VISION FOR DEEP GEOTHERMAL

ETIP-DG

European Technology & Innovation Platform on **Deep Geothermal**

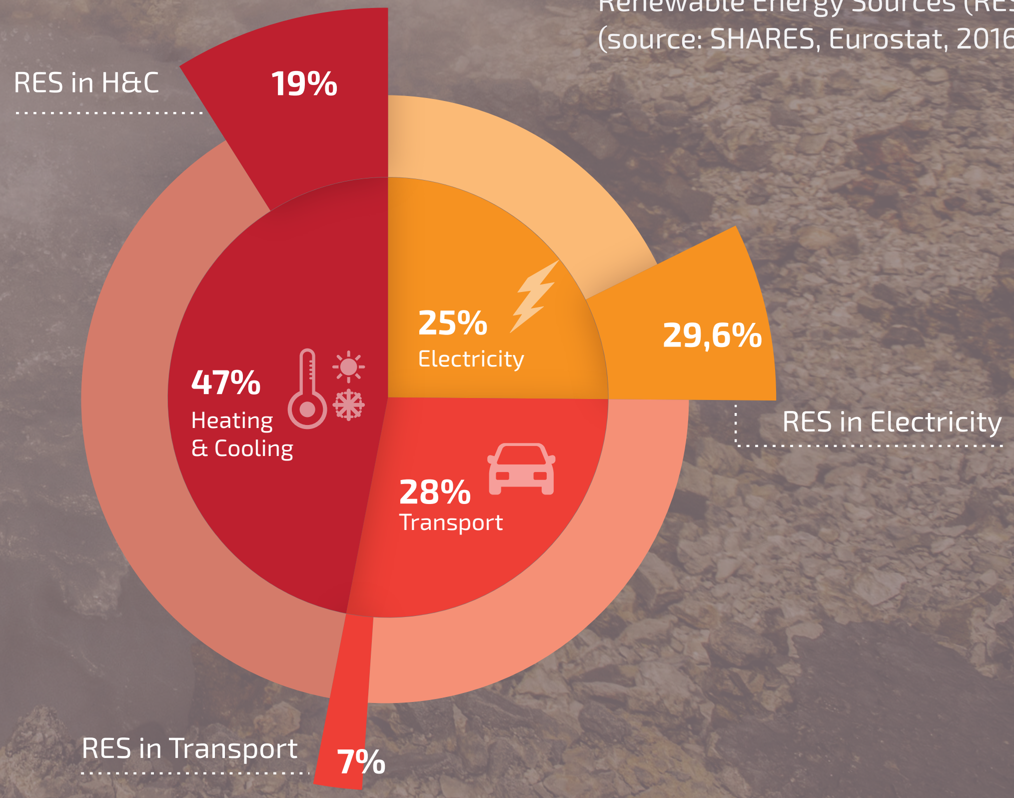
Rising to the **VISION**

Climate change and energy supply are two of the biggest challenges that the world is facing today. To tackle these issues, the European Union has designed the Energy Challenge in a move towards a reliable, sustainable and competitive energy system.

The current negotiation of the 2030 climate and energy packages aims to set ambitious targets regarding minimum shares of renewable energy consumption and energy savings, and thus to pave the way to the decarbonisation of the European economy by 2050 with more than an 80% reduction in greenhouse gas emissions (GHGs). The development of low carbon technologies is a key part of the EU strategy. Geothermal energy, and its generation of electricity, heating and cooling, can contribute to the local, regional and global energy transition toward reliable, clean and affordable energy sources.

To speed up the development and deployment of low-carbon technologies, including geothermal energy, and to strengthen the cooperation with Stakeholders under the Strategic Energy Technology Plan (SET-Plan), the European Commission has introduced Technology and Innovation Platforms (ETIPs).

FIGURE 1
Shares (%) of EU28 final energy consumption per sector (1143 Mtoe) and sectorial penetration of Renewable Energy Sources (RES) (source: SHARES, Eurostat, 2016).



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"City of the future", Andrei Cotrut

ISBN 9788879580359
Citation: European Technology and Innovation Platform on Deep Geothermal (ETIP-DG) (2018). "Vision for deep geothermal".

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CONTENTS

This **Vision for Deep Geothermal** looks towards the future of Deep Geothermal energy development in the few next decades, and highlights the great potential of untapped geothermal resources across Europe.

INTRODUCTION

FUTURE DEVELOPMENT OF DEEP GEOTHERMAL TECHNOLOGIES IN EUROPE

The Vision of the European Technology and Innovation Platform on Deep Geothermal (ETIP-DG) entails using geothermal energy to cover:

1. A significant part of the demand for **domestic heat;** and
2. Much of the demand for **electrical power** in Europe.

This includes fully exploiting the flexibility of the geothermal supply, providing large **centralized** as well as domestic and **decentralized** small scale options.

The ETIP-DG is an open stakeholder group, including representatives from industry, academia, research centres, and sectorial associations supporting the deployment of the next generation of geothermal electricity and heat plants. The ETIP-DG involves Research, Development and Innovation (R&D&I) for sustainable heat extraction from the earth. It is also a hub for sharing information and experiences. Despite the name "deep geothermal", depth is not a limiting factor, but in practice threshold temperatures (depending on utilisation technologies) for geothermal resources relate to a minimum depth typically exceeding 500 m.

Deep geothermal covers a wide range of technologies, some specific to the sector, others typically used in other sectors (e.g. heat pumps), which in combination enhance performance. The technologies are also highly relevant for heat storage and other renewable energy applications.

Geothermal has huge potential and opportunities. After nearly a decade of slow development, in the last five years there has been a resurgence of interest in geothermal applications in terms of electricity generation and direct uses of heat (above all district heating).

Many non-technical barriers are still to be overcome. The success of the energy transition entails designing optimal scenarios in terms of costs and affordability for the customers and the citizens, while guaranteeing energy comfort. New developments should also take into account other societal challenges such as social welfare and climate change. As a local and stable source of renewable energy, geothermal will be crucial in the future energy system.

The previous geothermal Vision was part of the Common Vision for the Renewable Heating & Cooling (RHC) sector in Europe, organized by the RHC Platform[1]. The main challenges and research needs for the full deployment of geothermal energy were laid out in 2011, and paved the road to our Vision today.

This Vision is designed to trigger a debate about how best to achieve a future for geothermal energy in Europe that is secure, affordable, low carbon and which has the least impact on nature. The Strategic Research Agenda and Roadmap documents, which will follow, will outline how the EU's energy policy needs to develop between now and 2050 if this Vision is to be achieved.

1 - 2020-2030-2050 Common Vision for the Renewable Heating&Cooling sector in Europe, RHC Platform, European Union 2011

Photo: Geothermal power plant in Italy

GEOTHERMAL IN EUROPE TODAY

The growth potential for geothermal has been recognized just recently, but geothermal has been a source of energy to humankind since the dawn of civilization. For centuries, hot springs have been used for bathing, healing, heating, and as a secure source of water in hundreds of places all over Europe. For example, the 46°C thermal springs in Bath (UK) were thermal baths in Roman times. In the Middle Ages, the hot springs of the Elvenschans (Belgium) were a secure source of flowing fresh water even during the harshest winters. Today, geothermal energy is being exploited as a direct source of heat on a large scale by tapping into hot-water-bearing underground layers. The resource is renewable, since heat is continuously supplied at depth by geological processes, and is dispersed through the soil. Using geothermal technologies, part of this heat is concentrated and used at the earth's surface. The geothermal industry in the EU is a world leader in the geothermal market, and exports its expertise and products globally.

