FUTURE CLIMATE AND ENERGY POLICY
A STRATEGY FOR LONG-TERM EU GREENHOUSE GAS EMISSIONS REDUCTIONS

EGEC RESPONSES

Brussels, 9TH October 2018

EGEC, the European Geothermal Energy Council, was founded in 1998 as an international non-profit association in Brussels, with the aim of promoting the use of geothermal energy. EGEC represent more than 500 entities from 28 European countries.

(Identification number in the register: 11458103335-07)

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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.

INTRODUCTION

As the European Commission is starting to draft its mid-century climate and energy strategy, it is opening up to stakeholders with the stated objective to avoid previous mistakes that led to a skewed approach to energy and climate policies. Through the consultation on the future climate and energy policy of the EU, the Commission is very interested in gathering the “visions and reflections of stakeholders involved from all sectors of the economy and society on how to reach the EU’s ambition”. As energy and climate action has taken off in the past decade, and support to the energy transition has strengthened and the challenge of achieving the full decarbonization of the European economy becomes more tangible after the first actions taken thus far, the European Commission acknowledges the importance of an open process that gathers expertise and research from all stakeholder to draft a consistent strategy. This approach is a sensible one, that is quite welcome. By recognising the plurality of solutions in policy making and to achieve the energy transition, the European Commission gives itself more chances to achieve the needed reduction of greenhouse gases in the right timeframe and with the most benefits for the EU’s citizens and economy.

Over the coming decades, the EU will need to decarbonise its entire economy if it is to meet the requirements of the Paris agreement which sets an objective of limiting the increase of average global temperatures to well below 2°C, aiming at limiting the increase to 1.5°C. This objective, adopted by all Member States of the European Union and the EU itself, suppose a rapid decrease in greenhouse gases emissions, as there is only a limited amount of carbon that can be emitted before these thresholds are crossed. The European Commission will therefore have to steer the EU’s energy system in the direction of a rapid shift towards renewable energy sources and a swift improvement of energy efficiency.

There is no silver bullet in terms of technology but there is no silver bullet either in terms of policy. Nuclear fusion CCS, shale gas in the past and now electrification of transport and h&c are too much simplifying an answer to a rather complex European energy system.

The long-term strategy will have to reflect this reality and lay out a vision and policy proposals that prevent the lock in of carbon emissions and favour a dynamic and integrated approach to decarbonisation, one that is holistic and focused on unlocking the potential of available resources for a cost efficient decarbonisation that is the basis of a just transition towards a sustainable EU economy.

A DYNAMIC INTEGRATED APPROACH TO DECARBONISATION: AVOIDING EMISSION LOCK-INS AND NARROW VIEWS

HEATING AND COOLING: THE MISSING PIECE OF THE PUZZLE

Renewable heating and cooling is key to decarbonisation

Heating and cooling represents nearly 50% of the final energy consumption in the EU, either for domestic or industrial purposes. Hence, it is by far the largest energy end-use sector. The vast majority (81%) of heating is today produced through the combustion of fossil fuels, while cooling is predominantly produced from electricity-driven processes and, therefore, also largely relies on coal and gas. This is why the current heating and cooling system is not only boosting costly imports of fossil fuels into Europe, but is also major contributor to the overall EU's greenhouse gas emissions.

A shift towards carbon-free and locally produced energy sources is crucial if the Union wishes to reduce its greenhouse gas emissions by 80-95% by 2050. Accordingly, the Energy Roadmap 2050 rightly recognises renewable heating and cooling (RES H&C), notably geothermal, as vital to decarbonisation.

The lack of a holistic approach

The decarbonisation of the European economy concerns all dimension of this economy. It is particularly the case in the energy sector, which is responsible for around 80% of EU emissions. The EU's energy system is made up of three sectors, heating and cooling, electricity and transport, which respectively represent 47%, 25%, 28% of the EU's final energy demand. To reduce the EU's energy related emissions, it is crucial to engage in a switch away from fossil fuels, towards renewable energy sources. In addition, this transition must be done following the principle of energy efficiency first, meaning, the consideration of the usefulness of the energy used and avoiding wasting energy in terms of quantity and in terms of quality, but also using available renewable resources in a dynamic and integrated manner.

Despite the efforts undertaken the European economy since the publication of the first Renewable Energy Directive, all three sectors are moreover dominated by non-renewable energy sources (fossil fuels and nuclear), which represent 93% of supply for transport, 81% of supply for heating and cooling and 70% for electricity (see figure 1 below). While the relative penetration of renewables is highest in the electricity sector, in absolute terms, more renewable energy is still produced for heating and cooling. As a whole, it is uncertain whether the EU is on track to meet its objective of 20% of renewable energy by 2020. This is notably due to a lack of progress both in the heating and cooling and the transport sectors, which did not engage in the transition fast enough. By contrast, the strong policy focus put on the electricity sector allowed it to progress further towards decarbonisation, although much of the current renewable electricity production predates the Renewable Directive.

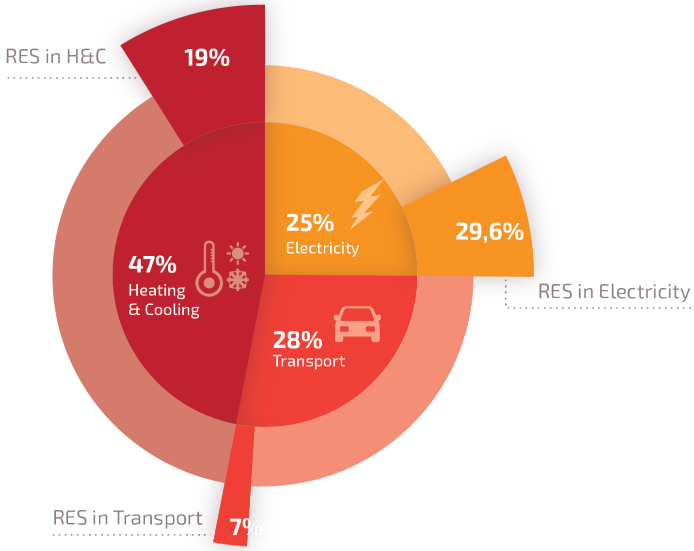

Figure 1.
Shares (%) of EU28 final energy consumption per sector (1143 Mtoe) and sectorial penetration of Renewable Energy Sources (RES)
(source: ETIP DG, based on Eurostat data)

A climate strategy that must overcome the limitations of economic models

Up to this point, the EU's energy and climate policies were largely based upon the outputs of economic modelling of the European energy system produced by the PRIMES model. This model is notably the source of the 2050 Energy Roadmap, of the Reference Scenario 2016. It is also the basis of the impact assessment accompanying the Renewable Energy Directive and other part of the Clean Energy for all European package proposed in late 2016. The overreliance on this model proved a problem however, as the model itself embeds strong biases, notably when considering the decarbonisation of the heating and cooling sector.

The "cost-efficient" energy transition requires a sensible approach that favours technologies relevant to a given situation: that means finding cheaper and more suitable technologies to meet specific needs. Renewable heating and cooling (RES-HC) technologies, such as individual geothermal heat systems or geothermal heating networks, are a very competitive solution – when suitable – to cover a large part of the EU's heating and cooling demand. When looking at the results of a model that disregards these solutions in favour of ETS-sector investments, policy makers may end up developing a bias towards promoting said ETS investments, which would for instance result in a wild electrification of the heating and cooling sector. They also remain unaware of renewable alternative options already available in the market. Policy making must acknowledges the decentralised nature of the heating and cooling sector – which allows for a more holistic approach that accounts for national, regional, and local specificities in terms of resources and needs. At the same time, strong policy signals must provide regulatory bodies, the financial sector and the renewable heating and cooling industries with the signal that give confidence in the willingness to engage in the decarbonisation of the sector.

