



# Geothermal Energy

## In brief

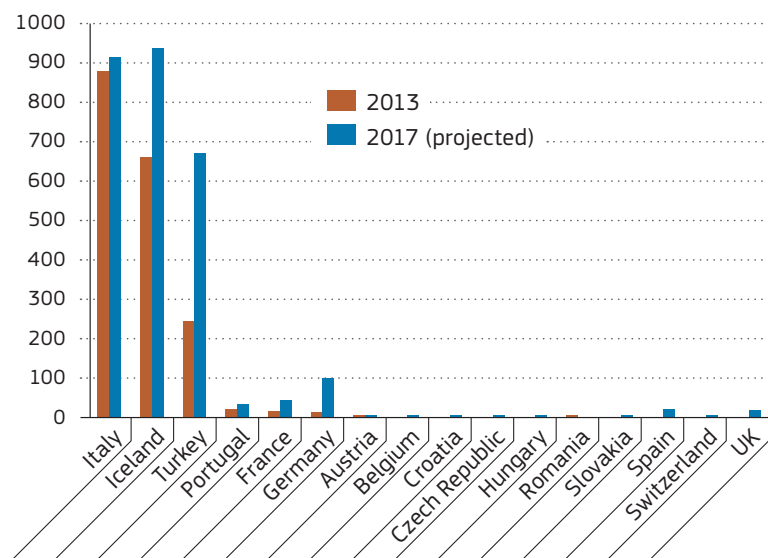
Geothermal literally means 'Earth's heat'. Geothermal energy is derived from the thermal energy generated and stored in the Earth's interior. The geothermal resource is renewable, as there is a constant heat flow to the surface and atmosphere from the immense heat stored within the Earth while the water is replenished by rainfall and circulation within the crust. Where natural water circulation is limited, fractures may be created and / or stimulated to create an Engineered Geothermal System (EGS). Successful development of EGS may multiply the potential for geothermal energy.

Nowadays, geothermal exploitation is divided into three technological aspects: the extraction of heat for power generation, the extraction of heat for direct use and the extraction of heat from shallow resources by means of ground source heat pumps. Power generation and distribution of heat may be combined in co-generation power plants and cascade utilisation may increase the total efficiency of the energy extraction process.

## The technology

The geothermal energy sector includes both **electric power** and **heat production**. Globally, about two-thirds of geothermal energy is available for heating and one-third for

Geothermal Installed Capacity by Country (MWe)



Source: EGEN

electricity power generation. The technology is at different levels of maturity, depending on the specific energy product (electricity or heat) and, in the case of heat, the conversion process, where geothermal energy may be used directly (e.g. district heating) or indirectly (e.g. heat pumps).

The technologies used to transform the heat into electricity are mostly linked to the temperature and pressure of the geothermal fluid.

**Direct dry steam turbines** use natural high-temperature steam resources directly to generate electricity, and result in the lowest power plant cost. For the high temperature mix of brine and steam, a **flash steam plant** separates the steam from the liquid and then expands it in a turbine. If the resource has lower temperatures (e.g. between 120°C and 180°C), a **binary cycle plant** is more efficient and has better environmental performance, although it is more expensive.

## Fact file

- In 2013, a global total installed capacity of 11.8 gigawatts (GW) of geothermal power was available in 24 countries worldwide, generating 72 terawatt hours (TWh) of electricity (EGEC, 2013; Matek, 2014). A further 19–26 GW was available for direct use in heating in a total of 78 countries (REN 21, 2014).
- The total installed capacity for geothermal electricity production in Europe (including Iceland and Turkey) in 2013 was 1.85 GWe from 68 power plants producing 11.7 TWh (terawatt-hours) of electricity per year. Of this, the EU-28 installed capacity was 0.95 GWe from 51 power plants generating 5.56 TWh of electricity per year (EGEC 2013).
- Geothermal power accounted for an estimated 3.7% of total renewable energy consumption in the EU in 2011 (6.2 Mtoe out of a total 169 Mtoe) (Eurostat).
- In 2013, there were 237 geothermal district heating plants in the EU, with an installed capacity of 1.1 GWth.
- In 2010 the geothermal energy sector is estimated to have employed over 43 000 people worldwide
- Of the estimated EUR 157 billion (USD 214 billion) invested in renewable energy sources worldwide in 2013, around EUR 1.8 billion were directed to geothermal heat and power, an increase of 38% over 2012 (Bloomberg/UNEP).

Beyond pure electricity generation, **geothermal combined heat and power** (CHP) is a natural energy-efficiency option used, for example, in district heating networks.

## Ongoing research

The geothermal research and development (R&D) environment is complex because most of the technologies are shared with other sectors and therefore do not contribute to geothermal energy alone. These include efforts to improve deep-resource extraction, deal with corrosive brine, produce materials for high temperature and high-pressure sources and develop geothermal heat pumps.