Although geothermal development in Europe dates back more than a century, it still occupies a niche market compared to other energy sources. The development of geothermal energy is hindered by limited knowledge about the technologies and their potential among policy makers, economic actors and the public. For example, few people are aware of the huge contribution of geothermal energy for district heating in the Paris Basin, which developed without a subsidy in the 1970s, or the fact that the city of Munich plans to decarbonize the city's energy supply by 2040 using geothermal resources which they found were the most economic of alternative renewable energy sources.

Other challenges are financial, legal, logistic and technical. Although EU support for geothermal research, development and innovation has increased, it is still lower than for other renewable energy sources. Complex and incomplete regulations, fragmented among EU Member States, and long and complex authorization have slowed down geothermal deployment.

FIGURE 2
Thanks to the continuous release of heat, underground temperature, with a trend that depends on local geological conditions, increases with depth. The average trend is technically called geothermal gradient.

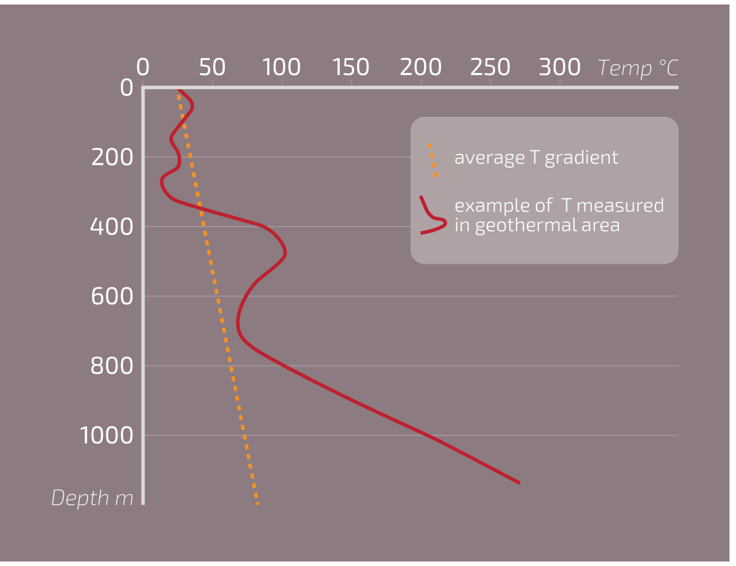


FIGURE 3
Since geothermal energy is constantly provided, the Capacity Factor (i.e. actually produced energy with respect to the full capacity) is much higher than for other renewable energy sources (sources: Renewables 2017 Global Status Report, REN21; EUROSTAT), resulting in a total cost (LCoE) comparable or lower than for other energy sources (source: IRENA, 2017)

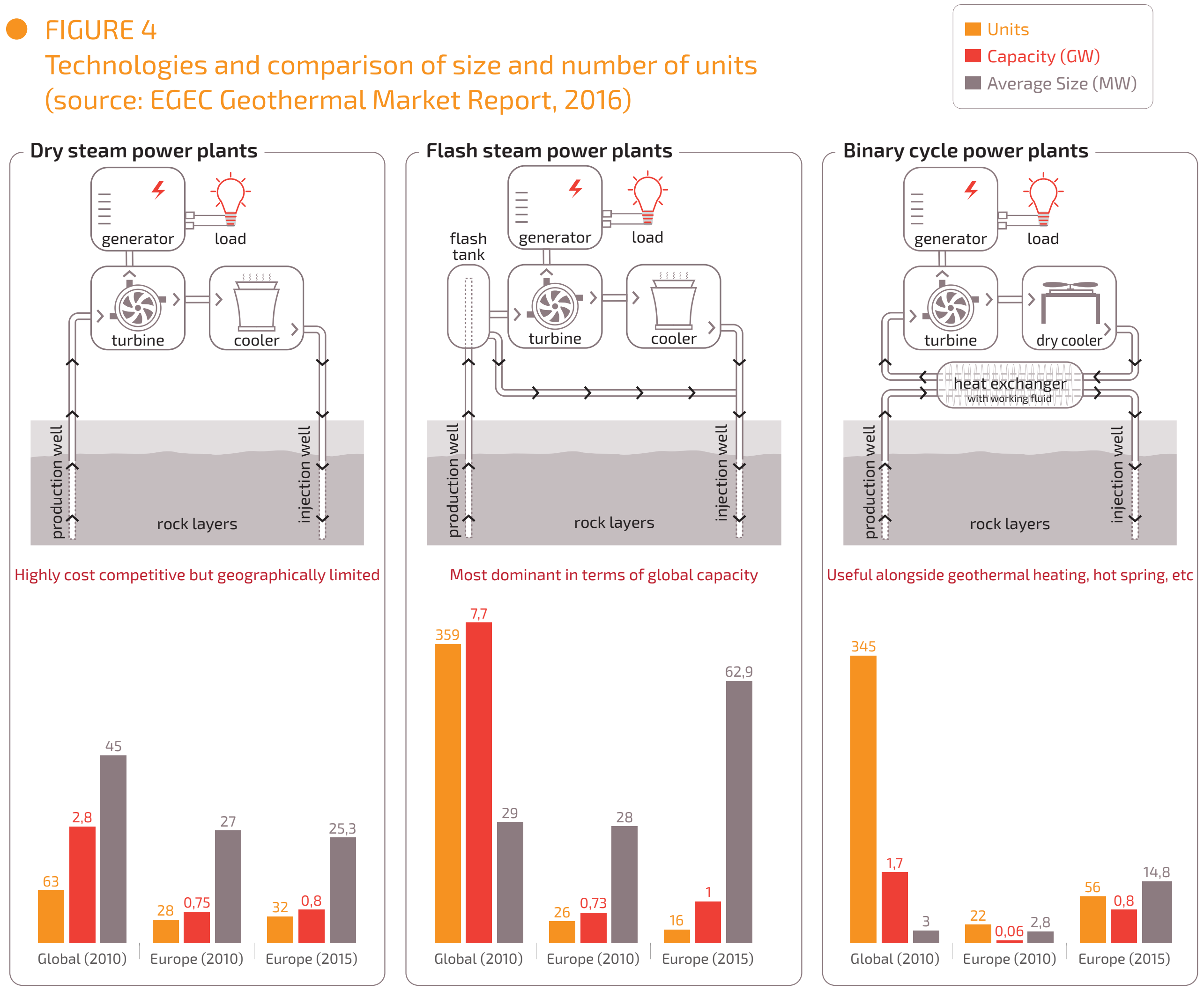
Electricity

Electricity is produced from geothermal fluids through a *turbine*, where heat is transformed into mechanical energy and then into electricity via a *generator*. The fluid sent to the turbine can be the geothermal fluid extracted from the ground (*direct or flash steam systems*) or a secondary fluid heated by the geothermal fluid through a heat exchanger (*binary systems*).

Electricity was first generated from geothermal resources in the first decade of the 20th century, when in the village of Larderello in Tuscany, Italy, geothermal fluids produced enough electricity to power the local industry in boron products.

