment and health

Using SGE generates little environmental impacts as it generates little greenhouse gas emissions and little local impacts. It allows for efficient electrification of the heating sector (Menberg et al., 2025) by replacing gas, oil, or wood fuelled boilers, thereby reducing the overall greenhouse gas emissions and air pollution caused by the heating sector.

Environmental risks

Temperature variations caused by SGE can alter physical, chemical, microbiological and ecological processes in the subsurface. However, in most cases, alterations in the subsurface remain minor at temperatures below 45°C, which are not reached by SGE. However, there are some impacts that can occur below 45°C that need to be considered in policy (Menberg et al., 2025):

- The balance between natural chemical reactions in the ground can slightly shift, increasing heavy metal concentration in sediment and groundwater.
- The water extraction and injection in open circles can lead to water losses, decreasing the groundwater level.
- Some microorganisms, particularly Amphipoda, can be impacted.

In comparison to fossil-fuel-based energy sources, these impacts are small. However, as they concern drinking-water availability and quality, regulation must be designed carefully to prevent damage.

Social and economic barriers

While SGE provides technological opportunities, there are considerable social and economic barriers to its implementation. The study of them is particularly relevant as they play a major role for both the feasibility and social justice of GSHP.

Upfront investments

While GSHP are economically beneficial on the long term, their high initial investment represents a major barrier. Vertical collectors, which require less space and can thus be installed more widely than horizontal ones, require particularly high investments. Many of the countries with the highest integration of geothermic energy have schemes to support the initial investment (e.g., Sweden, Germany, Switzerland, and Austria) (Aridi et al, 2025).

Social equity

Due to the high initial investment required, GSHP are often considered a luxury, particularly in single-family housing (Goetzl et al., 2018). The accessibility across different socio-economic groups remains a major concern (Aridi et al., 2025).

The French subsidy programme 'MaPrimeRénov' provides targeted support to low-income households by granting subsidies for heat pumps based on household income. For example, a household outside the Île-de-France region with two children and a taxable income of around €28,000 per year can receive a subsidy of €11,000 plus an additional bonus for energy savings. The combined subsidy thus amounts to a total of around €16,200, which covers the majority of the equipment investment of around €14,000 to €18,000 and, in some cases, part of the total installation costs (Defougères, n.d.).

In addition to targeted support programmes, focusing on collective systems with heating networks could also improve access for low-income households. These allow investment costs to be scaled and distributed across several households, thereby significantly reducing costs (Figueira et al., 2024).

On the EU level, there are several financing schemes for this. For example, the 2025-2026 work program of Horizon Europe (Cluster 5) includes specific calls for Underground Thermal Energy Storage (UTES) in dense urban areas, explicitly funding the integration of SGE into urban utilities, subways, and building foundations (European Commission, 2025a).

Another example is the LIFE program which includes calls dedicated to supporting district heating and cooling networks. This program requires projects to use at least 50% renewable energy; SGE is explicitly named as a key technology to meet this 'efficient district heating' criteria (European Commission, 2025b).

One example of national legislation that supports SGE is the German Heat Planning Act (*Wärmeplanungsgesetz*). This act requires municipalities with over 100,000 inhabitants to develop a heat plan by 2026. Heat plans will raise awareness of available opportunities and establish a framework for district heating networks.

Finally, communication emphasizing the long-term cost benefits of GSHP (IEA, 2021) could challenge the image of SGE as a luxury energy source and hence promote accessibility.

Acceptance and political awareness

In a case study in the Netherlands, Liu et al. (2025) found that social influence and people's personal evaluation of GSHP were more important factors in their intention to use them than their financial ability to do so. Public acceptance is hence a key factor in the adoption of GSE systems. Limited knowledge among decision-makers and the public decreases acceptance despite the associated health, environmental, and local economic benefits (Aridi et al., 2025; Liu et al, 2025). Early stakeholder engagement and transparent communication can positively influence acceptance (Reith et al., 2013).

A broader awareness of GSHP is also relevant because coordinated approaches require complex planning and decision-making. Many stakeholders reported problems relating to the low consideration of technology in policymaking. For instance, building renovation strategies often overlook SGE (Figueira et al., 2024).

Furthermore, regulations governing temperature fluctuations in the soil caused by SGE are inconsistent. In Germany, for example, these regulations are stricter than in other European countries and exceed the recommendations of ecotoxicological studies. In other countries, on the other hand, there are no regulations at all, which could compromise ecological integrity and the quality of drinking water (Mehnberg et al., 2025).

