BRIEFING

European Parliament

Geothermal energy in the EU

SUMMARY

Geothermal energy is heat generated within the Earth's crust. It is used mainly for electricity generation, district heating and industrial processes. Several geothermal technologies exist, at different levels of maturity. Heat is usually extracted from the ground using heat pumps to power district heating systems, or used directly to heat builidngs. Electricity generation uses the heat stored underground, converting it to electrical power. The three main technologies for electricity generation are dry steam, flash steam and binary cycle.

According to the International Renewable Energy Agency (IRENA), geothermal energy provides electricity generation in more than 30 countries worldwide, reaching a total installed capacity of around 16 gigawatts (GW) in 2021. In the EU, the gross capacity for electricty was just over 1 gigawatts electric (GWe) that year. EU electricity production amounted to 6 717 gigawatts thermal (GWth), with Italy responsible for most of it. Several other EU countries produce electricity from geothermal (Germany, Portugal, France, Croatia, Hungary and Austria), albeit with considerably smaller production. The geothermal district heating and cooling sector has seen a 6 % growth rate in installed capacity, reaching 2.2 GWth in 2021. Geothermal represented 0.5 % of the global renewable electricity market in 2022, generating 0.2 % of electricity in the EU.

Geothermal energy is a sustainable and reliable source that produces minimal greenhouse gas emissions while providing constant baseload energy generation. The challenges for large-scale geothermal energy capacity include high upfront development costs, long project development timelines and higher risk during the early phases of exploration. Another significant obstacle to the development of geothermal is the fragmented nature of statistics on geothermal energy and insufficient geothermal resource mapping.

The EU's commitment to the geothermal sector is deeply rooted in the European Green Deal. Draft national energy climate plans show that EU Member States have promising ideas for geothermal. The development of geothermal is also set to be supported by the recently revised Renewable Energy and Energy Efficiency Directives. Moreover, the European Commission's announced heat pump action plan has the potential to encourage the use of small and large geothermal heat pumps in buildings, heating and cooling systems, and industry.

IN THIS BRIEFING

EPRS | European Parliamentary Research Service

Author: Monika Dulian
Members' Research Service

PE 754.566 – October 2023

EN

Introduction

Geothermal energy is heat generated within the Earth's crust as a result of the planet's formation and the radioactive decay of materials. Thermal energy is stored in rocks and fluids in the centre of the Earth. Drilled wells connect the geothermal resource with the surface in order to use the energy contained in the fluid. Geothermal energy can be a source of electricity generation; it can provide direct heat for multiple uses such as district heating, water heating, industrial processes, greenhouse food production and fish breeding. In addition, the term relates to the use of energy extracted from the Earth's constant temperatures at shallow depth (usually up to 500 metres) by means of ground-source heat pumps. In terms of geothermal gradients, the resources are divided into shallow geothermal, middle deep geothermal and deep geothermal. This determines the temperature available, as on average it increases by about 25 °C for every kilometre of depth. In the context of the European Green Deal and the EU's ambition to phase out fossil fuels by scaling up the roll-out of renewables, home-grown geothermal energy can play a greater role in meeting the EU's energy needs for both electricity and heating and cooling.

Geothermal use and technologies

Several geothermal technologies exist, with different levels of maturity. Temperatures between 40 °C and 150 °C are ideal for district heating. For electricity generation, medium- to high-temperature resources are needed.

Table 1 – Simplified scheme of geothermal resources, application and technology

Temperature	Fluid type	Application	Technology
High (> 150 °C)	Water, vapour	Electricity generation Direct heat use	Dry steam, flash plants Heat exchanger
Medium (90-150 °C)	Water	Electricity generation Direct heat use	Binary cycle Heat exchanger, heat pump
Low (< 90 °C)	Water	Direct heat use	Heat exchanger, heat pump, direct heat use

Source: I. Nardini, 'Geothermal Power Generation', *The Palgrave Handbook of International Energy Economics*, 2022.

District heating

Geothermal district heating systems typically consist of a central heat production facility, a network of pipes for heat distribution, and individual heat exchangers in buildings to transfer geothermal heat to indoor spaces and hot water systems. Heat is extracted from the ground using heat pumps or other geothermal technologies. Some systems using shallow geothermal resources operate on large heat pumps able to increase temperatures beyond 80 °C, thus expanding potential uses beyond residential heating. These systems can be small, from 0.5–2 megawatts thermal (MWth), and larger (50 MWth), where MWth is the input energy required. Hot water can also be used directly in heating or cooling applications.

Electricity generation

Electricity generation from geothermal energy involves harnessing the heat stored beneath the Earth's surface and converting it into electrical power. Geothermal power plants use fluids from underground reservoirs to produce steam, which then drives turbines to generate electricity. The three main types of geothermal technologies are dry steam, flash steam and binary cycle.

- **Dry steam power plants** use high-pressure, high-temperature steam directly from the Earth to turn turbines connected to generators. Wells connect the plant with geothermal reservoirs where the steam naturally rises to the surface and is then routed to the power plant. Direct dry steam plants range in size from 8–140 MW.
- **Flash steam power plants** are the most common type of geothermal power plant. They use high-temperature water from geothermal reservoirs. The mechanism brings hot water to the surface and allows it to 'flash' into steam as it passes through a pressure reduction system. The steam resulting from the 'flashing' then drives a turbine and generates electricity. The remaining cooler water flows back into the reservoir to maintain pressure. Flash plants vary in size depending on whether they are single (0.2–80 MW), double (2–110 MW) or triple-flash (60–150 MW) plants.
- **Binary cycle power plants** work by using a secondary working fluid with a lower boiling point than water contained in a closed loop. The hot geothermal fluid heats this secondary fluid, which vaporises, generating enough pressure to drive a turbine connected to a generator. Binary power plants, which usually use geothermal fluids with lower temperatures than required for flash and dry steam, can work in a completely closed cycle, with geothermal fluid returning to the reservoir.