It is therefore crucial to provide a thorough and proper analysis of the heating sector so to develop such a sensible and holistic approach. A step toward this direction is a clear understanding of the H&C market and its characteristics. The figure below illustrates the complexity of the sector.

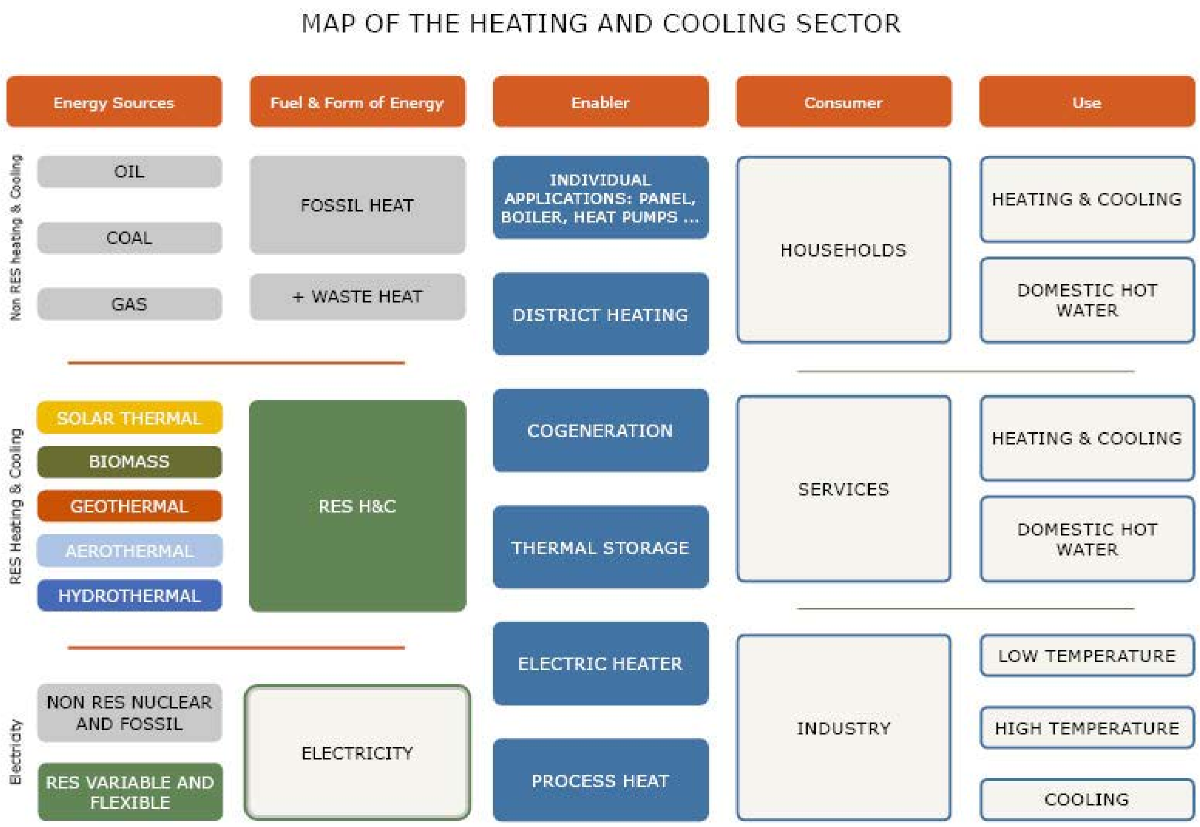

Figure 2.
Map of the heating and cooling sector
(source: FrONT project)

The heating and cooling sector is characterised by a great variety of possible energy sources, from geothermal energy to coal, which can be delivered through different means (directly through combustion, or through a carrier such as district heat or electricity). The utilisation of different energy sources is allowed by an enabling technology, such as heat pumps or boilers.

The question of the nature of the energy source considered is quite relevant for the heating and cooling sector: if storing heat is much simpler than storing electricity, different heat sources canbe limited as to the temperature level they can supply. This is particularly challenging in the industry (steel-making, cement factories…) where very high temperatures are needed. For space heating however, low temperature (~50-60°C) heat can be a very efficiency way to provide thermal comfort, and high temperature (~80-100°C). This is typically the range that thermal renewables such as geothermal can provide.

A modelling that assesses the cost efficiency of the energy transition must represent these different dimensions and acknowledge the role of renewable heat solutions, as they often are directly competitive with the prevalent fossil alternatives.

Indeed, it is another issue of the heating and cooling sector that renewable heat technologies tend to have costs that are comparable with those of fossil energy, especially on the long term. However, the path dependency is extremely strong in this sector and the partial information on various technologies limits the adoption of renewable alternatives by consumers (see for instance the conclusions of the FrONT project). Despite these constraints, the modelling in PRIMES constantly underestimates the deployment of renewables in the heating and cooling sector (see figure 3 below).

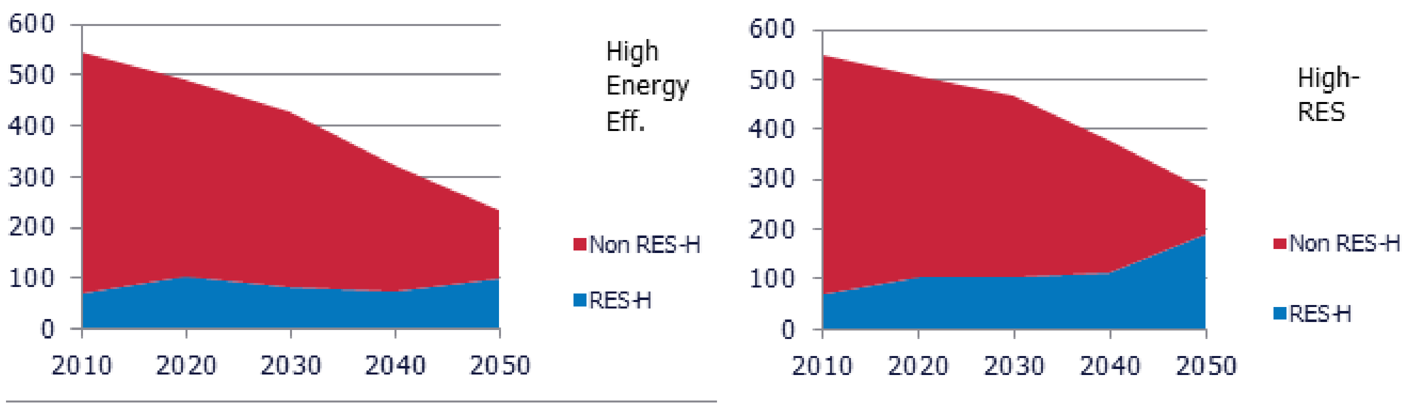

Figure 3.
Estimates of heating and cooling final demand and RES penetration: high energy efficiency and high RES scenarios of the Energy Roadmap 2050 as modelled by PRIMES
(source: EGEC own calculations based on European Commission publications)

In its policy paper on the European Commission's "Energy Roadmap 2050", EGEC made an estimation of the trends modelled by PRIMES for heating and cooling to 2050 - on the basis of statistics and available information (see figure above). The model assumes a competition between energy efficiency and RES-HC for investment, however while in any case it models a decrease in energy consumption in the heating and cooling sector, the high efficiency scenario is notable for a production of thermal renewables hovering around 100Mtoe until 2050. This is to put in perspective with the 99 Mtoe of thermal renewable production in 2016 (SHARES), up 5 Mtoe from the year 2015 (or the exact amount of additional RES-HC production addition between 2020 and 2030 modelled by the EUCO30 scenario for the REDII impact assessment).