By the 1970s, only a few plants had been installed in Europe, mainly in Italy and Iceland, followed by France (Guadeloupe), and Turkey. All of them used high temperature (over 250 °C) resources with direct or flash steam turbine technology. With the development of binary cycle technologies that can produce electricity from lower temperatures (as low as about 110 °C), geothermal plants were then set up in other countries (Austria, Germany, Portugal). Today, there are 102 geothermal power plants in the seven countries mentioned above with a total installed capacity amounting to around 2.5 GWe, producing some 14.6 terawatt-hours (TWh) of electric power every year.[2]

FIGURE 4
Technologies and comparison of size and number of units (source: EGEC Geothermal Market Report, 2016)



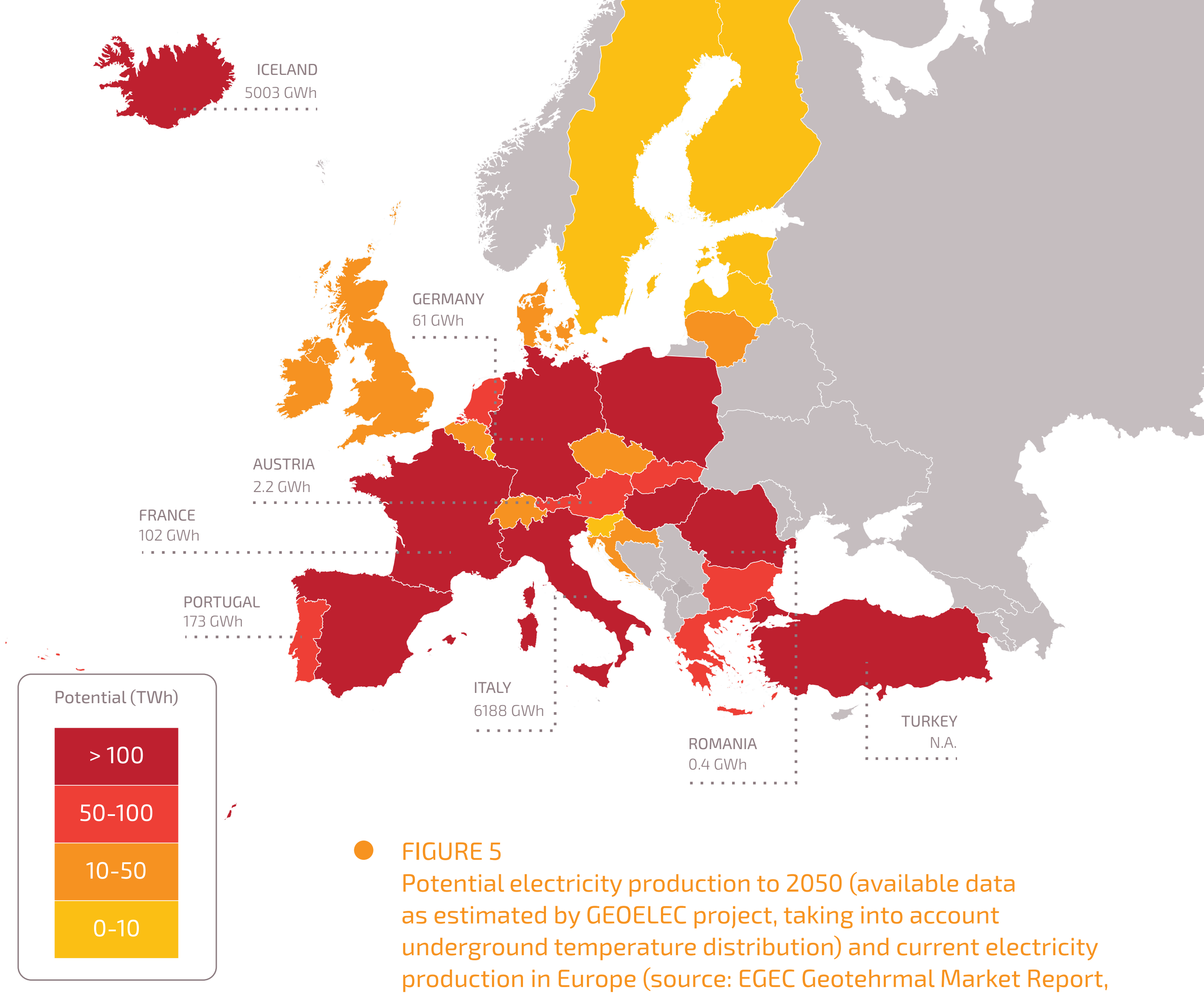


FIGURE 5
Potential electricity production to 2050 (available data as estimated by GEOELEC project, taking into account underground temperature distribution) and current electricity production in Europe (source: EGEC Geotehrmal Market Report, 2016)

Electricity generation from geothermal resources has a huge potential in Europe, especially when the new generation of technologies for enhancing heat extraction become competitive. The economic potential for geothermal power in Europe in 2030 and 2050 has been estimated using a cost (Levelised Cost of Electricity, LCoE) value of less than 150 €/MWh for 2030 and less than 100 €/MWh for 2050. The total geothermal electricity potential in the EU is 34 TWh, about 1% of the projected total electricity supply in the EU in 2030. Economies of scale, innovative concepts for accessing the underground, and substantial cost reductions, should lead by 2050 to a coverage of as much as 50% of the projected electricity supplied in the Europe (including Iceland, Turkey and Switzerland)[3]. Geothermal electricity could be generated in most European countries.

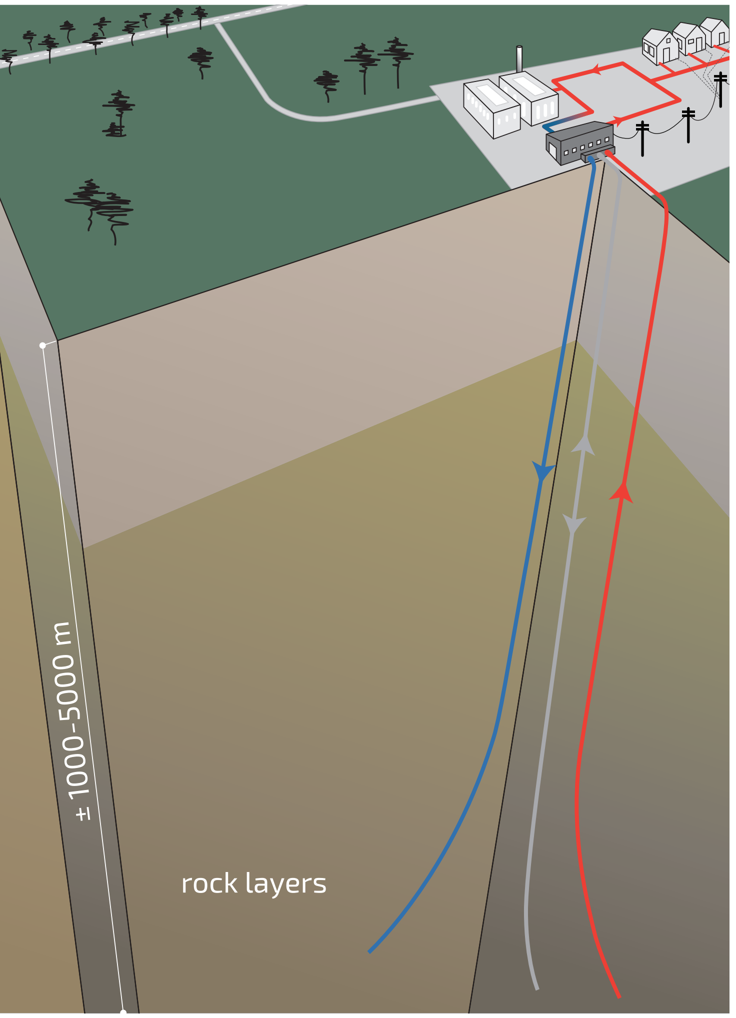
2 - EGEC Geothermal Market Report 2016

3 - Towards more geothermal electricity generation in Europe, GEOELEC Project, 2014

Heating and cooling

The **heating and cooling sector** represents nearly 50% of Europe's energy demand, and geothermal energy is becoming more and more attractive as a competitive renewable heating source, as the energy sector as a whole is facing a dual challenge: decarbonisation whilst securing the provision for heating at an affordable price for consumers.

To cover demand for heating and cooling, Deep Geothermal energy offers vast resources to be utilized for numerous technical options, ranging from the supply of heat and cold (H&C) to single houses also in combination with geothermal heat pumps, up to providing heat to whole cities or city quarters through large district heating (DH) networks.