Geothermal energy in numbers

According to the International Renewable Energy Agency (IRENA), geothermal energy provides electricity generation in more than 30 countries worldwide, reaching a total installed capacity of around 16 gigawatts (GW) in 2021. In the early 1950s, that capacity amounted to only 200 megawatts electric (MWe), before geothermal energy saw an increase in the 1970s and 1980s partly due to oil crises. Since 2000, installed geothermal electricity capacity has increased at an average annual rate of about 3 %. Despite this growth, geothermal represented only 0.5 % of the global renewable electricity market in 2022. A report from the European Commission's Joint Research Centre indicates that in 2021, gross capacity for electricity in the EU reached over 1 GWe, while net capacity was 877 MWe. EU electricity production amounted to 6 717 GWh, with Italy responsible for most of it (6 026.1 GWh). Other countries have considerably smaller productions: Germany 231.0 GWh, Portugal 217.2 GWh, France 133.2 GWh, Croatia 93.7 GWh, Hungary 16.0 GWh, and Austria 0.1 GWh. More recent data show that geothermal generated 0.2 % of electricity in the EU. The geothermal district heating and cooling sector has seen a growth rate in installed capacity of 6 %, and in 2021, there were 262 systems with a total installed capacity of 2.2 GWth. Overall, geothermal made up 2.8 % of renewable energy sources used for production of primary energy in the EU in 2021. According to the European Geothermal Energy Council (EGEC), an industry organisation, geothermal energy is able to satisfy around 25 % of heating and cooling consumption in Europe and around 10 % of electricity. However, the real potential of geothermal is hard to assess due to the fragmented nature of statistics on geothermal and insufficient geothermal resource mapping, as noted in Parliament's ITRE committee draft own-initiative report on geothermal energy.

Benefits and challenges of geothermal energy

Geothermal energy is a long lasting, cost-effective and weather-independent source of renewable energy. According to IRENA, geothermal can help stabilise electricity grids, partly offsetting risks connected to the fast deployment of variable renewables (mainly wind and solar). As a heat source, geothermal has low operating costs, offers efficiency gains by supplying heat directly, and can be expanded according to needs. As an electricity source, geothermal offers high plant efficiency, low greenhouse gas emissions and a small ecological footprint. Moreover, geothermal energy exploitation presents an opportunity to recover from geothermal brines minerals such as lithium, silica, zinc, manganese, as well as several rare-earth elements. Extraction and commercialisation of lithium (used in batteries) could be a way to finance geothermal projects. Furthermore, sourcing lithium from geothermal brines is more environmentally friendly than traditional lithium production from dry salt lakes or hard-rock mining.

The main challenges are that geothermal has longer project development timelines, requires higher upfront capital expenditures, and comes with high risk during the early phases of exploration. Both for electricity generation and heating, challenges relate to difficulties accessing financing, complex and fragmented regulatory frameworks, long permitting procedures and lack of a qualified workforce. Another challenge is public acceptance, mainly because of limited information on geothermal technology, and concerns about land use and environmental and social impacts. Ways to overcome hurdles to market growth include: i) taking advantage of beneficial regulatory frameworks and interconnecting regional electricity grids to export geothermal electricity from countries with high potential; ii) increasing synergies with renewable hydrogen production to tackle financial constraints; iii) improving the efficiency of electricity production from medium-temperature geothermal resources in order to avoid risky deep drilling.

Policy support

EU support for the geothermal sector is rooted in the European Green Deal. Draft national energy climate plans submitted to the Commission show that Member States have promising ideas for geothermal. The latest revision of the Renewable Energy Directive increased the overall target for the share of renewable energy sources (RES) by 2030, and set a binding target for an annual percentage point increase in the RES share for heating and cooling. The directive gives priority access to geothermal electricity and envisages incentives for investment such as feed-in tariffs or premiums. The revision also ensures simpler permitting for small and large heat pumps. The revised Energy Efficiency Directive includes an amended definition of an efficient heating and cooling system aiming to boost RES. The definition steadily increases minimum requirements in order to establish continuous growth of the amount of renewable energy and waste heat in the system. Geothermal energy also features in the Commission proposal for a net-zero industry act, as one of eight strategic technologies. Lithium that could be extracted from geothermal brine is covered in the proposed critical raw materials act. The announced heat pump action plan envisages at least 10 million additional heat pumps by 2027 and 30 million by 2030. The plan would encourage use of small and large geothermal heat pumps in buildings, heating and cooling systems, and in industry.

MAIN REFERENCES

Bruhn D. et al., Clean Energy Technology Observatory: Deep Geothermal Energy in the European Union – 2022 Status Report on Technology Development, Trends, Value Chains and Markets, Publications Office of the EU, 2022.

European Geothermal Energy Council, EGEC Geothermal Market Report 2022.

IRENA and International Geothermal Association, Global geothermal market and technology assessment, February 2023.

DISCLAIMER AND COPYRIGHT

eprs@ep.europa.eu (contact)

www.eprs.ep.parl.union.eu (intranet)

www.europarl.europa.eu/thinktank (internet)

http://epthinktank.eu (blog)