# KEY MESSAGES

Geothermal Energy is the energy stored in the form of heat beneath the earth's surface. This energy can be found at different temperatures in the ground and the ground water, depending on local geology and depth.

> For the EU 27, the geothermal heat flux can be assessed to a total of 260 Mtoe per year.

> The extent of the deployment is therefore limited only by the demand for heat. By 2050, a value in excess of 150 Mtoe of heat production is deemed possible.

> According to the recent GEOELEC resource assessment, in 2050 the economic potential of geothermal power in the EU amounts to 2570 TWh (potentially covering as much as 50% of the projected electricity produced in the EU[1]).

> Renewables for heating and cooling and flexible renewable electricity generation, such as geothermal, must be a pillar of the EU's strategy for long-term greenhouse gas emissions reductions.

> Efficient renewable heating and cooling (h&c) technologies, including geothermal, can provide a cost-effective contribution to the decarbonisation of the energy sector, while increasing security of supply and render heat affordable. On the contrary, electrification of the heat sector should not be overestimated. As renewables represent only 30% of the electricity consumption today, the electrification of the heat sector would make decarbonisation more difficult.

> Dispatchable power plants from stable renewable energy sources such as geothermal, have to be largely deployed for covering half of the power consumption in 2050, providing the desirable flexibility option along with demand-side management, interconnections, and storage.

> A continuation of the three-targets approach, including binding targets for renewable energy covering all sectors (electricity, heating and cooling and transport), will be needed to achieve the 2050 targets in the most cost-efficient way. Alongside renewable energy, an ambitious energy efficiency binding target is necessary as well for a successful decarbonisation.

[1]Considering the projections of the European Commission 2050 Roadmap (2011).

- When assessing costs of policy measures it is of paramount importance to be as transparent as possible. In the power sector this means taking decisions based on the full costs to society (including system costs and other externalities) rather than on the LCoE (Levelised Costs of Energy) of single generation technologies. The difference in market value of predictable and controllable power output versus power output dictated by external natural variations should be included in the assessment of the value of the renewable power production;

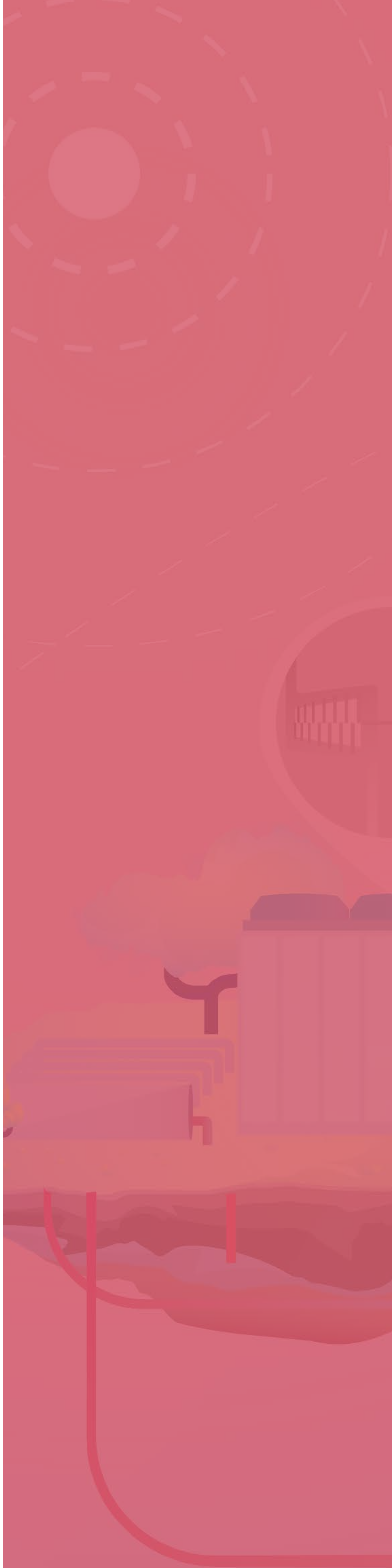
- The EU ETS is neither promoting innovation nor competitiveness and jobs. A 2050 framework for energy and climate policies based on a greenhouse gas approach is needed but is not sufficient to drive investments for decarbonising the economy;