Conclusion: learnings for political action

- GSHP are often the most cost-effective heating and cooling option and has a minimal environmental impact. However, the technology is not widely known, there are too few planners and installers, and there is a general lack of trust. Political communication should emphasize the potential environmental, economic, and health benefits of GSHP to allow for a wider recognition. This may also lead to a more positive overall reception of the heat transition.
- Due to high upfront investment costs, the use of shallow geothermic energy requires financial support. However, considering the investment and operational costs over the entire lifetime, GSHP provide cheaper heat than other renewable and fossil alternatives, meaning that the investment pays back. Therefore, supporting mechanisms can be designed, especially for wealthy households, to support the investment but not cover the entire costs. This could for example be done via interest-free loans, as implemented in EU countries like Germany, Spain, or Italy (REGEOCITIES, n.d.). Direct subsidies without repayment obligations, on the other hand, should be targeted specifically at low-income households.
- As of today, GSHP are primarily used as individual systems in single-family homes. Adopting district heating grids could allow for their use in neighbourhoods that are too dense for individual systems, and decrease system costs. Collective approaches are therefore important for a wide use of GSHP. They provide tenants and lower-income households with access to low-cost technology and the necessary economic support, which is important for social justice. However, constructing district heating grid systems requires complex organization between several sectors and stakeholders, calling for supportive policy frameworks. Due to the significant social potential of collective heating approaches, the impact of existing programs and legislation must be closely monitored and extended.
- Existing regulations on SGE vary strongly from country to country and often do not align with the most recent scientific findings. Science-based, EU-wide standardized regulations could increase the security of SGE, build trust, and accelerate planning and implementation.
- After a press release by EGEC (2025b) the European Commission plans to release a European Geothermal Strategy and Action Plan in 2026. Among other things, the trade association asked that the proposal include an EU-wide target of 250 GW of geothermal capacity by 2040, targeted financial instruments to leverage private capital, more efficient permissions processes, and easier access to market and geological data (EGEC, 2025a).

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References

- AMS Schiphol. (n.d.). Thermal energy storage at the airport. https://www.schiphol.nl/en/sustainability/at-the-airport/sustainable-climate-control-at-the-airport/
- Aridi, M., Maalouf, E., Yehya, A., & Aridi, R. (2025). Sustainability challenges and opportunities of shallow borehole geothermal systems. *Renewable and Sustainable Energy Reviews, 224*, Article 116102. https://doi.org/10.1016/j.rser.2025.116102
- Bäumer, A. (2025, November 19). *Heat pumps: Phases of transition differ strongly among countries in Europe*. Heinrich-Böll-Stiftung. https://eu.boell.org/en/2025/11/19/heat-pumps-phases-transition-differ-strongly-among-countries-europe
- Defougères, C. (n.d.). *Les aides pour une pompe à chaleur géothermique en 2026*. Quelle Énergie. Retreived January 16, 2026, from https://www.quelleenergie.fr/economies-energie/pompe-chaleur-geothermique/aides-subventions
- Dulian, M. (2023, October 26). *Geothermal energy in the EU* (EPRS briefing No. 754566). European Parliamentary Research Service. https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/754566/EPRS_BRI(2023)754566_EN.pdf
- European Commission. (2025a, April 28). *Underground Thermal Energy Storage in dense urban areas* [Web page]. CORDIS. Retrieved February 10, 2026, from https://cordis.europa.eu/programme/id/HORIZON_HORIZON-CL5-2026-02-D3-22
- European Commission. (2025b, July 17). *Supporting district heating and cooling networks* [Web page]. CINEA. Retrieved February 10, 2026, from https://cinea.ec.europa.eu/funding-opportunities/calls-proposals/supporting-district-heating-and-cooling-networks_en
- European Geothermal Energy Council. (2025a, December 5). *The European geothermal strategy and action plan: Making Europe competitive, secure and affordable.* https://www.egec.org/policy-documents/european-geothermal-strategy-and-action-plan/
- European Geothermal Energy Council. (2025b, March 17). *Dan Jørgensen, Commissioner for Energy and Housing, confirms the Geothermal Action Plan will be*

published in Q1 2026. https://www.egec.org/media-publications/dan-jorgensen-commissioner-for-energy-and-housing-confirms-the-geothermal-action-plan-will-be-published-in-q1-2026/