In the electricity sector, the current R&D focus is on enhanced geothermal systems (EGS), a technology that does not require natural convective hydrothermal resources. Several EU countries are focusing on EGS research, including France, Germany, the UK and the Czech Republic. Research aims to lower drilling costs, improve reservoir stimulation and management, map reservoir conditions suitable for EGS exploitation, improve imaging of existing wells and perform real-time measurements.

The Icelandic Deep Drilling Project (IDDP) is attempting to test the potential exploitation of sites in volcanic regions that contain water under supercritical conditions at 2–5 km below the surface.

“Geothermal energy is a dynamic and flexible source of renewable energy, which is recognised as being a pivotal contributor to Europe’s energy mix now, and also in the future.”

European Geothermal Energy Council (EGEC)

R&D for flash steam plants focuses on increased efficiency, scaling prevention and improved resistance to corrosion from brine and gases in the geothermal resource. Some research focuses on the production of silica and other minerals from geothermal brines as a useful side product.

In the geothermal heat pump sector, the focus is on developing components that are easy to connect and disconnect from the surface, as well as advanced control systems, natural and more efficient working fluids, reducing thermal resistance in boreholes, single-split and multi-split heat pump solutions for moderate climate zones and the increased efficiency of auxiliaries, such as pumps and fans. Hybrid plants with biomass and or biogas are also being developed.

For the sector as a whole, there is also R&D on identifying and exploiting alternative and cascading uses of geothermal energy so as to improve the economics of the technology.

## The industry

Interest in geothermal energy is growing, with 223 TWh of geothermal energy produced globally in 2012 – most (two-thirds) of it as heat and one-third as electricity<sup>1</sup>. Some 300 MWe of electricity generating capacity were added, globally, in 2012. In 2013 the geothermal sector was the only renewable energy to see a rise in new investment – up 38% to about EUR 1.8 billion – while, globally, new investment in renewables fell compared to 2012 (Bloomberg/UNEP).

Iceland, which is not a member of the EU-28, has by far the largest resources of geothermal energy in Europe. A growing number of EU countries are also developing geothermal projects – including Italy, Germany, France and the United Kingdom. Germany, for example, generated 18.8 GWh of electricity from geothermal energy in 2011, and produced 6.32 TWh of thermal energy (DENA). In both Sweden and Germany, well over 20 000 ground source heat pumps were sold in 2012.

The European Geothermal Energy Council (EGEC) predicts that geothermal installed capacity in Europe will grow to 3 GWe (1.15 GWe for EU-27) by 2016 and to 3.87 GWe (1.42 GWe for EU-27) by 2019. EGEC aims for the geothermal sector to contribute 5% of the total energy production in Europe by 2030.

Subsidies and other support from the EU are important for developing the geothermal sector. EU research Framework Programmes

1. <http://www.renewables-made-in-germany.com/en/renewables-made-in-germany-start/geothermal/geothermal-energy/market-development.html>

(such as FP6 and FP7), as well as the European Investment Bank (EIB), have been instrumental in pursuing EU geothermal objectives, especially in funding enhanced geothermal systems (EGS) research and development. A total of EUR 29.4 million was made available under FP6 and FP7 by March 2012.

The EC, EIB and EU Member States are also helping to fund demonstration projects through the NER300 facility, under the Emissions Trading Directive. This includes EUR 39.4 awarded to a geothermal demonstration project in southern Hungary, under the first call in 2012.

The EU-funded GEOFAR (Geothermal Finance and Awareness in European Regions) project is developing and promoting finance for geothermal projects as part of the Intelligent Energy Europe (IEE) programme.

## Barriers

The main barrier to exploiting geothermal energy is the high cost of drilling. Geothermal electricity plants are traditionally built on the

edges of tectonic plates where high temperature geothermal resources are available near the surface. Most geothermal technologies also require the use of underground water, which cannot be found everywhere. Partly for these reasons, success ratios for exploration wells may be as low as 20% and no higher than 60%.

It also takes an average of 5-7 years to develop geothermal power projects to the point of commercial deployment, which is a long return on investment. Two other important barriers continue to be a lack of appropriate legislation, such as on resource ownership, and a complex licensing system. The financial incentives, legal framework and support schemes across different EU Member States are inconsistent and in some cases inadequate. This lack of clarity means long lead times to obtain necessary permits, and uncertainties for investors over issues like the right to own and use geothermal energy.

Other potential barriers include public opposition in some regions due to seismic, visual and odour-related impacts. Fragmentation of existing knowledge hinders progress in

the sector and knowledge gaps increase the financial risk. Finally, there is a shortage of qualified workers.

## Needs

Policy needs to address specific legal and financial measures in the sector, such as funding of risk insurance and the creation of additional financial incentives. The European Geothermal Energy Council (EGEC) has recently proposed a risk insurance fund to encourage investments in the sector.