- EU energy and climate policies should aim to achieve competitiveness and affordable energy prices while taking into account all costs to society. Reducing the share of imported energy to improve our trade deficit should be one of the pillars on which such a policy has to be designed. Such an approach addresses the competitiveness of the EU as a whole and not only of those supposed declining sectors;

- The GHG emissions reduction potential in non- ETS sectors (the Effort Sharing Decision) was underestimated and targets were set too low. By setting more ambitious GHG emissions reduction targets in non-ETS sectors, the EU can achieve decarbonisation in a much more cost-efficient way;

- There is a need to strike the right balance between a bottom-up approach and top-down guidance from the European Commission. Attention should be paid to reducing the overall costs of decarbonisation;

- The 2050 strategy for EU energy and climate policies requires increased focus on energy system integration and local/regional energy supply (in line for instance with the Smart Cities and Communities Initiative). Investments in local renewable energies (such as geothermal) and energy efficiency can boost local economies and improve urban environment conditions.



# RECOMMENDATIONS

In order to reach our climate objectives for 2050, it is crucial to trigger a prompt fuel switch to renewables. Beyond 2020, existing measures should be strengthened, addressing the full decarbonisation of the heating and electricity sectors.

The European Geothermal Energy Council puts forward the following recommendations to achieve this goal:

> A level-playing field is needed. Fossil fuels subsidies must be phased-out with the utmost urgency. Carbon outside the ETS sectors should be priced. Where this is not politically feasible fuel switch to renewable sources of heating should be supported. Concerning the ETS, the Market Stability Reserve is a first step to fix the system, yet it is not sufficient to trigger fuel switch to flexible RES technologies. Tailor made enabling policies are therefore needed.

> It is crucial to mobilise existing Structural and Investment Funds to finance RES heating and cooling and flexible renewable electricity generation. Financing tools must include risk capital, guarantees and grants.

> Implementation of existing legislation is essential. Member States must notably launch large national information campaigns to increase awareness of citizens and facilitate access to information regarding RES h&c suppliers and installers.

> In the heat sector it is crucial to collect and update regularly reliable statistics on and distinguish between energy sources, enablers, and end-users. This would enable informed decision making.

> The EU should continue supporting technological development. RD&I in geothermal technologies is needed to reduce costs, enhance system performance, and facilitate the integration of into existing infrastructure. It is also needed to increase the temperature level provided by geothermal technologies and cover additional industrial sectors.
Horizon Europe and national R&D programmes are also much needed to develop the new generation of flexible renewable energy technologies as well as to improve the flexibility of their electricity production. In the period beyond 2020, a strong boost can come from the new Innovation Fund. This should see the EU making upfront funding available at an early stage and bearing part of the risks.

> In the framework of the Commission's work on a new market design and of the Member States' implementation of the new EU state aid rules, it is crucial to value energy capacity and, most importantly, the flexibility that renewable energy sources can offer to system operators.

> In line with the European Parliament's call, the Commission should submit an analysis of how stable sources of renewable energy can complement variable renewable sources. As a follow-up, the Commission and Member States should develop a strategy to further deploy flexible renewable energy sources in order to boost the flexibility of the power system.

# GEOTHERMAL ENERGY'S CONTRIBUTION TO DECARBONISATION

Per definition, Geothermal Energy is the energy stored in the form of heat beneath the earth's surface. This energy can be found at different temperatures in the ground and the ground water, depending on local geology and depth. For all Europe, the geothermal heat flux, transporting heat from beneath into underground layers in accessible depth, can be assessed to a total of 610 Mtoe annually, of which 260 Mtoe per year are produced under the surface of the EU 27.

Hence the potential of geothermal energy in Europe is huge.

The extent of the deployment is therefore limited only by the demand for heat. By 2050, a value in excess of 150 Mtoe of heat production is deemed possible.