Deep Geothermal installations require the extraction of fluids from the underground and their reinjection after use, in a typical doublet or triplet system (as in Figure). The heat from the fluids can be used directly, or enhanced by ground source heat pump (GSHP) technologies. Heat pumps can be used to adjust the temperature of geothermal fluids to the (higher) level needed, for example, in a residential building, or to adjust the temperature of heat coming from cooling the building to the (lower) level required to inject it into the ground. Systems can be small (from 0.5 to 2 MWth), or large with a capacity of 50 MWth or more.

In 1930, the first geothermal district heating (GeoDH) system in Europe was installed in Reykjavik, Iceland. The government of Iceland promoted the exploration for geothermal resources as well as research into the various ways geothermal energy can be utilised. The Icelandic government also set up an Energy Fund to further increase the use of geothermal resources.[4] Since then, the direct use of geothermal heat has grown continuously, with peaks in development shortly after the first oil crisis and over the last decade.

Today, Europe has 280 plants for GeoDH[5]. 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.

4 - Geothermal development and research in Iceland, ORKUSTOFNUN, 2010

FIGURE 6
A typical doublet/triplet system for fluid management: a production well (in red) for extracting hot fluids from the underground; an injection well to re-inject fluid cooled after heat utilization (in blue). A third well can be added for production or injection.

5 - EGEC Geothermal Market Report 2016

TOP 7 COUNTRIES
for geothermal district heating production (Source: EGEC Geothermal Market Report 2016)

- **Iceland** › 6421 GWth
- **France** › 1335 GWth
- **Germany** › 662 GWth
- **Hungary** › 380 GWth
- **Austria** › 272 GWth

FIGURE 7
Installed capacity of geothermal heat for different applications in Europe (Source: Antics et al., 2016)