- Eurostat. (2025, March 5). *EU renewable energy for heating and cooling reaches 26%*. https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20250305-1
- Figueira, J. S., Gil, A. G., Vieira, A., Michopoulos, A. K., Boon, D. P., Loveridge, F., Cecinato, F., Götzl, G., Epting, J., Zosseder, K., Bloemendal, M., Woods, M., Christodoulides, P., Vardon, P. J., Borg, S. P., Poulsen, S. E., & Andersen, T. R. (2024). Shallow geothermal energy systems for district heating and cooling networks: Review and technological progression through case studies. *Renewable Energy*, 236, 121436. https://doi.org/10.1016/j.renene.2024.121436
- Goetzl, G., Heiermann, M., Kłonowski, M., & the GeoPLASMA-CE Team. (2018). *Joint report on the user demands and barriers for the implementation of shallow geothermal methods in energy planning strategies* (Deliverable D.T4.1.2). Interreg Central Europe.
- International Energy Agency. (2024). *The Future of Geothermal Energy*. https://www.iea.org/reports/the-future-of-geothermal-energy.
- International Energy Agency. (2021, November 29). *Levelized cost of heating (LCOH) for consumers for selected space and water heating technologies and countries*. https://www.iea.org/data-and-statistics/charts/levelized-cost-of-heating-lcoh-for-consumers-for-selected-space-and-water-heating-technologies-and-countries
- Intergovernmental Panel on Climate Change. (2011). *IPCC special report on renewable energy sources and climate change mitigation* (O. Edenhofer et al., Eds.). Cambridge University Press.
- Liu, Z., Qian, Q. K., Li, B., Jin, C., & Visscher, H. (2025). Dutch householders' intentions to adopt shallow geothermal systems for energy transition of existing buildings: A theory of planned behavior approach. *Energy and Buildings, 347*, Article 116386. https://doi.org/10.1016/j.enbuild.2025.116386
- Marijanovic, Z., Theile, P., & Czock, B. H. (2022). Value of short-term heating system flexibility–A case study for residential heat pumps on the German intraday market. *Energy*, *249*, 123664. https://doi.org/10.1016/j.energy.2022.123664
- Menberg, K., Hemmerle, H., Bayer, P., Bott, C., Bidarmaghz, A., Ferguson, G., Bloemendal, M., & Blum, P. (2025). Opportunities, benefits and impacts of shallow geothermal energy. *Nature Reviews Earth & Environment*, *6*(12), 808–823. https://doi.org/10.1038/s43017-025-00736-0
- Miocic, J. M., & Krecher, M. (2022). Estimation of shallow geothermal potential to meet building heating demand on a regional scale. *Renewable Energy, 185*, 629-640. https://doi.org/10.1016/j.renene.2021.12.095
- Mijnwater. (n.d.). *Warmte en koude* [Web Page]. Retrieved January 23, 2026, from https://mijnwater.com/warmte-koude/

- REGEOCITIES. (n.d.). *Financing shallow geothermal projects: Factsheets on geothermal heat pumps*. Retrieved January 23, 2026, from http://ubeg.de/Regeocities/Factsheet-Financing.pdf
- Reith, S., Kölbel, T., Schlagermann, P., Pellizzone, A., & Allansdottir, A. (2013). *Public acceptance of geothermal electricity production* (GEOELEC Deliverable No. 4.4).
- Sanner, B., Antics, M., Baresi, M., Urchueguía, J. F., & Dumas, P. (2022, October 17–21). European geothermal summary 2022 [Conference paper]. *Proceedings of the European Geothermal Congress 2022*, Berlin, Germany. https://geothermie-schweiz.ch/wp_live/wp-content/uploads/2022/12/00-EUROPEAN-SUMMARY-EGC-2022-country-updates.pdf
- Smart Energy Europe, & DNV. (2022). *Demand-side flexibility in the EU: Quantification of benefits in 2030*.
- Walch, A., Li, X., Chambers, J., Mohajeri, N., Yilmaz, S., Patel, M., & Scartezzini, J. L. (2022). Shallow geothermal energy potential for heating and cooling of buildings with regeneration under climate change scenarios. Energy, 244, Article 123086. https://doi.org/10.1016/j.energy.2021.123086