According to the recent GEOELEC resource assessment, in 2030 the economic potential of geothermal power in the EU amounts to 34 TWh. Thanks to economies of scale, innovative drilling concepts and cost reduction, the economic potential in the EU grows to approximately 2570 TWh in 2050 (potentially covering as much as 50% of the projected electricity produced in the EU).
Geothermal energy is a renewable energy source that is vastly under-taped at the European level. However, thanks to technological innovation, it has been growing steadily across the EU in recent years. Moreover many countries which have only recently starting exploiting their geothermal energy resources are among the most dynamic markets in Europe for new developments. Meanwhile, historical countries, where the geothermal industry is older and more established, are undergoing a new era of development. These trends are quite positive and allow expecting a significant new development of geothermal energy. Moreover, the upcoming innovation, or technologies that are still at early technology readiness levels will be proven and market ready in the coming decade, allowing for widespread deployments by the middle of the century provided the right framework is in place across the EU.

## HEATING AND COOLING: THE MISSING PIECE OF THE PUZZLE

Renewable heating and cooling technologies can replace gas and other fossil fuels in the residential and tertiary sectors.
In this context, geothermal energy is of particular interest. Geothermal is available 24 hours a day, all throughout the year and all over Europe.
Geothermal can be harnessed and distributed through efficient technologies such as district heating and /or heat pumps. Another option is the direct use of geothermal resources through small and large scale district heating systems.

## GEOTHERMAL PROVIDES SECURE AND RENEWABLE HEAT TO INDUSTRY

Geothermal heat production can provide many temperature levels for different types of processes. While Innovation in new technologies and unlocking geothermal heat in new areas of Europe can allow industrial processes to utilize this reliable heat source, which has the benefit of low operational expenditures and continuous supply. As can be seen in the third part of this document, geothermal heat can be an opportunity for a new industrialisation of Europe, based on renewable sources.

## DEEP GEOTHERMAL POTENTIAL FOR HEATING

The use of geothermal energy for district heating is an established and proven technology. Today, Europe has 280 plants for GeoDH. The plants are spread over 24 countries and represent a total heating capacity of some 4.8 GWth. In 2015, they supplied about 12.9 TWh of heat. With 163 plants under construction or investigation in 2016, the heating capacity from deep geothermal sources in Europe is expected to grow significantly. The figure below shows the repartition of resources for geothermal district heating in Europe. It highlights the widespread presence of geothermal resources across Europe.