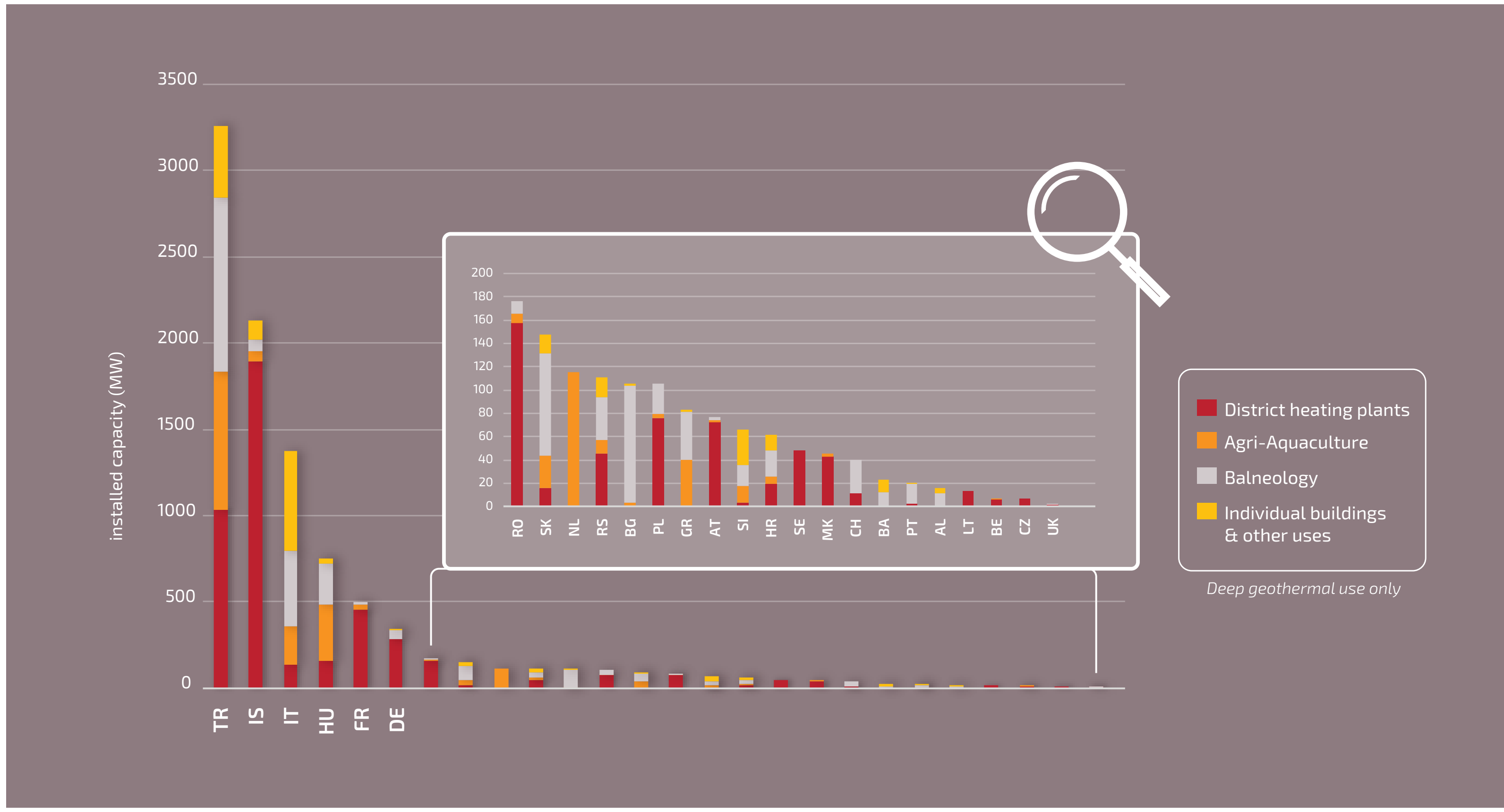


Photo: *Greenhouse heated by geothermal in The Netherlands*

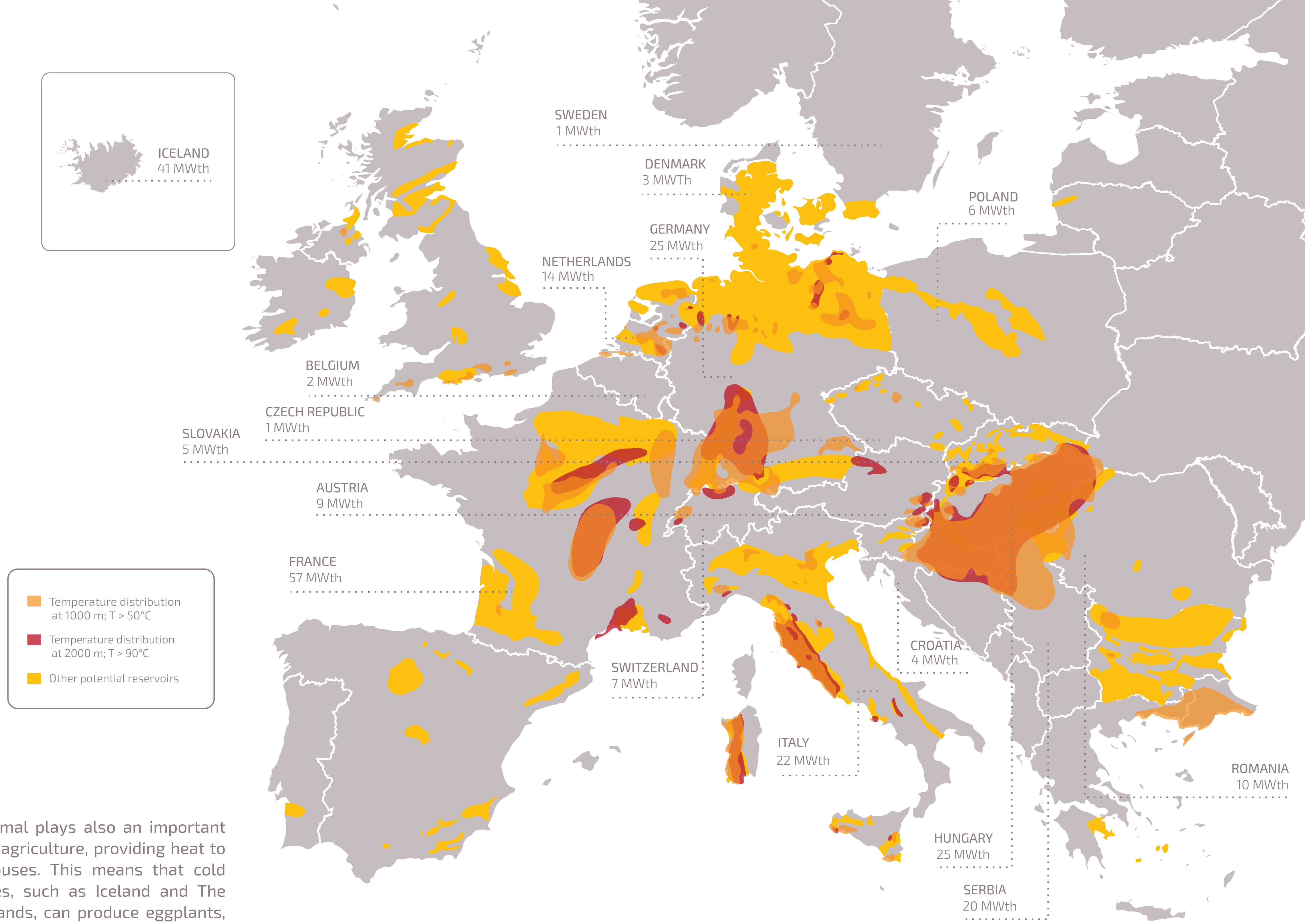


FIGURE 8
Areas suitable for geothermal heating and cooling networks (combination of high heat demand and areas where the temperature at 2 km depth is higher than 60°C. Source: update GeoDH, 2014, and available data), and actual geothermal district heating installed capacity (Source: EGEC Geothermal Market Report, 2016).

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. Also countries with a mild climate can benefit of geothermal heat: greenhouses in geothermal areas of Italy produce flowers and basil for the Italian market during winter.

UNLOCKING GEOTHERMAL ENERGY

Heat generation development

Thanks to continuous technological developments, geothermal resources that previously were out of reach will be explored and developed. The new technologies will make it technically and economically feasible to deliver hot fluids even in **areas with an average or low geothermal gradient**, by enhancing heat extraction, going deeper, or with the help of heat pumps to lift the temperature. High temperature geothermal sources will also drive absorption chillers, making deep geothermal a unique energy source for fourth generation district heating & cooling (DHC) networks and for industrial processes.

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 demands. 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 day-time 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.

Photo: Blue Lagoon, Iceland

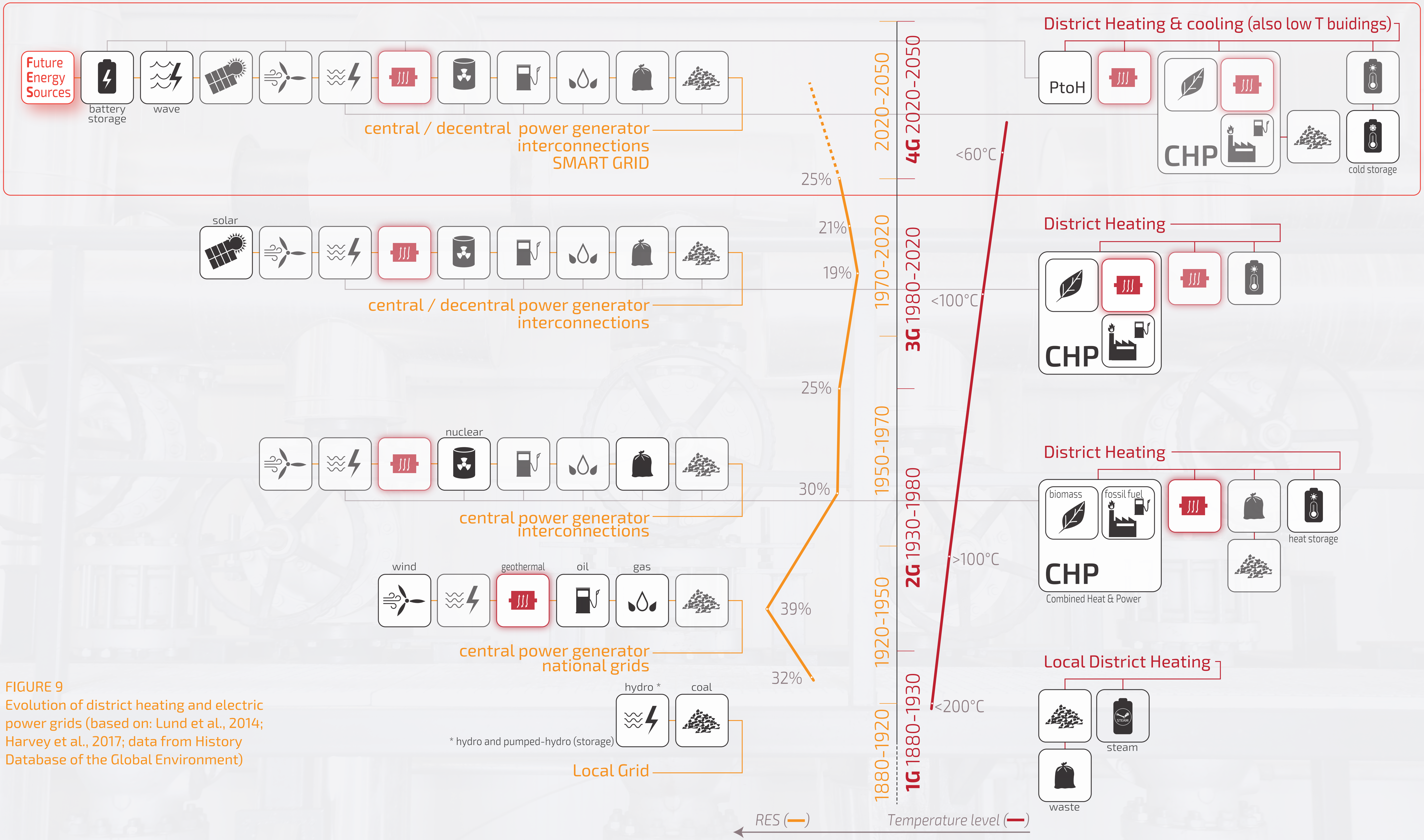


FIGURE 9
Evolution of district heating and electric power grids (based on: Lund et al., 2014; Harvey et al., 2017; data from History Database of the Global Environment)

Electricity generation development

The use of geothermal heat for producing electricity is the most flexible way to produce a clean renewable and sustainable energy, easily transportable even over long distances and ready for use for the end-users. Only two conditions are necessary: the hot fluid produced via a geothermal well must have a sufficient flow rate and must have a temperature above a given threshold.[6]

6 - The threshold depends on used technology, including hybrid generation, and satisfies the thermodynamic principle.

The "temperature parameter" affects the efficiency of transformation from heat to electricity, whereas the "flow rate constraint" is related to the number of wells required for a given supply threshold. The highest potential for massive supply from geothermal resources is in areas showing high temperature at relatively shallow depths (e.g. in magmatic areas, as in Iceland, Italy, Turkey and volcanic areas). However, with new technologies geothermal electricity generation will be possible everywhere, **going deep** enough to reach the required temperature and **improving heat extraction** wherever the natural flow rate proves to be too low.