The Final report of the Advisory group on the Energy Roadmap 2050[1] provides a critical perspective on the narrow emphasis put on the electricity sector:

"Members raised the question of domain, and the extent to which the Roadmap should focus on energy in the wider sense, rather than place too much emphasis on electricity. The view was expressed that decarbonisation of electricity was more straightforward than other energy sources and uses, and that the Roadmap should explicitly recognise all these other energy dimensions, rather than focussing exclusively on electricity."

The Commission published all the results of the modelling for electricity as well as for transport. It is therefore incomprehensible why only distributed heat/steam numbers have been disclosed, while RES H&C figures have only been reported in relative terms and the total heating and cooling demand is completely omitted.

What is certainly true is that aggregate data on electricity are easier to gather while systematic collection of information on the heating and cooling markets is missing on a European level. The final result of the Commission's exercise is eventually a broken roadmap lacking in proper analysis and modelling. The next step to improve the Roadmap is to map the heating sector. The mapping should cover all dimensions of this complex sector as illustrated in Figure 2.

[1]The Ad Hoc Advisory Group (the Group) was set up with the aim to provide independent advice to the Commissioner for Energy in the preparation of the Roadmap.

The **Common Vision for Renewable heating and cooling sector in Europe** points out that in the current decade increasingly competitive geothermal heat will gain market shares as efficiency rises. The Common vision also highlights how by 2030 geothermal heat will be firmly established, especially in buildings and for industrial processes.

Instead of reporting the above potential, previous energy system modelling relying on PRIMES mainly refer to the heating sector in relation to its electrification without further clarifying what this exactly means. For instance, geothermal heat pumps hold enviable energy efficient potential as the external energy input amounts to approximately 25% of its final output produced. On the other hand, direct electricity uses for heating purposes in buildings (such as electrical radiator heaters) result in poorer energy efficiency (around 30%) at higher costs if compared to entirely renewable heat technologies. It is also worth noting that as recent harsh winters have shown in France or current worries in Belgium, a single energy source does not ensure a reliable supply under all circumstances.

Considering that all scenarios suggest that in the next 20 years electricity price will rise, encouraging the electrification of the heating sector would therefore bring about a trade-off with the objective of providing affordable supply. This should be avoided, notably when other truly renewable technologies, such as geothermal, are available and capable of delivering better solutions.

In other instances, the PRIMES model has proven less than able to consistently estimate renewable deployment in the heating and cooling sector, notably on the long term. In the case of the impact assessment on the recast renewable directive (see figure below), it is quite obvious that the model (assessing the evolution of the energy system over a decade) does not provide a perspective of the heating and cooling sector that is satisfying. Indeed, this economic modelling fails to account for the reality of economic trends and to reflect the renewable heating and cooling industries that are established.

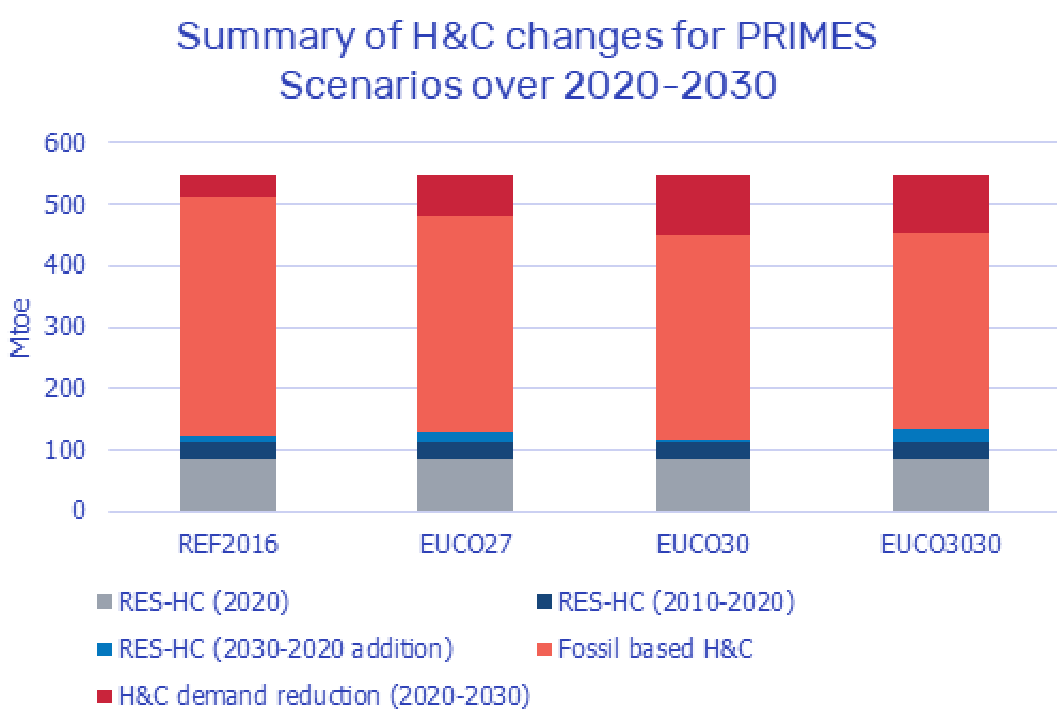

Figure 4.
Summary of H&C changes for PRIMES Scenarios over 2020-2030
(Source: EC impact assessment to the RED, 2016; SHARES 2016; NREAPs; own calculations)

As referred above, the figure of an increase of 5 Mtoe of annual renewable heat production over the 2020-2030 decade in the EUCO30 is a ludicrous one. As comparison, the EU added 10 Mtoe of new renewable heat production between 2014-2016.

This amounts to an average of 5 Mtoe per year, or 10 times the rate presented by the model. Over the 2005-2015 decade, the EU increased renewable heat production by an average of 3 Mtoe per year, in a framework of emergence of renewable heating and cooling technology, and a weak political and financial support to their deployment.

It is also worth reminding that this decade includes the 2008 financial crisis and its fallouts on the European economy. By contrast, all the scenarios considered in the recast renewable Directive impact assessment expect RES-HC deployment to be twice as low (one third lower in the case of EUCO3030) as the past decade.

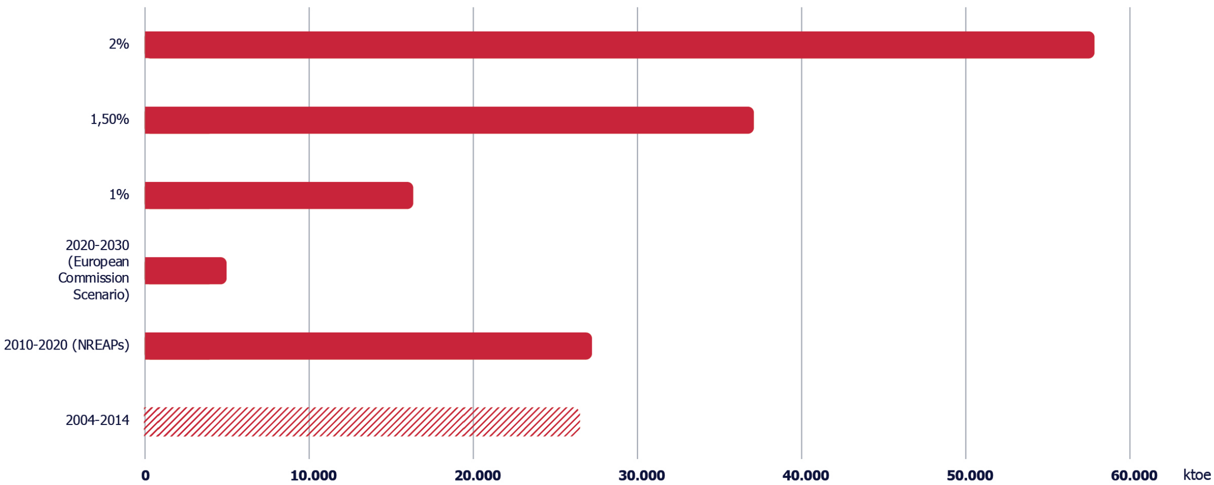

Figure 5.
Additional energy from renewable sources for heating and cooling in EU28 (ktoe)
(Source: EC impact assessment to the RED, 2016; SHARES 2016; NREAPs; own calculations)