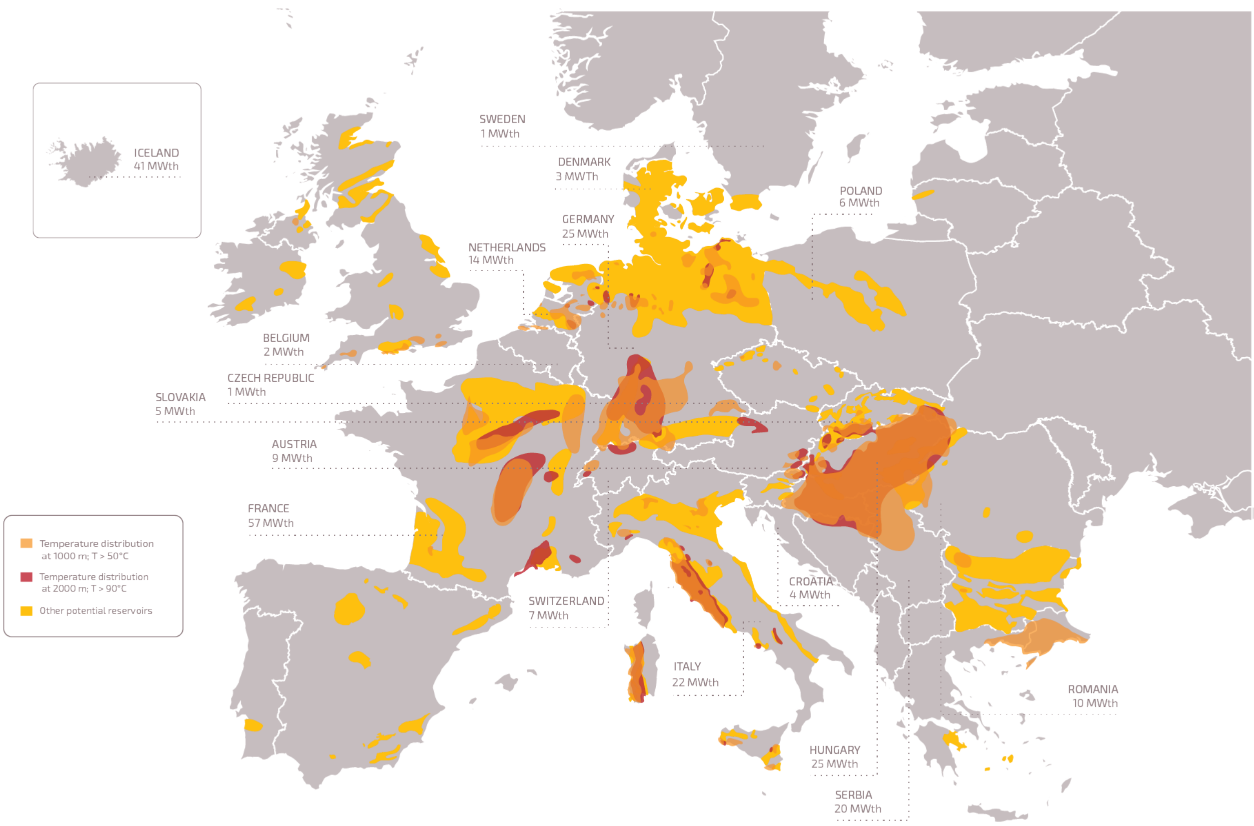



Figure 6.
Areas suitable for geothermal heating and cooling networks (combination of high heat demand and areas where the temperature at 2 km depth is higher than 60°C) and actual geothermal district heating installed capacity
(Source: ETIP DG vision for deep geothermal)

In terms of new development of deep geothermal district heating, there are currently 190 plants under development or investigations across Europe. For the 81 plants where is an estimate on the future production capacity, the total expected addition represents 1.3 GW of new geothermal capacity to come online in the coming years (of which 1 GW in the EU). This figure does not include the over 100 projects where there is no estimate capacity available. In the short term, the EU could increase its DH capacity by between 50%-100%. The current framework in many countries is positive, with an acceleration of developments in the Netherlands, the emergence of the Polish market, or the British one, and renewed interest in France, Germany, Hungary and Italy.

The GeoDH project explores the geothermal district heating potential of Europe. Its key finding is that around 25% of the European population lives in area directly suitable for geothermal district heating. This figure allows to consider that geothermal district heating could represent up to 25% of the EU demand for space heating. In addition, Geothermal sources are also used for industrial purposes, as in Alsace (France) where heat is supplied to a bio-refinery, or in Tuscany (Italy) for beer production. Furthermore, the use of geothermal heat is being investigated for desalination and other innovative industrial applications. HORIZON 2020, INTERREG and local programmes such as UDG in the Netherlands, should all lead to a growing number of industrial applications of deep geothermal energy all over Europe.
Geothermal plays also an important role for agriculture, providing heat to greenhouses. This means that cold countries, such as Iceland and The Netherlands, can produce eggplants, tomatoes and other plants for both local use and export to other countries. Countries with a mild climate can benefit of geothermal heat as well: greenhouses in geothermal areas of Italy produce flowers and basil during winter (source: ETIP-DG).

In 2050, this use of geothermal should be widespread and optimised as experiences are shared and cost diminish with economies of scale in the industry and a better knowledge of the resource across Europe, notably in new markets.

A key measure to unlock of the potential of geothermal district heating and more importantly an acceleration of deployment, is the greater development of low temperature district heating networks, and more generally the planning of heating and cooling infrastructure at the local level. The presence of adequate infrastructure, or the use in large buildings, can allow exploiting lower temperature geothermal resources (e.g. 40°), further unlocking the potential of geothermal district heating to make up a large portion of the European demand for heating and cooling by the middle of the century.