Clear definitions are needed for ownership, access rights and environmental regulatory conditions, while the legal frameworks and rules concerning ownership and exploitation of geothermal energy must be clarified. Furthermore, permit procedures should be harmonised and the various financial support mechanisms in different Member States made more coherent.

Increasing public acceptance of geothermal energy will require education and awareness campaigns, as well as R&D to minimise

## Fact file

### Deployment costs

- The start-up costs are highly site-specific and can range from EUR 2 500 per kW for large power plants extracting from hydrothermal volcanic reservoirs at 2-3 km depth to 13 000 EUR per kW for small EGS plants extracting from 5 km depth.
- Drilling typically accounts for 30-50% of total development cost for electricity generation. Drilling two boreholes to a depth of 3 000 metres can cost up to EUR 14 million, while piping costs vary from EUR 200 to EUR 6 000/metre in urban areas.
- Private insurance premiums can cost up to 25% of the sum insured although institutional insurance is more reasonable.
- Over half of the total production costs over the lifetime of the project are

expenses associated with the well field. 50% or more of the wells might have to be replaced over the course of the project, potentially increasing electricity cost by 15-20%.

- Geothermal heat pumps cost approximately EUR 2 000/kW of capacity, with average capacities of 5-20 kWth.
- In 2012 levelised costs of electricity (LCOE) for geothermal electricity varied from EUR 50-90 MWh for conventional, high-temperature plants and EUR 100-200/MWh for low-temperature plants.
- The LCOE for Enhanced Geothermal System power plants was between EUR 200-300/MWh.

### Anticipated greenhouse gas savings

- For the 14 countries that are members of the Geothermal Implementing Agreement (GIA),<sup>2</sup> the International Energy Agency (IEA) estimates that geothermal

power production in 2012 avoided the equivalent of 8.4 million tonnes of CO<sub>2</sub> from gas power stations, 34.0 Mt from oil and 39.8 Mt from coal fired power stations (IEA-GIA 2012).

- In 2012, total CO<sub>2</sub> emissions savings by geothermal heat uses in the 14 GIA member countries amounted to about 5.8 Mt CO<sub>2</sub> from gas replacement, 24.4 Mt CO<sub>2</sub> from oil replacement and 28.4 Mt CO<sub>2</sub> from coal replacement (IEA-GIA 2012).
- The installed capacity of geothermal district heating in Europe in 2013 was around 4.3 GWth, producing 12 883 GWh of thermal power (EGEC)<sup>3</sup>.

<sup>2</sup>. Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, Korea, Spain, Switzerland, the United Kingdom, and the United States.  
<sup>3</sup>. <http://egec.info/wp-content/uploads/2011/03/Geothermal-MR-2013-2014-M-2014.pdf>

the environmental impacts of geothermal exploitation. There is also a need for further research on emerging concepts, such as enhanced geothermal systems (EGS), hybrid systems and cascading uses such as mineral extraction.

International research collaboration and centralisation of existing knowledge and data in geothermal and related sectors, within and outside the EU, will be critical. Assuring a qualified work force for the sector requires vocational training and certification.

## Installed capacity

Natural geothermal energy resources are deployed commercially to produce electricity and heat.

In Europe as a whole, Iceland and Italy lead in geothermal electricity generation, followed by Germany, Portugal and France. Most (93.6%) of the EU's installed capacity is in Italy, with 882.6 MWe in 2013, concentrated in two geothermal areas of the country.

If Iceland and Turkey are included, the total installed capacity for geothermal electricity production in the European region in 2013 was 1.85 GWe from 68 power plants producing 11.7 TWh (terawatt-hours) of electricity per year. Of this, the EU-28 installed capacity was 0.95 GWe from 51 power plants generating 5.56 TWh of electricity per year (EGEC 2013).

The capacity of the geothermal **power sector** in the EU is expected to reach 1 GW in 2020 and 1.3 GW in 2030. The estimated maximum potential for geothermal power in the EU-27 is up to 6 GW by 2020 and 8 GW by 2030. This represents about 1% and 1.3% of projected EU gross electricity consumption by 2020 and 2030 respectively. (Source: Europa)

The geothermal **heat sector** is led by Sweden, Italy, Greece, France, Germany and Hungary (as well as Turkey, Iceland and Switzerland outside the EU). Installed thermal capacity in the EU in 2013 was about 15 GWth (GW thermal) including both heat pumps and direct heat use. In 2013,

there were 237 geothermal district heating plants in the EU, with an installed capacity of 1.1 GWth.

The estimated maximum potential for geothermal in the heating sector is up to 40 GW by 2020 and 70 GW by 2030 (direct and indirect use combined) (Source: Europa).

### For further information:

**European Geothermal Energy Council:**  
<http://egec.info>

**IEA-GIA Trends in Geothermal Application (2012)**  
<http://iea-gia.org/wp-content/uploads/2013/11/2012-Trend-Report-Weber-30Aug14.pdf>

**SETIS pages on geothermal energy:**  
<http://setis.ec.europa.eu/technologies/geothermal-power>