The figure 5 above perfectly illustrates the issue with inadequate modelling as a basis for policy making. It compares estimated results of the European Commission proposal for an article 23 of the recast Renewable Energy Directive with the EUCO30 estimate, and the past decade activity (as well as the NREAPs objectives).
The figure highlights the inadequacy of the European Commission proposal that *"Member State shall endeavour to increase the share of renewable energy supplied for heating and cooling by at least 1 percentage point (pp) every year"*.
The final agreement on the provision, that Member States endeavor to a 1.3 percentage point increase, is likely more in line with pas decades deployment, but not with a significant acceleration of the decarbonisation of the heating and cooling sector.

The European Commission proposal for the recast Renewable directive shows that PRIMES modelling results for the heating and cooling are an issue not in themselves, but because they are taken as "crystal ball" forecast of the future European energy system by policy makers. Biased modelling distorts policy making due to several factors:

> **Absence of transparency regarding the parameters of the PRIMES model, including the algorithm**: the lack of transparency on the parameters of the model (how the starting assumptions are treated to produce the output results) limits the possibility for constructive criticism of the results which allow policy makers to understand the limits of the figures they are presented with. Instead, the black box lays out absolute values without clearly underlining the limits of the less than robust ones, which leads to uniformed decisions.

> **Lack of explicit acknowledgement of the limitations of the results presented in the European Commission publications.** This factor comes to reinforce the effect of the "black box" model, further strengthening the confidence that may be put in the figures. Efforts such as the European Commission article 23 come to counterbalance the proposals that may arise from the model, but due to an overreliance on the model, these proposals end up lacking robustness.

Regarding the latter limitation, the current process undertaken by the European Commission is the right one to aim at solving the issue of acknowledging the limitation of the result and correcting them as much as possible. Regarding the former limitation, there has been an opening of the model to some extend, with a welcome consultation of stakeholders on parameters. This consultation has highlighted some issues in the assumptions put forward, and the inputs of stakeholders were considered to correct them to some extent.

Mitigating the impact of climate change means that the EU needs to decarbonise its economy by operating a transition away from fossil energy sources and towards renewable energy. This transition on the energy level must operate according to the following principle: shift the supply towards renewables that you use the most efficiently possible. An efficient use of energy does not just mean being economical of the energy used. It means using available resources according to the services they can provide, respecting the principle of exergy (or useful energy). This principle should be the basis of policy making when planning energy infrastructure, notably for heating and cooling where temperature levels are very important, and it is usually not worth having high temperature processes for space heating or cooling.

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.

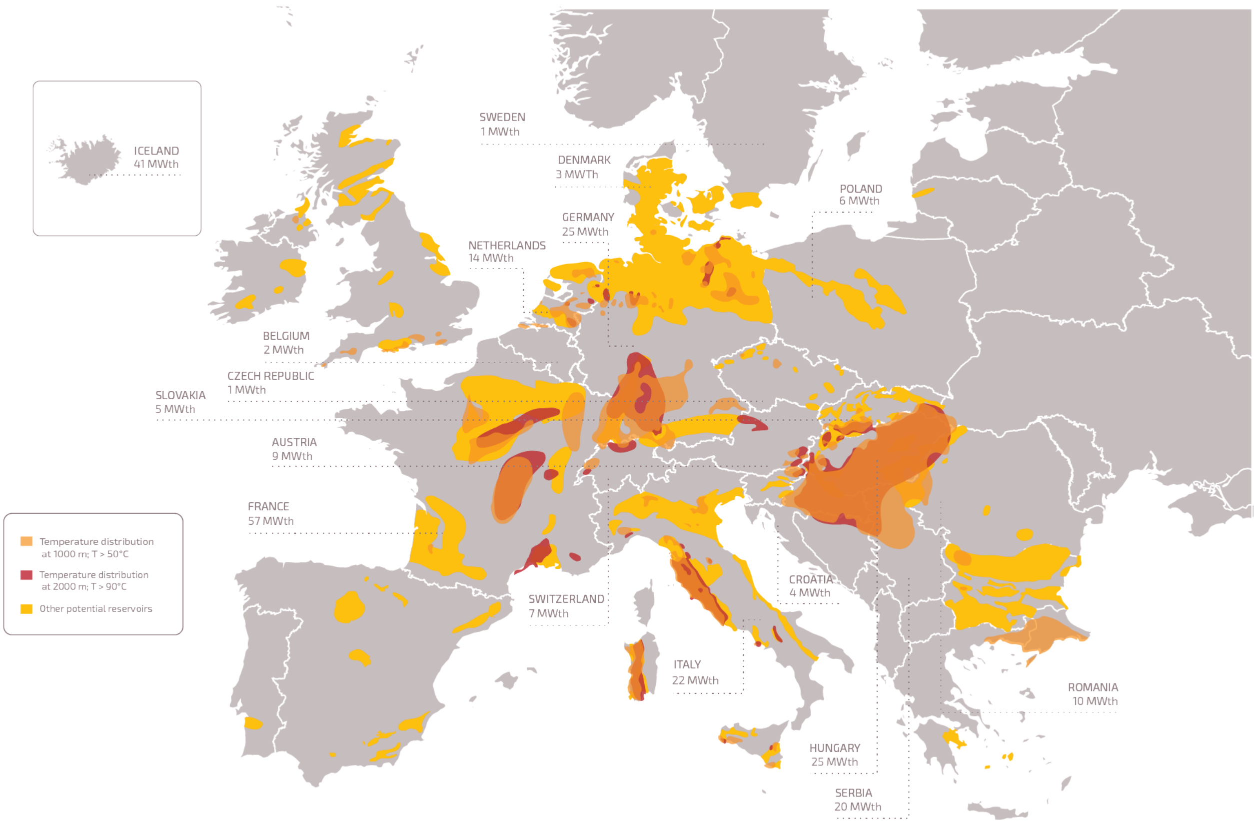

Figure 6.
Areas suitable for geothermal heating and cooling networks (combination of high heat demand and areas where the temperature at 2 km depth is higher than 60°C) and actual geothermal district heating installed capacity
(Source: ETIP DG vision for deep geothermal)

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.

GEOTHERMAL FOR COOLING:
A SOLUTION FOR A WARMER EUROPE

Use of the underground to serve for space cooling either directly of with a heat pump;

> **Direct cooling**
> **Underground Thermal Energy Storage**
> **Geo-cooling (free cooling)**
> **Indirect cooling (HP)**

Potential: with the right framework, key technology to deliver geothermal heating and cooling. It can be developped across Europe and meet the EU's need for a large part of space cooling, for small or large buildings. It is also an interesting option to mitigate the urban heat island effect.