Over the last decades, the supply and return temperatures of DH networks have been reduced. Since modern, energy efficient buildings and new heating systems allow rooms to be comfortably heated at supply temperatures of 40°C and less, the operative temperatures of the DHC network can be further reduced. Third and fourth generation DH and DHC networks will be developed, and it will be possible to integrate low temperature geothermal resources in district heating in urban areas anywhere in Europe.

Through demand site management or thermal energy storage it will be possible to balance heat demand and supply in a DH network. While demand in a DH network fluctuates on a daily, weekly and seasonal basis, the supply from a geothermal source is constant all year round. Increasing the number of full load hours of the geothermal installations has a direct impact on profitability. One way to balance supply and demand is by demand site management in order to lower peak demand. Another option is to use thermal energy storage systems, to supply additional thermal power during periods of peak demand. Thermal energy storage can take different forms, e.g., local water storage tanks to balance daytime fluctuations in demand, large underground seasonal storage systems, or thermo-chemical storage systems.

The sequential operation of geothermal heat by integrating different technologies that use progressively lower temperatures, known as cascade applications, will further improve efficiency, with a positive economic impact in project development and major benefit for local communities in utilising clean cheap heat for air conditioning, agricultural or industrial applications, and even for hydrotherapy and healing as in the “Blue Lagoon” in Iceland.
The future of geothermal district heating goes through the development of smart thermal grids, systems that consider the value of the heat they provide to many uses, at different temperature levels, from a variety of resources. This means a more decentralised heat network, where renewables are at the core.

## THE CONTRIBUTION OF SHALLOW GEOTHERMAL SYSTEMS TO THE ENERGY TRANSITION

Geothermal heating and cooling systems have a specific role to play in the decarbonisation of the heating sector: they are very efficient (typically requiring less auxiliary energy than alternative of comparable scale) and can be deployed at many different scales across the whole of Europe.

The value of geothermal heating systems resides in their versatility: they correspond to a wide array of resources and can be fitted to all types of space heating and cooling needs. A small system may be installed in new individual housing on shallow depth, while another may utilise a deep low temperature aquifer for a large building (e.g. hospital, university…) with rated thermal outputs in the MWth range.

When considering geothermal heating system from the point of view of enablers, often meaning heat pump technologies, there is a risk of confusion due to over-simplifications. While from a policy-making perspective it may be tempting to simplify technical issues as much as possible, in the case of heat pumps and geothermal heating system, this may lead to policy framework that are not consistent with a cost-efficient decarbonisation of the heating and

cooling sector and may result in negative system externalities. A policy design with a single category of heating system in mind may inadvertently create barriers to investment in other systems which may be more cost efficient in some situations, increasing the cost of decarbonisation.
For instance, in the current heating and cooling system for buildings, dominated by individual fossil fuel boilers or high temperature district heating networks, a tempting policy option might be to replace the current stock of heating system with renewable based alternatives. This however fails to acknowledge the importance of a bottom-up integrated approach, which would for instance consider investments in heating and cooling infrastructure. In the case of geothermal heating systems, small systems can be a solution for individual houses, larger ones being suitable for large buildings, or at the neighbourhood level, notably associated with low temperature district heating.

Geothermal heat pumps can be used anywhere in Europe, utilising geothermal energy even at very low temperatures to supply heating and cooling to buildings of all sizes (from small single-family houses to very large buildings such as hospitals, shopping centres or the headquarters of the North Atlantic Treaty Organisation, NATO). Heat pumps enable the use of the low temperature geothermal energy by allowing the temperature to be adjusted to the level required to meet the building's needs.

Beyond straightforward small-scale geothermal heating (and cooling) systems, some installations also use underground conditions as a way to store energy seasonally (altering the temperature underground). These systems are referred to as "Underground Thermal Energy Storage (UTES)". There is no sharp delineation between geothermal heat pumps and UTES; large GSHP plants typically have a high share of the annual energy turnover inside the BHE field or the aquifer, not with the surrounding or underlying ground, thus qualifying for the term 'storage'. In all of these large installations it is crucial to pursue a long-term balance of heat extracted from the ground and injected into the ground.