Enhanced technical solutions will boost the electrical potential development:

- The utilisation of geothermal resources will be optimized, with a focus on increasing efficiency and reducing LCoE for low temperature binary plants;
- The existing high temperature technologies (heat exchanger, flash/steam plants) will be improved, even through disruptive ideas on cycle design, novel materials, and more;
- Technologies for enhancing heat extraction at depth will be optimized, proved at a large scale, and safety precautions will be standardized;
- The unique capability of geothermal energy to operate in hybrid mode with other renewable energy sources (photovoltaic, concentrated solar, biomass and biofuels) will be intensified, with an overall increase in total energy conversion factor;
- New technologies will enable us to access and manage deep and extremely hot resources, whose productivity will be ten times higher than in existing hot systems;
- Cutting-edge technologies will be extensively assessed for producing from untapped resources that pose peculiar issues, such those off-shore, close to magma shallow intrusions, depleted or unproductive hydrocarbon fields and more.

Geothermal energy will also play a unique role on **islands and in remote areas**, where its flexibility and stability can be a major asset for small local grids, solving critical problems for isolated communities.

Photo: Combined biomass-geothermal power plant "Cornia 2", Italy

Combining renewable heat and electricity sectors and markets for an optimal use of geothermal energy

Combined production of Cool, Heat and electrical Power (CCHP) will be optimized thanks to low temperature (binary) conversion technologies, which are less vulnerable to maintenance. These can be improved and made affordable by:

- Increasing the efficiency, and reducing losses and internal consumption;
- Improving reliability and durability (resistance to corrosion, abrasion) of equipment;
- Extending the economic resource base by breakthroughs in technologies for subsurface access and heat extraction from the underground;
- Reducing the overall cost for CCHP generation. Our target is to reach an LCoE of 10 €/MWh within a few decades.

Deep geothermal adds flexibility to the energy landscape of the future with its interconnected local energy grids that are fed by a variety of local (renewable) energy sources and that connect the various energy sectors (i.e., electricity, heating & cooling and transport). The local grids will be driven by **new market models** in which the separation between energy producers and consumers becomes less sharp than it is today.

The integration of local renewable resources such as photovoltaics, solar thermal, (small) wind turbines or digesters will allow users to become both producers and consumers of energy, i.e. "*prosumers*".

Balancing the energy networks will become more challenging due to the intermittent character of various renewable energy sources, the actions of prosumers and the interconnection between electricity, heating & cooling, gas and transportation. Deep geothermal bridges different energy sectors, as it can be used for base load supply or adjusted to deal with imbalances in demand and supply:

- Geothermal CCHP plants create flexibility to supply heat/cold or electricity depending on demand;
- By linking geothermal sources to heat pumps, the heat supply during periods of high heat demand increases;
- The excess heat from other sources is stored underground by geothermal wells;
- The excess electricity supply can be stored underground as heat for later use;
- Fuels (e.g. gas, methanol) produced by geothermal fluids and heat can be used to store energy or for transportation purposes.

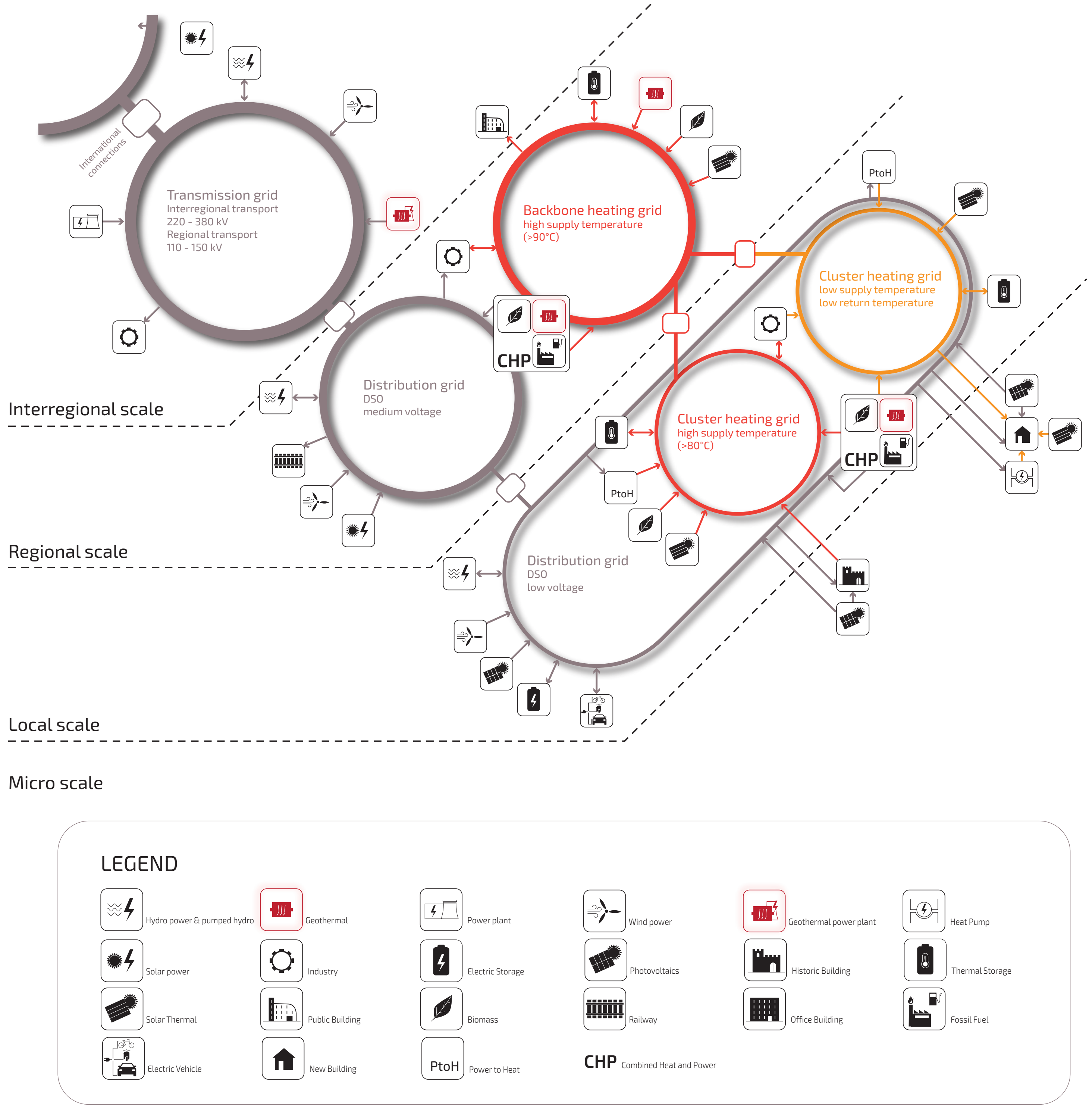


FIGURE 10
In the interconnected energy networks based on renewable energy sources, geothermal and underground thermal storage play an important role (courtesy of DNV GL, based on: Noordhoff Uitgevers B.V., 2012)

Due to this flexibility, deep geothermal can balance energy flows in DHC networks that integrate multiple renewables (over all energy vectors). This adds to the attractiveness of geothermal as indigenous, locally available, environmental benign, clean, renewable and sustainable energy source.

CITY OF THE FUTURE

We have a vision of the "**city of the future**": a combination of renewable energy sources, for local electricity and heating/cooling supply at house level, with or without storage facilities, and electrical cars integrated into the system. We envisage large heating networks fed by geothermal heat, with intelligent exchanges of energies between houses and the major supply pole. It will be a city that has **100% renewable power sources in terms of electricity, heating/cooling and mobility**, with zero impact on the environment (no pollution, no GHG emission, no long distance transportation of fossil fuels), where citizens will act as "prosumers" in a smart, clean, renewable and sustainable system.