Key measure needed: level playing field for heating and cooling systems, and consideration of the cooling part when comparing individual geothermal H&C systems with alternative.

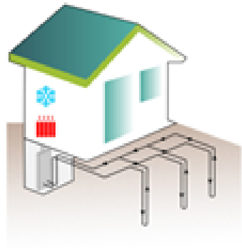

Illustration of a shallow geothermal system (copyright EGEC)

TYPES OF COOLING USED:
- Reservible geothermal heat pumps
- Direct cooling
- Larger systems (large individual building, district cooling) in geothermal absorption cooling

DEPLOYING GEOTHERMAL HEAT PUMPS

In heating and cooling policy-making, heat pumps (HP) are usually considered, or at least referred to, as a consistent ensemble. However, the category covers many different technologies and scales and can utilise different energy sources. At system scale, the differences in HP efficiency, which translates in different electricity consumption profiles, can significantly impact the electricity system. Robust policies for decarbonising the heating and cooling sector should consider a system scale approach and not rely on over simplifications.

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 MW thermal 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.

The efficiency level of a heat pump is a major characteristic to define this technology. Heat pumps are at the same time lauded for their efficiency ("above 100%") and considered as renewable technology. Yet if the former is usually true, the latter is not always. By convention, the Seasonal Performance Factor is used to assess whether a heat pump can qualify as "renewable" or not. The current threshold rules that a renewable heat pump system must have a SPF of at least 2.5.

Geothermal heat pumps, which supply heating, cooling and domestic hot water, usually have a Seasonal Performance Factor (SPF) of around 4, with a lower range of 3. In cooling mode, geothermal systems can have a SPF of 20. Medium size and large size heat pumps assisting geothermal can have higher efficiency with a SPF above 5.

The differences between heat pump technologies' efficiency can have huge impact on the electricity demand. The increase in the electricity consumption due to the development of HP for decarbonising the heat and cooling consumption in the building sector, can be reduced by 50% just by developing more geothermal HP.

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.

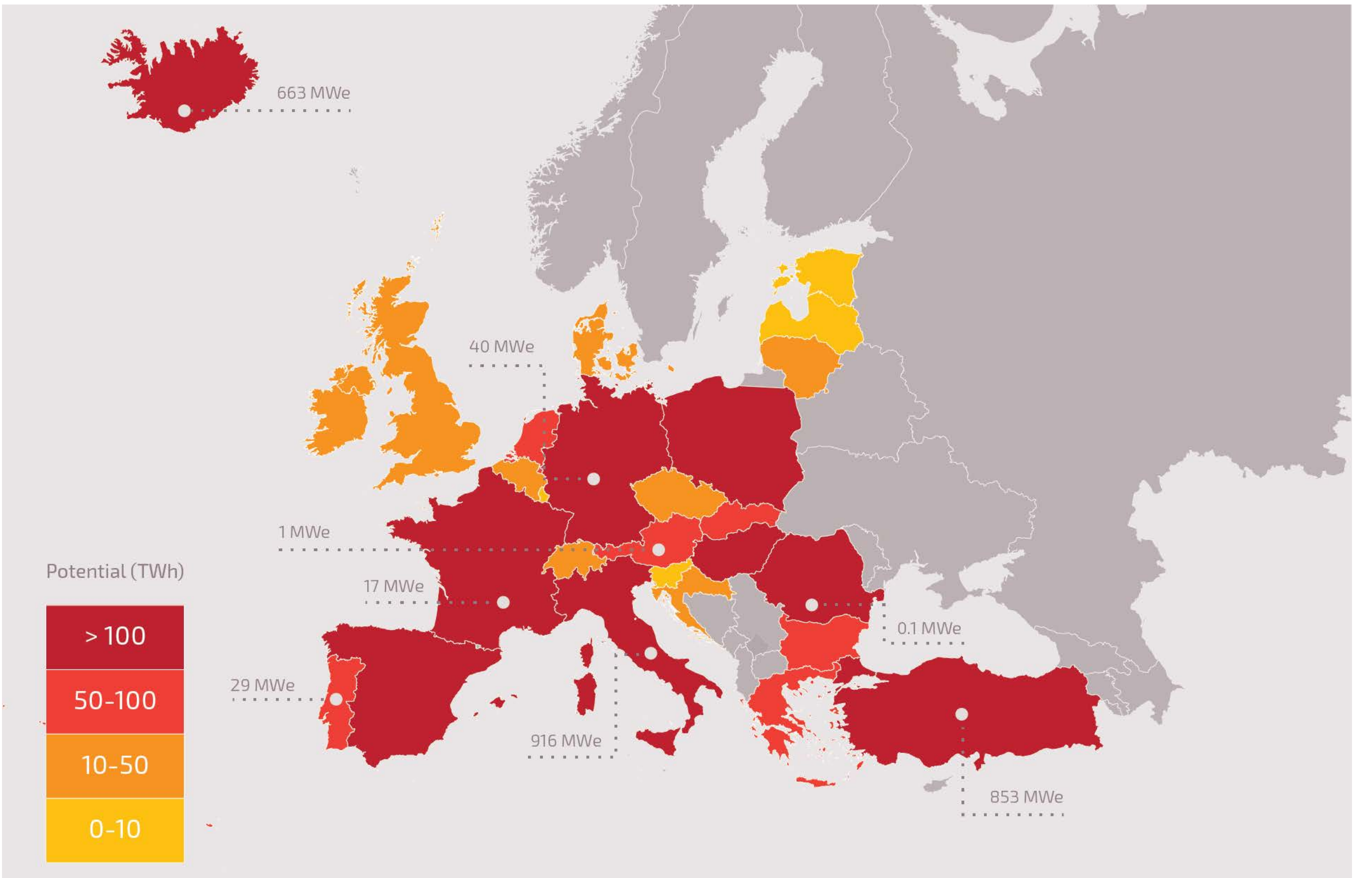

Figure 7.
Potential electricity production to 2050 (available data as estimated by GEOELEC project, taking into account underground temperature distribution) and current electricity production in Europe
(source: ETIP DG vision)

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.