Geothermal heat pump systems are the most widespread form of geothermal energy use across Europe, both in terms of geographical dispersion, number of units sold, capacity installed and amount of energy produced.

Currently, there is an estimated 1.5 million geothermal heat pump systems in the European Union (EGEC Market Report 2017). This represents a production of at least 23 TWh of geothermal heating and cooling. There is a notable trend towards the adoption of this technology in colder European countries, explained in particular by the lower operating costs for heating compared to investment, which is especially suitable for high heating demand.

An observable trend in the development of shallow systems for geothermal heating and cooling is increasingly towards large installations (at sizes that are not distinguishable in terms of capacity from district heating systems). These large installations are either supplying large buildings or district heating networks as is the case in Milan. By 2050 such system, notably coupled with UTES systems should be widespread, as they represent the best option, with proven technologies for a smart coupling of the heating and cooling sector and the electricity one.

Altogether, geothermal heating and cooling system should represent a large share – if not the majority – of heating and cooling system linked to the electricity sector.

# A EUROPEAN VISION FOR GEOTHERMAL ELECTRICITY

A rational, consistent and far sighted approach to electricity supply is critical for ensuring a transformation of the power sector. Geothermal is the only source of renewable energy capable of driving a consistent and reliable (24h per day, 365 days per year) electricity production. Geothermal energy utilization is based on harvesting the continuous heat flux coming from the earth which represents 25 billion times the world annual energy consumption, therefore representing an almost unlimited and renewable source of energy. The heat flux from the earth to the atmosphere if not harvested is otherwise lost. It is available everywhere, this local electricity production will reduce the reliance on imports from unsecure suppliers, averting conflict between nations.

The lack of a secure and affordable source of energy is always highlighted as one of the critical point in the energy transition; by removing dependence on fossil fuel imports geothermal energy alleviates a big burden. In addition, the integrated use of heat and power has shown to have an even bigger effect on job.

The high temperature regions cover about ten percent of the Earth's surface. The total amount of available heat is huge, about 42 1018 MJ. The priorities to unlock their potential and allow the EU to tap into the huge potential for deploying geothermal electricity capacity include in the short term:

> Development of the hydrothermal resources in Europe from the known High temperature resources, and from Medium temperature resources.

> Expand the EGS concept in the different regions and geological conditions of Europe through the construction of power plants and heat systems, thus maintaining the leadership in this new technology development. This also includes the development of a more efficient conversion processes.

> Establish the basis of a European model of geothermal power plants in harmony with the environment: medium size plants with fluid re-injection to minimize the impact on landscape, environment and the Grid, and to maximize the benefit to communities through an innovative use of hot fluid from the power plant.

> Launch EU wide exploration programs to allow optimum funding allocation between the different underground potential uses (including geothermal)

> Europe has pioneered electricity generation by the exploitation of geothermal resources for over 100 years in Larderello and the EU still maintains a leading role due to the development of EGS technology. All efforts need to be maintained to keep this leadership in developing the geothermal industry of the future, both for research and commercial development.

In the medium term, the key priorities for unlocking the potential of geothermal electricity in Europe include:

> Bring down the cost of power plants thanks to technical developments to become competitive with other sources of energy.

> Start implementation of massive construction programs to replace ageing and increasingly costly fossil fuel-based power plants, starting with the most promising areas

> Transfer EGS technology outside Europe in areas lacking hydrothermal resources thanks to the technical expertise developed and the capability of the European industry to develop large engineering projects around the world.

> Develop mature technologies for exploitation of supercritical fluids and temperatures.

In the long term, by the middle of the century, therefore in the framework of the European strategy on emissions, geothermal is expected to represent a substantial part of the electricity supply, notably providing baseload electricity and providing grid services to variable generation.

> EGS is mature enough to be developed everywhere at a competitive cost, the challenge will then be to implement it widely and quickly enough to capture a large market share from other type of base-load power plants (Coal, nuclear, fuel, etc) in Europe and outside Europe.