INCREASING SOCIAL WELFARE IN EUROPE

The Europe 2020 strategy aims to overcome the shortcomings of the current energy growth model in order to achieve smart, sustainable and inclusive growth.[7]

Geothermal technologies will thus improve the quality of life, the quality of the environment and social inclusion, as well as cohesion and solidarity within and among Member States[8]. The geothermal approach aims to comply with Responsible Research and Innovation (RRI) that has sustainability, inclusion and public engagement within its key dimensions.

7 - Indicators for promoting and monitoring Responsible Research and Innovation, European Commission

8 - Responsible Research and Innovation: options for research and innovation policy in the EU, by Owen R., 2014

Geothermal technologies will achieve a lower **environmental footprint** than any other renewable energy source:

- Any contaminant contained in geothermal fluid will be re-injected into the subsurface or captured and utilised, when useful, or correctly disposed of;
- The total re-injection of geothermal fluids into the subsurface will guarantee that the current zero emissions of industrial plants due to the absence of combustion will be accompanied by zero natural greenhouse gas emissions whenever geothermal fluids contain non-condensable gases;
- There will be no induced seismicity hazard thanks to advanced fluid extraction and injection technologies, and the abundant and transparent monitoring data to distinguish between natural and industrially-driven phenomena;
- Any unwanted and/or unpredictable interactions with other geological or ecological systems will be avoided through comprehensive monitoring and remediation.

Geothermal deployment will create **wealth**: local jobs and investments will be at the service of citizens. Geothermal skills will be reinforced to provide a more stable European market and to expand exports of equipment and expertise. Local energy solutions with citizen participation and attention for the socially weak will be designed. The technologies for micro-supply will further expand the decentralised energy distribution and facilitate the evolution from consumers to prosumers.

By strengthening **dissemination, education and outreach**, society will be aware of the benefits and impacts of geothermal energy. Further specialisation will create new jobs opportunity. Citizens will be ready to actively contribute to a sustainable and effective geothermal growth planning by a mutual exchange of perspectives.

The Deep Geothermal sector also aims to guarantee **protection and empowerment** of customers, offering meaningful and efficient choices and expecting their increasing participation in the energy market, both as consumers and prosumers.

NOVEL TECHNOLOGIES FOR FULL AND RESPONSIBLE DEPLOYMENT OF GEOTHERMAL POTENTIAL

We are forecasting a very ambitious development of geothermal energy utilization in Europe, both for electricity and heat. However, in order to make our Vision a solid reality in the near future, we have to go beyond the business-as-usual approach and to promote **breakthroughs** in all the technological and cross-cutting innovation themes, while pursuing the EU long-term goal[9] of **reducing costs** and **increase performance** of geothermal technologies and installations.

A new generation of technologies and knowledge management for a full and responsible deployment of geothermal potential is foreseen, and challenges in the technological and cross-cutting innovation themes will be completed.

9 - SET Plan, Declaration of intent on Strategic Targets in the context of an Initiative for Global Leadership in Deep Geothermal Energy, European Commission 2016

1 Prediction, assessment and access to the resource

A better understanding of complex and deep geological processes will enhance the predictability of physical and chemical underground conditions; deep exploration technologies will have high-resolution imaging capacity and data modelling will be fully integrated; there will be safe, rapid and automated technologies for accessing the underground.

2 Resource development

Extraction of heat from the underground will be maximized by improved well designs, and safe and sustainable flow enhancement; lifetime of boreholes and system components will be prolonged by monitoring, augmented with in-depth understanding of reservoir and thermal loop processes; geothermal energy storage will be efficient, fully integrated in the energy systems and responsive to demand.

3 Heat and electricity generation

The net efficiency, performance and cost-effectiveness of production systems will be optimized, extending the temperature range of application; conversion of heat to electricity and to chill will be only constrained by physical laws and the production will be totally responsive to the demand and sustainable; hybrid, multi-source and multipurpose high-efficiency systems embedding geothermal technology will become the European standard.

4 Assessment and optimization of environmental, social and economic footprints

... will

1) help to establish a legislative framework that will sustain geothermal deployment, its penetration and profitability while guaranteeing that resources are properly managed;

2) provide low environmental impact technologies;

3) define economic evaluation criteria, including technical and economic risk assessment;

4) sustain partnerships between companies and consumers, by strengthening reciprocal trust through ethics and security .

5 Data and knowledge sharing

Information, communication and analytics capabilities will be enabled on a large scale; underground data will expand in number and type, will be globally organized and made easily accessible; terms of reference for reporting and computing geothermal potential, production and capacity will be harmonized; data sharing will improve scalability and extrapolation of the information, improving the capacity to forecast techno-economic parameters and influencing energy planning.

FULL AND RESPONSIBLE DEPLOYMENT OF GEOTHERMAL RESOURCES

KEY MESSAGES

RESOURCE POTENTIAL

Geothermal is a widely available energy source, since underground heat is available everywhere

FIT FOR PURPOSE

Geothermal has a large potential of expansion in numerous applications and places

STABILITY & AVAILABILITY

Geothermal energy is available around the clock and has a predictable output

GROWTH

Production from untapped geothermal resources has the potential to become a local economic development booster

SUSTAINABILITY

The geothermal environmental footprint is much lower than those of other energy sources

COGENERATION & HYBRIDISATION

Geothermal can be combined with other energy sources and technologies to optimise efficiency

OPTIMISATION

Geothermal is a versatile energy, whose multiple-applications are optimised by cascading uses of heat at progressively lower temperatures

COOL & APPEALING

Beside cooling the air of our houses, working spaces, malls, and airport geothermal is simply beautiful because it is essentially invisible

FLEXIBILITY

Geothermal operates continuously to meet the minimum level of power demand and may adapt to meet variable levels of energy demand

MARKET PENETRATION & SOCIAL DIMENSION

Geothermal is a domestic and green resource, secure, stable, clean, and contributes to energy efficiency

GLOSSARY

BASE LOAD
The minimum amount of energy that a utility or distribution company must generate for its customers, or the amount of energy required to meet minimum demands based on reasonable expectations of customer requirements.

BINARY SYSTEM
A type of geothermal plant that uses geothermal fluids to heat a secondary fluid, which is in turn used to generate electricity by mean of a turbine. It differs from Flash Steam systems in that the water or steam from the geothermal reservoir never comes in contact with the turbine/generator units.

CAPACITY FACTOR
The ratio between the energy actually produced and the energy that would be produced at full capacity.

CASCADE USES
A sequential operation of geothermal heat by integrating different technologies that use progressively lower temperatures. The resulting poly-generation exploits the available energy after each use, and optimises the generation benefiting in different uses of lower temperature requirements.

CONSUMERS
Persons purchasing and consuming energy (or any goods and services in other contexts).

DISTRICT HEATING
A system for distributing, via a network of pipes, hot water generated in a centralised location for residential and commercial heating requirements such as space heating and water heating.

DISTRICT HEATING AND COOLING
An expansion of the district heating concept, combining technologies for centralised generation and distribution of heating and cooling.

ENVIRONMENTAL FOOTPRINT
It measures the effect on environment involved in the production of the energy under consideration (or any other good or service in other contexts).

EUROPEAN STRATEGIC ENERGY TECHNOLOGY PLAN (SET-PLAN)
European plan for accelerating the development and deployment of low-carbon technologies. It seeks to improve new technologies and bring down costs by coordinating national research efforts and helping to finance projects. The SET-Plan promotes research and innovation efforts across Europe by supporting the most impactful technologies in the EU's transformation to a low-carbon energy system. It promotes cooperation amongst EU countries, companies, research institutions, and the EU itself.

EUROPEAN TECHNOLOGY AND INNOVATION PLATFORMS (ETIPS)
An open platform created to support the implementation of the SET-Plan by bringing together EU countries, industry, and researchers in key areas. These platforms promote the market uptake of key energy technologies by pooling funding, skills, and research facilities.