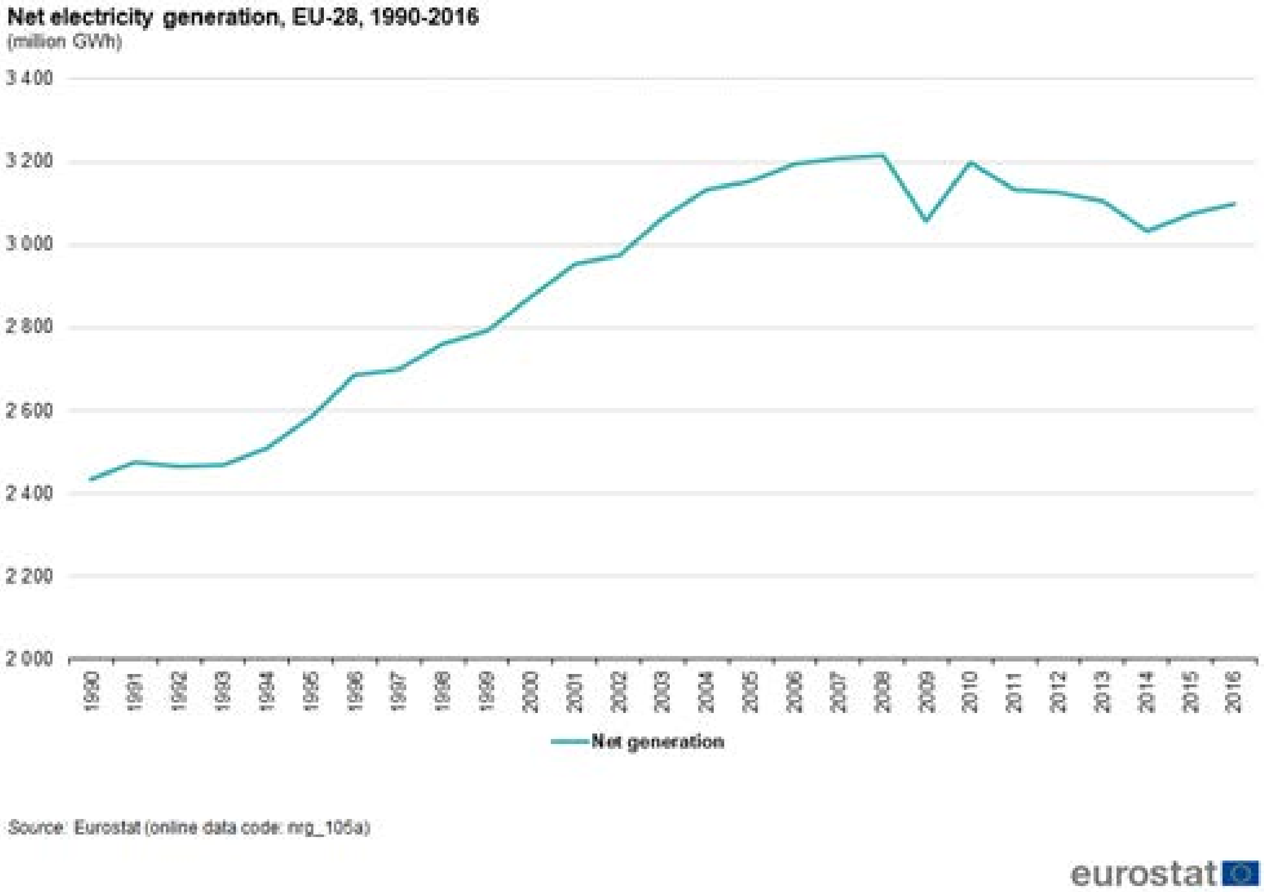

Figure 9.
Net Electricity generation, EU-28, 1990-2016 (million GWh)
(Source: Eurostat)

A stable electricity system needs to be based on a variety of sources and technologies, producing power close to demand centres, where it has the highest value and ensure electricity security. This approach can alleviate the need for additional transmission and distribution infrastructure as well as costly storage. Overall, a focus on flexible renewable energy sources will result in lower system costs, lower imports of gas, and more social support for the transformation of our energy system.

The main advantage of geothermal power is its base load capability. In contrast to other volatile renewables, geothermal power plants are dispatchable and can produce around 8000 hours per year. This means a capacity factor of over 90%.

> Geothermal for electricity production has traditionally been a purveyor of baseload power due to a very low marginal cost, with plants operating at capacity factors up to 100%. However, geothermal plants have proven to be able to provide grid services that go well beyond their rated outputs.

> In some cases, they are an essential supplier of stable electricity generation for the industry. In other, they are able to ramp up and down their output very quickly to adapt to the need for balancing the variability of other technologies.

> This is true for all geothermal electricity technologies, from more conventional steam turbines to highly innovative binary-cycle generation. Tests in geothermal plants in Germany have shown that output can be ramped up or down by 70% in 15 second!

> When it comes to security of supply, geothermal is also a solution, with companies signing long terms power purchase agreements with geothermal plants to guarantee their continued renewable electricity supply, or industries like aluminium smelters in Iceland to keep their plant running.

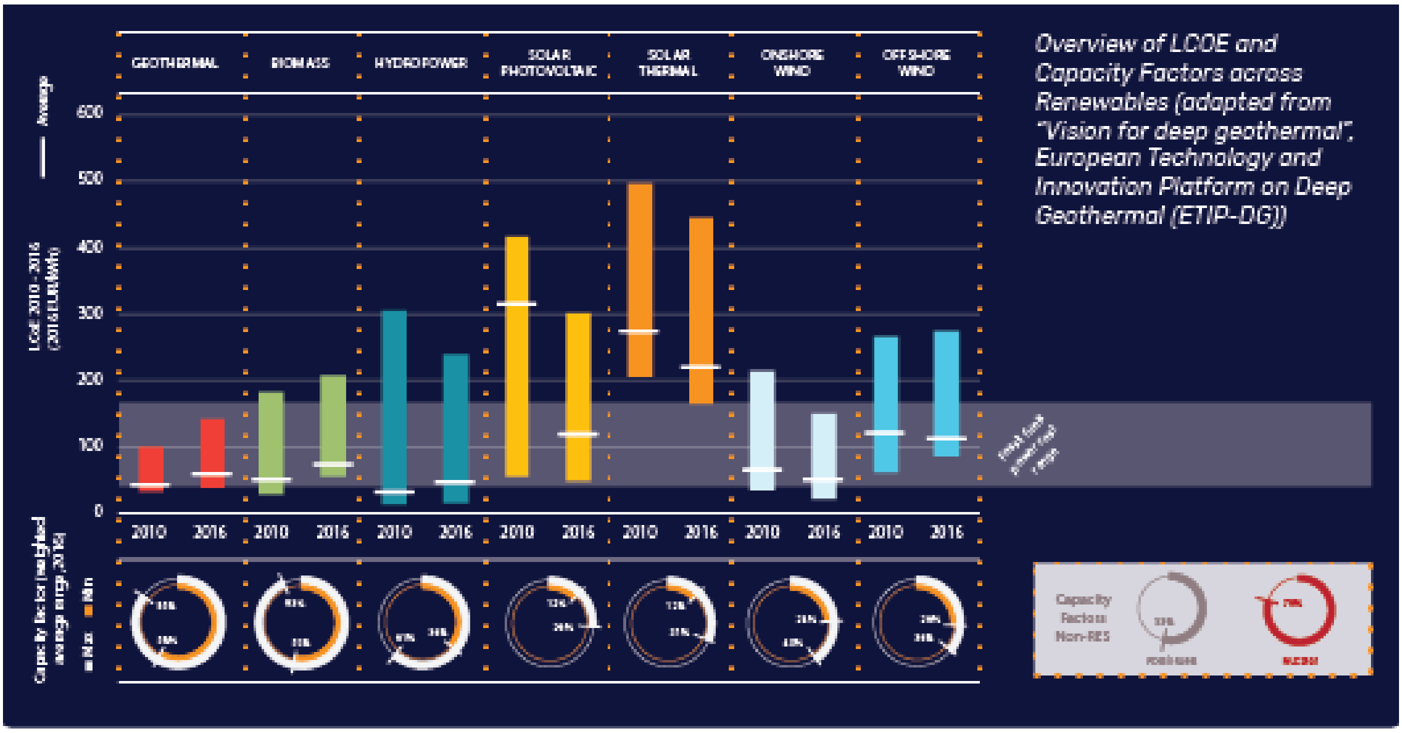

Figure 10.
Overview of LCOE and Capacity Factors across Renewables
(adapted from "Vision for deep geothermal", European Technology and Innovation Platform on Deep Geothermal (ETIP-DG))

Geothermal electricity production has among the largest capacity factor of electricity production, and is competitive with fossil energy on LCOE basis – a measure that is not very interesting to measure the value of an energy source in terms of grid stability for instance. The barriers to geothermal energy can be overcome should the right framework be in place, which the effort to decarbonise the whole European energy supply would require.