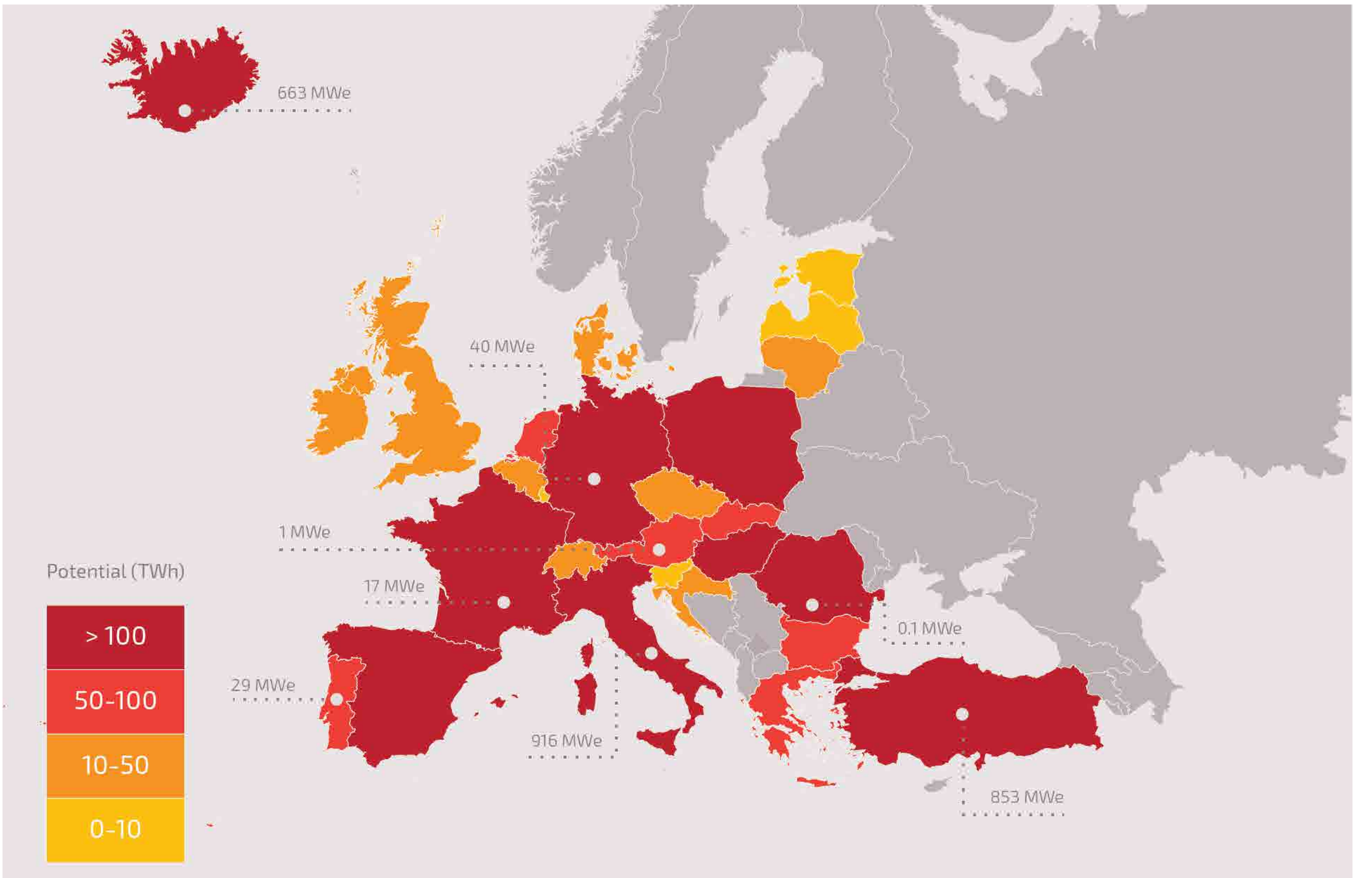



Figure 7.
Potential electricity production to 2050 (available data as estimated by GEOELEC project, taking into account underground temperature distribution) and current electricity production in Europe
(source: ETIP DG vision)

The geological potential (heat in place) for geothermal power has been translated to an economical potential, using a Levelised Cost of Energy (LCoE) value of less than 150 EUR/MWh for the 2030 scenario and less than 100 EUR/MWh for the 2050 scenario:

> The total geothermal electricity potential in the EU-27 is 21,2 TWh for the year 2020;
> In 2030 this amounts to 34 TWh in the EU;
> Thanks to economies of scale, innovative drilling concepts and substantial cost reduction, the economic potential in the EU grows to approximately 2570 TWh in 2050 potentially covering as much as 50% of the projected electricity produced in the EU) and more than 4000 TWh including Iceland, Turkey and Switzerland.