FLASH STEAM SYSTEM
A type of geothermal plant that uses geothermal fluids in the vapor phase to drive a turbine and produce electricity (see Binary system).

GREENHOUSE GASES
Any gaseous compound in the atmosphere that is capable of absorbing infrared radiation, thereby trapping and holding heat in the atmosphere.

HYBRID SYSTEMS
Two or more modes of power generation combined together, usually using renewable technologies.

HEAT PUMP
A device that moves thermal energy in the opposite direction of spontaneous heat transfer by absorbing heat from a cold space and releasing it to a warmer one.

LEVELISED COST OF ENERGY (LCOE)
The ratio between the cost of a generating an asset during its whole lifetime and the electricity produced. Representing the total costs, it can be used to compare different technologies that have unequal lifespans, project sites, capacities, capital, and operating costs and revenues.

PROSUMERS
People who both consume and produce energy.

QUALITY OF LIFE
A broader concept than economic production and living standards, including the full range of factors that influence what people value in living, beyond the purely material aspects.

PUBLIC ENGAGEMENT
It envisions impacts and reflect on the underlying assumptions, values, and purposes to better understand how R&I shapes the future. This yields to valuable insights and increase our capacity to act on what we know[1].

RE-INJECTION
Injection of geothermal fluids, cooled after heat extraction, in the underground, typically close by the extraction area.

RESEARCH AND DEVELOPMENT AND INNOVATION (R&D&I)
Promoting R&D&I is an important European Union objective laid down in Article 179 of the Treaty, which states that "[t]he Union shall have the objective of strengthening the scientific and technological bases by achieving a European research area in which researchers, scientific knowledge and technology circulate freely, and encouraging it to become more competitive, including in its industry, while promoting all the research activities deemed necessary"[2].

RESPONSIBLE RESEARCH AND INNOVATION (RRI)
According to this approach societal actors work together during the whole research and innovation process in order to better align both the process and its outcomes, with the values, needs and expectations of European society[3].

SUSTAINABLE DEVELOPMENT
Meeting the needs of the present whilst ensuring future generations can meet their own needs. It has three pillars: economic, environmental and social. To achieve sustainable development, policies in these three areas must work together and support each other[4].

TURBINE
A device that converts the kinetic energy into mechanical energy and, combined to a generator, to electrical energy.

1 - *https://www.rri-tools.eu/about-rri*

2 - Official Journal of the European Union 27/6/2014

3 - "RRI. Europe's ability to respond to societal challenges", EU Commission, 2012

4 - EU trade policy and sustainable development

TERMS & ABBREVIATIONS

CCHP
Combined Cool, Heat and electrical Power

DH
District Heating

DHC
District Heating and Cooling

EU
European Union

GEODH
Geothermal District Heating

GHG
GreenHouse Gases

GSHP
Ground Source Heat Pump

H&C
Heating and Cooling

LCOE
Levelised Cost of Energy

O&M
Operation and Maintenance

R&D&I
Research, Development and Innovation

RES
Renewable Energy Source

RRI
Responsible Research and Innovation

The Secretariat of the European Technology & Innovation Platlform on Deep Geothermal (ETIP-DG) is jointly managed by:

EGEC GEOTHERMAL vito

igg National Research Council of Italy

REFERENCES

Antics M., Bertani R., Sanner B. (2016). "Summary of EGC 2016 Country Update Reports on Geothermal Energy in Europe". Proc. European Geothermal Congress 2016.

EGEC (European Geothermal Energy Council) (2017). "EGEC Geothermal Market Report 2016". Available at: *https://www.egec.org/media-publications/egec-geothermal-market-report-2016/*

European Union (2011). "2020-2030-2050 Common Vision for the Renewable Heating& Cooling sector in Europe, RHC Platform". ISBN 978-92-79-19056-8 doi:10.2788/20474. Available at: *http://www.rhc-platform.org/fileadmin/Publications/RHC_BROCHURE_140311_web.pdf*

European Commission (by Owen R.) (2014). "Responsible Research and Innovation: options for research and innovation policy in the EU". Available at: *https://ec.europa.eu/research/innovation-union/pdf/expert-groups/Responsible_Research_and_Innovation.pdf*

European Commission (2015). "Indicators for promoting and monitoring Responsible Research and Innovation. Report from the Expert Group on Policy Indicators for Responsible Research and Innovation". Available at: *https://ec.europa.eu/research/swafs/pdf/pub_rri/rri_indicators_final_version.pdf*

European Commission (2016). *"SET Plan Declaration of intent on Strategic Targets in the context of an Initiative for Global Leadership in Deep Geothermal Energy". Available at: https://setis.ec.europa.eu/system/files/integrated_set-plan/declaration_of_intent_geoth_0.pdf*

EUROSTAT database. "SHARES 2016". Available at: *http://ec.europa.eu/eurostat/documents/38154/4956088/SHARES-2016-SUMMARY-RESULTS.xlsx/97eeb23c-9521-45d6-ab30-578246f1a89d*

EUROSTAT database. "Energy balances, 2018 edition". Available at: *http://ec.europa.eu/eurostat/web/energy/data/energy-balances*

EUROSTAT database. "Infrastructure – electricity – annual data". Available at: *http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_113a&lang=en*

Harvey, A., Larson, A., and Patel, S. (2017). "History of Power: The Evolution of the Electric Generation Industry". Power Magazine, 10/01/2017

History Database of the Global Environment. *http://themasites.pbl.nl/tridion/en/themasites/hyde/index.html*

GeoDH Project (2014). "Map tool, GeoDH Map". Available at: *http://geodh.eu/geodh-map/*

GEOELEC Project (2013). "A prospective study on the geothermal potential in the EU". Available at: *http://www.geoelec.eu/wp-content/uploads/2011/09/D-2.5-GEOELEC-prospective-study.pdf*

IRENA webtool. "LCOE 2010-2016". Available at: *http://resourceirena.irena.org/gateway/dashboard/?topic=15&subTopic=38*

Lund, H., Werner, S., Wiltshire, R., Svendsen, S., Thorsen, J.E., Hvelplund, F., and Vad Mathiesen, B. (2014). "4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems." Energy 68: 1-11.

Noordhoff Uitgevers B.V. (2012). "De Bosatlas van de energie".

ORKUSTOFNUN (National Energy Authority) (by Sveinbjörn Björnsson, Inga Dóra Guðmundsdóttir, Jónas Ketilsson) (2010). Geothermal development and research in Iceland. ISBN: 978-9979-68-273-8. Available at: *http://www.nea.is/media/utgafa/GD_loka.pdf*

REN21 (2017) "Renewables 2017 Global Status Report". ISBN 978-3-9818107-6-9. Available at: *http://www.ren21.net/wp-content/uploads/2017/06/17-8399_GSR_2017_Full_Report_0621_Opt.pdf*

SHARES-EUROSTAT webtool. Available at: *http://ec.europa.eu/eurostat/web/energy/data/shares*

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European Technology & Innovation
Platform on **Deep Geothermal**

The European Technology & Innovation Platform on Deep Geothermal (ETIP-DG) is an open stakeholder group, endorsed by the European Commission under the Strategic Energy Technology Plan (SET-Plan), with the overarching objective to enable deep geothermal technology to proliferate and reach its full potential everywhere in Europe.
The primary objective is overall cost reduction, including social, environmental, and technological costs.
The ETIP-DG brings together representatives from industry, academia, research centres, and sectoral associations, covering the entire deep geothermal energy exploration, production, and utilization value chain.
For more information on its activities visit www.etip-dg.eu

Vision for Deep Geothermal
ISBN 9788879580359

To obtain this publication visit: **www.etip-dg.eu**

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The sole responsibility of this publication lies with the author. The European Union is not responsible for any use that may be made of the information contained therein. Co-funded by the European Union's Horizon 2020 research and innovation programme [GA. No 773392]