SECTOR COUPLING MEANS UNDERSTANDING THE VALUE OF ENERGY, MAXIMISING THE RESOURCES AND USEFULNESS

In addition, as the figure below comes to illustrate, the future of the energy system is not as fragmented as the current one. In addition to smart thermal grids for the supply of heat integrating many parameters such as the demand or the temperature level needed, the integration of the electricity, the heating and cooling and the transport system will happen, carried by technologies, but also the maximization of the useful energy that local renewable resources can supply. In that regard, geothermal energy is ideally placed at a crossroad of the electricity/heating and cooling nexus, with many examples of the use geothermal energy for electricity and heating (and the maximization of temperature levels for many processes, from the industry to space heating; including obviously recreational uses such as spa resorts).

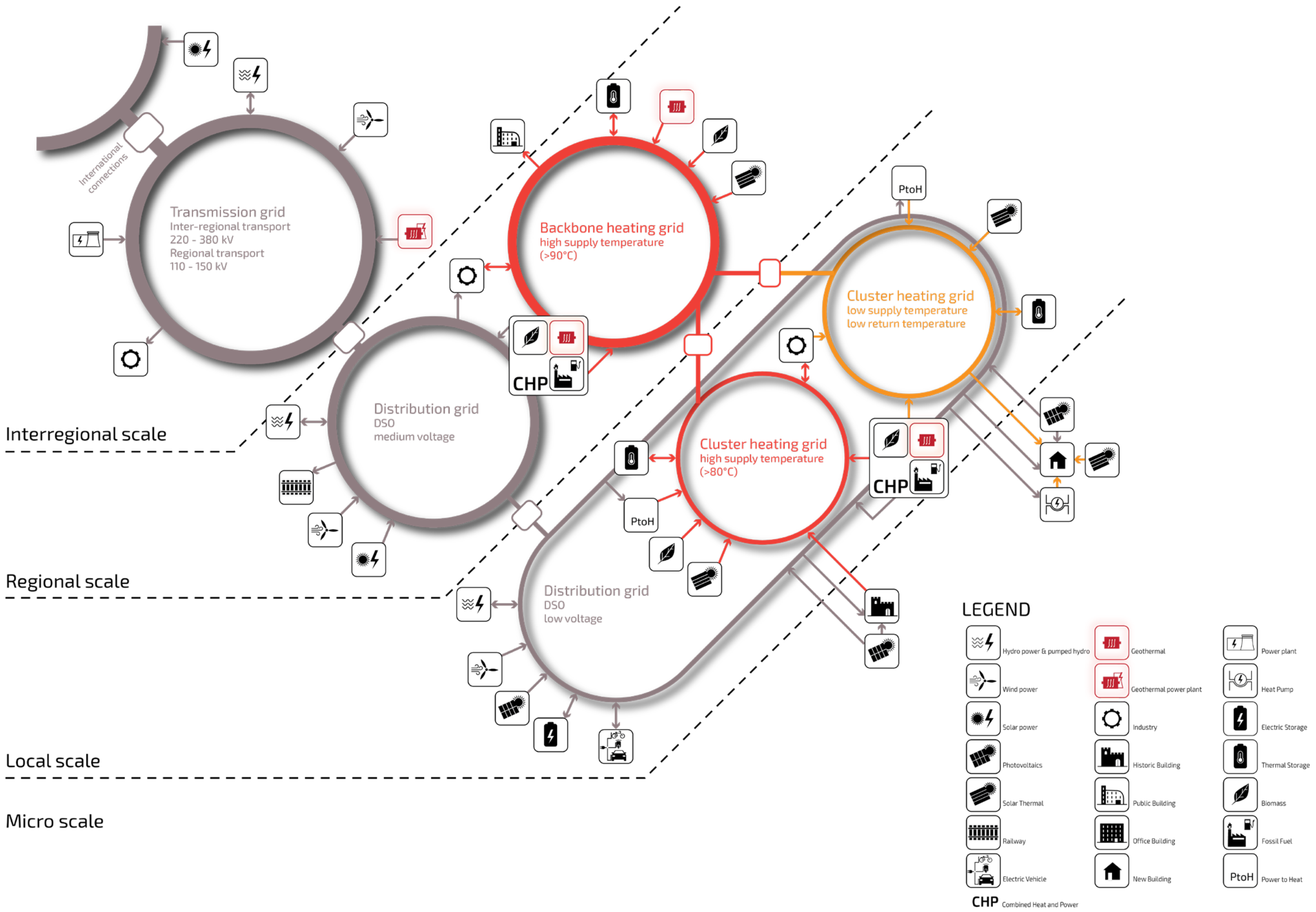

Figure 11.
In the interconnected energy networks based on renewable energy sources, geothermal and underground thermal storage play an important role
(Source: "Vision for deep geothermal", European Technology and Innovation Platform on Deep Geothermal (ETIP-DG))

ACHIEVING THE ENERGY UNION THROUGH RENEWABLE-BASED DECARBONISATION: ENERGY EFFICIENCY, SECURITY OF SUPPLY, RD&I

The Energy Union is a very powerful concept as it brings together all the different streams of the EU energy and climate policy. Implementing the Energy Union implies, amongst other things, the full integration of its five dimensions.

ENERGY EFFICIENCY

Renewable energy and energy efficiency are not competing resources. They are – and must be acknowledged as such – jointly required if the European Union is to ever reach its objective of a decarbonized economy. Objectives such as that of a decarbonized building stock by the middle of the century in Energy Performance of Buildings Directive must imperatively by taken into account in the EU long term strategy on greenhouse gas emissions. Investments in energy efficiency improvement must lead to a reduction in the waste of energy. It must also go towards a better use of useful energy, and reducing this waste as well. Typically, this means a greater thinking and more thorough planning around the different needs for heating and cooling in terms of temperature levels.

Binding targets on energy efficiency are necessary for this essential resource of decarbonisation to be invested in adequately. EGEC is supporting a robust energy efficiency framework that takes an integrated approach to energy savings and avoids the pitfall of locking in emissions through energy efficiency investments in marginally more efficient fossil fuel equipment and infrastructure. Energy efficiency must be approached in an integrated approach where efficiency investments seek synergies with renewable sources towards a decarbonised energy system, and conversely renewable investment must seek the efficient use of renewable energy, according to the usefulness (i.e. exergy and temperature levels).

SECURITY OF SUPPLY

Currently, EU gas imports from Russia are mostly used to cover its extensive heating demand which accounts for almost 50% of its final energy consumption.

Across all economic sectors, natural gas consumed in the EU is mainly used for heating purposes. For instance, 40% of the natural gas consumed in the EU is used in residential and tertiary buildings- mainly for space heating and domestic hot water[1]. The EU's building sector consumes up to 61% of all net imported gas[2]. Significantly, those Member States most dependent on Russian gas imports, consume more than 40% of their gas in buildings, reaching up to 79% in Hungary.

[1]In residential buildings, 85% of the energy consumed is used for heating, cooking and cooling. In non-residential buildings, these uses still account for about 80% of the final energy consumption (Source: Ecofys, "Increasing EU energy independency", October 2014, p.8).
[2]Ecofys, "Deep Renovation of buildings: an effective way to decrease Europe's energy import dependency", 2014, p.4.

The energy transition is an opportunity to move away from these dependency and reap the benefits of local renewable resources in terms of energy of supply, conferring a more robust geopolitical position to the EU in a more uncertain world. Renewable energy, notably renewable heat, is indeed a factor of strength and resilience for the EU economy. Unlike fossil sources, or sources that rely overwhelmingly on large centralized infrastructure which may be a liability, notably in the context of increased climate variability and more intense climate impacts across the EU. The decentralization of the supply of renewable heating and cooling, for instance in the case of geothermal, shelters local communities from outside disruptions, and allow them to weather storms with more serenity.