## ENSURING BASELOAD AND FLEXIBLE SUPPLY OF ELECTRICITY WITH DEEP GEOTHERMAL POWER PLANTS

**Where:** Sauerlach, Bavaria, Germany
**What:** Combined geothermal heat and power plant operated by the city of Munich

*Picture: Sauerlach plant (source: Stadtwerke München)*

**Key data:** In January 2014, the largest geothermal power plant in Germany, located near Munich, was put into operation. Operated by a public utility company of Munich (Stadtwerke München), it supplies around 16,000 households in the city of Munich and provides the inhabitants of Sauerlach with the option to connect to geothermal district heating. The new plant has an electrical capacity of around 6MW and a thermal output of 5 MW. The plant providing heating and power derives water with a temperature of around 140°C from wells with a depth of 5 km.

**Objective:** The Sauerlach geothermal plant represents a true stepping stone for the city of Munich towards achieving its objective of running 100% on green energy by 2025. Thanks to favourable geological conditions (i.e. the Molasse Basin) and the proximity to a large number of potential consumers, the Munich region is one of the best regions in Germany for the development of geothermal.

| COUNTRY | ECONOMIC POTENTIAL (in TWh) | | |
|---|---|---|---|
| | 2020 | 2030 | 2050 |
| AUSTRIA | 0 | 0 | 67 |
| BELGIUM | 0 | 0 | 22 |
| BULGARIA | 0 | 0 | 50 |
| CROATIA | 1 | 3 | 50 |
| CZECH REPUBLIC | 0 | 0 | 31 |
| DENMARK | 0 | 0 | 29 |
| ESTONIA | 0 | 0 | 2 |
| FRANCE | 0 | 0 | 653 |
| GERMANY | 0 | 1 | 346 |
| GREECE | 0 | 0 | 81 |
| HUNGARY | 9 | 17 | 174 |
| IRELAND | 0 | 0 | 27 |
| ITALY | 11 | 12 | 226 |
| LATVIA | 0 | 0 | 3 |
| LITHUANIA | 0 | 0 | 19 |
| LUXEMBOURG | 0 | 0 | 3 |
| POLAND | 0 | 0 | 144 |
| PORTUGAL | 0 | 0 | 63 |
| ROMANIA | 0 | 0 | 105 |
| SLOVAKIA | 0 | 1 | 55 |
| SLOVENIA | 0 | 0 | 8 |
| SPAIN | 0 | 1 | 349 |
| SWEDEN | 0 | 0 | 1 |
| THE NETHERLANDS | 0 | 0 | 52 |
| UNITED KINGDOM | 0 | 0 | 42 |

Figure 8.
Economic Potential per country (2020 = LCOE < 200 EUR/MWh; 2030 = LCOE < 150 EUR/MWh; 2050 = LCOE < 100 EUR/MWh)
(Source: GEOELEC)

## GEOTHERMAL FOR THE FULL DECARBONISATION OF THE POWER SECTOR

An increasing deployment of fluctuating renewable technologies (wind and photovoltaic) within the electricity system has created several challenges for grid management, and therefore to security of electricity supply. This new reality calls for urgent measures in order to stabilise the grid. Flexible generation is one of the four pillars to make the power system flexible along with demand-side management, interconnections, and storage, ensuring stability to the power system.

Despite their potential and benefits, the role of flexible electricity generation from RES technologies such as geothermal, small hydropower, solar thermal electricity (STE, also known as concentrated solar power - CSP), biomass and biogas, is not sufficiently taken into consideration today in energy policies and scenarios.

The voice of geothermal in Europe

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