Geothermal Energy

IN BRIEF

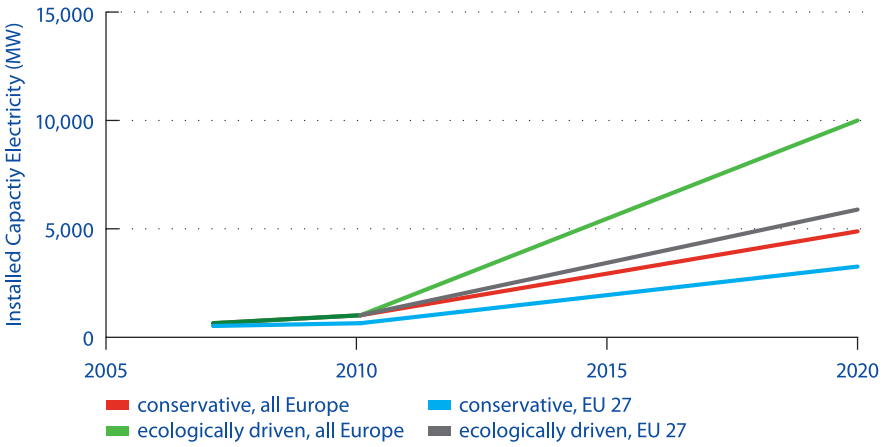
Geothermal literally means 'Earth's heat'. The layers of rock that make up the Earth's surface grow increasingly hot with depth, from crust to mantle to core, and this heat can be tapped as energy. The heat may be held in the rocks themselves (geothermal) or in subterranean water, brine or steam (hydrothermal). Humans have used geothermal energy for thousands of years, for example, using the heat from the ground for cooking or bathing.

Nowadays, geothermal exploitation is divided into two technological aspects: the extraction of heat energy and its transformation into a usable form such as electricity. Extracted heat energy may be used directly, for instance, by pumping water heated by rocks to heat buildings. In addition, different types of power plants can transform geothermal heat to electricity; most use a turbine driven by steam to drive a generator that produces electricity.

THE TECHNOLOGY

The geothermal energy sector comprises **electric power** and **heat production** sub-sectors. Various levels of technological maturity exist, 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**).

GEOTHERMAL POWER: ESTIMATED INSTALLED CAPACITY (MW)



Source: European Geothermal Energy Council

The technologies used to transform the heat into electricity are mostly linked to the temperature and pressure of the geothermal fluid. **Direct 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 and 180 °C), a **binary cycle plant** is more efficient and has better environmental performance, although it is more expensive.

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 only to geothermal energy. 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 map reservoir conditions suitable for EGS exploita-

FACT FILE

Geothermal energy needs no external fuel and no harmful polluting gases are produced. However, in some cases care must be taken to avoid surface emissions.

Geothermal power plants emit only excess steam and very few trace gases, and take up very little land compared to traditional fossil-fuel plants.

Geothermal electricity is more 'available': Fossil-fuel power plants produce electricity 65-75% of the time, compared to 90% for geothermal power plants. (Source: WWF)

Of the estimated €75 billion (USD 101 billion) invested in renewable energy sources worldwide in 2009, around €800 000 (USD 1.1 billion) were directed to geothermal heat and power.

- Figures from the Global Trends in Sustainable Energy Investment 2010 (UNEP/BNEF)

In 2010, about 10 715 Megawatts (MW) of geothermal power is already online in 24 countries worldwide and is expected to generate 67 246 GWh of electricity.

This represents a 20% increase in online capacity since 2005, projected to grow to 18 500 MW by 2015.

- Figures from the International Geothermal Association (IGA).

At least 75 countries have installed direct geothermal capacity for district heating, space heating, spas, industrial processes, desalination and agricultural applications.

For example, direct-use of geothermal energy provides 89% of Iceland's space heating needs. This saves about €90 million in unnecessary oil imports.

tion, improve imaging of existing wells and perform real-time measurements.

The Icelandic Deep Drilling Project (IDDP) attempts to test the potential exploitation of sites that contain water under supercritical conditions at 4–5 km below the surface.

R&D for flash steam plants focuses on increased efficiency and improved **resistance to corrosion** from brine and other contaminants 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 easy to connect and disconnect from the surface, as well as advanced control systems, natural and more efficient working fluids, single-split and multi-split heat pump solutions for moderate climate zones and the increased efficiency of auxiliaries, such as pumps and fans.

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

Although **many areas in Europe lack the hydrothermal resources** currently used for geothermal power, a growing number of EU countries - including Germany, France, the United Kingdom and Italy – are developing geothermal projects. Germany, for example, has over 150 geothermal power plant projects at some stage of development, and expects to have over 280 MW of generation capacity online by 2020.

Subsidies and other supports from the EU are important for developing the geothermal sector. EU research Framework Programmes (such as FP6 and FP7), as well as the European Investment Bank (EIB), have been instrumental in pursuing EU geothermal objectives, especially in funding EGS research and development. The European Commission, European Investment Bank and EU Member States will also contribute to the funding of demonstration projects in future through the so-called "NER300" facility under the Emissions Trading Directive.

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.

The **European Geothermal Energy Council** (EGEC) aims for the geothermal sector to contribute 5% of the total energy production in Europe by 2030.

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%.

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 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. Clear definitions are need 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 the acceptance of geothermal energy will require **education and awareness** campaigns, as well as **R&D to minimise 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

Currently, the European geothermal market is concentrated in different countries according to sector:

- **ELECTRICITY**
  Italy, France and Portugal lead in electricity generation, but 92% of the EU's installed capacity is in Italy, where the running capacity is 671 MW.

> **"Geothermal energy is the energy stored in the form of heat beneath the earth's surface. It has been used since ancient times for heating. It is a sustainable, renewable, nearly infinite energy source, delivering heat and power 24 hours a day throughout the year. And yet, until now, we have only used a small fraction of the geothermal energy potential."**
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> European Geothermal Energy Council (EGEC)

FACT FILE

Deployment costs
Start-up costs are relatively high: an average geothermal plant costs €2 000 per kilowatt (kW) installed *(versus €1 200 per kW installed for a natural gas plant).*

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 €14 million, while piping costs vary from €200 to €6 000/metre in urban areas.

Meanwhile, 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%.

Data from Greece suggests heat pump capital costs of €1 200 – 1 500/kWth, with electricity and maintenance costs of €28/MWhth, giving total costs of €48/MWhth. *(By comparison, the capital costs of diesel are €72/MWhth, with €58-65/MWhth for natural gas.)*

Anticipated greenhouse gas savings
At their maximum potential, geothermal power and heat could avoid up to 40 Mt/year CO_2 in 2020 and 50 Mt/year CO_2 in 2030. The corresponding cumulative avoided CO_2 emissions over the period 2010 to 2030 would be 700 Mt CO_2.

Increased electricity and heat generation from geothermal resources could also help to avoid the need for new fossil fuel-based plants.

The European Geothermal Energy Council (EGEC) says that geothermal heating supplied around 2.5 Mtoe (million tonnes of oil equivalent) in the EU in 2007.

Forecasts for the maximum potential for geothermal power and heat could avoid up to 12 Mtoe in 2020 and 16 Mtoe in 2030, with a cumulative fossil fuel avoidance for 2010-2030 of 200 Mtoe.

The total installed capacity for geothermal electricity production in the EU in 2008 was 850 MW, producing more than 5 000 gigawatt-hours (GWh) of electricity per year. This accounts for 8% of the world's geothermal electricity installation, which has been relatively stable in recent years. The EU's total geothermal energy capacity could grow to around 3.5 GW by 2020. This would represent about 1% of projected EU gross electricity consumption.

- **HEAT**

The heat sector is led by Sweden, Italy, Greece, France, Germany and Hungary (as well as Turkey, Iceland and Switzerland outside the EU). Installed capacity in the EU is about 12 GWth (GW thermal) including both heat pumps and direct heat use, accounting for an annual heat production of 95 Petajoules (PJ).

For further information:

SETIS section on geothermal power
http://setis.ec.europa.eu/technologies/Geothermal-power
European Geothermal Energy Council
http://www.egec.org