In addition, geothermal energy is a factor of security of supply for companies, with many corporations sourcing geothermal electricity and heat specifically not for the sustainability credential, but for the security of supply it provides over all other forms of energy.

RESEARCH, DEVELOPMENT & INNOVATION

Research, Innovation and Competitiveness is key to ensure energy security, energy efficiency and the decarbonisation of the EU economy. It contributes to the European leadership in renewable energies and allows the development of the next generation of renewable technologies.

Renewables for heating and cooling and flexible renewable electricity generation are important components of the future energy system and will contribute to achieving the objectives of the Energy Union. EU RD&I priorities to the middle of the century should include:

> Market uptake of small-scale renewable heating and cooling installations: Geothermal, Solar thermal, Biomass and Aerothermal small-scale systems face non-technical barriers to their development;

> Innovation for allowing the fuel switch in District Heating and for industrial process: low temperature systems, energy efficient devices etc.

> Demonstration of flexible RES power plants: For having increasing the flexibility robustness of the power system, flexible generation is essential and must be developed with renewable sources. Some renewables, including geothermal plants, usually run as base load, but new technology such as binary turbines allow them to be flexible in their production. More demonstration plants must be installed in different market contexts.

> Research and Development of the next generation of RES technologies such as EGS: Breakthrough renewable technologies could be the future game changer for decarbonising the energy system.

> Towards a smart integrated energy system: The future energy system should make a strong link between its three sectors: electricity, heating & cooling, transport. Smart energy grids will play an important role in the future smart cities and communities by ensuring a reliable and affordable energy supply to various customers with renewable energy carriers like geothermal energy.

Figure 12.
Vision of the city of the future, that 100% renewable energy sources in terms of electricity, heating and cooling and mobility, with zero impact on the environment, where citizens are involved. It is based on intelligent exchanges of energy through the electricity and heat grids
(source: ETIP DG, vision for deep geothermal, 2018)

A JUST TRANSITION FOR A SUSTAINABLE ECONOMY: GEOTHERMAL ENERGY AS PART OF THE SOLUTION

The energy transition that the EU must undergo to meet its objective of a full decarbonization of the energy system by the middle of the century, an imperative for having a remote chance to meet the objectives of the Paris Agreement, represent a huge economic and social challenge. Massive amounts of capital and public subsidies will have to be shifted away from fossil assets, infrastructures, and flow towards enabling the development of renewable alternatives. This means workers will have to switch jobs, some area may be affected by a harsh transition with potential dramatic social impacts if the transition is not soundly conducted at the political level.

The energy transition however is not only a threat for the European economy, nor is it a sinister omen for the European workers, notably in industrial sectors, or for communities that rely on the fossil industry. Many recent examples show the potential for economic and social development in areas where geothermal was developed. This dimension of renewable energy development, most notably that of geothermal, should be considered when drafting a European Union strategy that aims to align the European economy with the imperatives of climate mitigation. These positive externalities from renewable projects, which are well documented in the case of geothermal heat, must be considered.

SOCIAL AND EMPLOYMENT

While we tend to frame the debate on the energy transition only in the financial frame, comparing the cost of technologies, the various subsidies awarded, etc. this is far from the main challenge of the kind of profound energy transition that the long-term strategy on GHG emissions should plan for. Indeed, the shift away from a fossil fuel-based economy to an efficient and renewable based one implies deep and far reaching social changes, and means that many people will have to undergo a professional transition in order to adapt their careers to the requirements of a decarbonized economy.

Renewables, as they are at the center of the solution to meet the decarbonization objective, are a solution to the challenge of the social and employment transition. Geothermal energy in particular has proven that it can provide communities with value that far exceed that of the MWh of heat produced or of electricity generated.

> Local development:

Renewable energy production is made by exploiting local resources, usually with smaller scale projects. This means that local communities can directly benefit from the employment. It also creates development opportunities at the local level, through not only the direct impact of the geothermal project for instance, but also thanks to the thinking that it entails in terms of opportunities to reshape the community around this local and sustainable energy source.

> Energy poverty is heat poverty: renewable heat is the solution.

Geothermal for heating and cooling is the answer to the issue of heat poverty. Geothermal energy has low operating costs whether it is used in district heating or in individual systems. It allows reducing the expenditure on heating and cooling, which is a major challenge or risk for up to 23% of the European population. The reliance on an efficient use of renewable heat resources reduces energy poverty in the long term, erasing the vulnerability to swings in fuel prices.

> Jobs creation with geothermal energy: direct/indirect and induced

As a whole, geothermal energy can be considered to be among the most job intensive for of energy. In terms of direct jobs, geothermal energy creates high quality jobs, notably in the domain of geoscience or engineering, but also more trade skills jobs during the construction of the project. However, geothermal project also create a lot of indirect jobs, most notably in the service companies that are involved in the geothermal value chain but may not have a typical focus on this energy source (typically steel pipes makers). Finally, geothermal's value as a energy source notably derives from the amount of induces jobs that are created within the communities where geothermal energy is developed. The supply of geothermal heat to businesses, notably for processes creates a value for the business, first in terms of low and stable cost of heat, but also a marketing value for using a local, renewable resource. The example of Vapori di Birre is quite striking in that regard of a beermaking company that markets itself as a geothermal product. But induced jobs can also be created without a specific marketing focus, it is notably the case in the Netherlands' greenhouses where geothermal heat replacing natural gas (which is now a depleted resource in the Netherlands) allow the country to continue producing large quantities of vegetables at an affordable cost.

> Geothermal as a solution to socio-economic challenges: the example of coal regions, and the potential in islands

> Geothermal in coal regions in transitions

Fossil mining sites tend to correlate with geothermal resource availabilities (see the case of MijnWater, overleaf, and the GeoHeatPol project for switch to geothermal in coal regions). This allows the development of renewable resources with skilled workers in their own region. Geothermal project development requires many of the same skill set that mining workers possess: Expertise in geosciences; Management of drill cutting; Management of flow extraction, with corrosive and high temperature fluids; Electricity and heat production skills; Reservoir engineering; District heating design and management... And many more. Geothermal projects, although of different scale than conventional fossil ones, tend to also share business model similarities, particularly regarding the uncertainty inherent to underground production. However, the differences in cash flows and profitability make a sound expertise in preparatory studies all the more precious.

In addition, geothermal can have a positive social impact in these area, notably by offering reconversion opportunities to workers from the coal industry, providing opportunities for economic development in an area that relied on coal usually entirely. Geothermal is also an opportunity to reduce energy poverty, which is often quite high in coal regions, and improving quality of life (notably regarding air quality, which is a documented driver towards geothermal heating in countries such as Poland).

> Geothermal for islands

Many European islands lay on volcanic areas, therefore possessing large amounts of geothermal resources. Other islands have potential for low and medium temperature. Geothermal energy could provide islands with ***a stable, sustainable, and affordable energy supply.***

Acknowledging indigenous, flexible, and renewable energy sources, including geothermal, and integrating them in the energy system is crucial to allow European islands to move away from unsustainable forms of energy and to strengthen their resilience. Geothermal energy is not just electricity. It can be used for ***a wide variety of purposes***, such as: space heating and cooling for hotels and other facilities, greenhouse heating, underground energy storage, agriculture drying, desalination, industrial uses, snow melting, road de-icing, balneology, etc.

Geothermal projects can offer competitive solutions both for industries and buildings, especially with ***integration into smart thermal grids.*** Innovative district heating and cooling systems can be sizable to supply urban areas even at lower temperatures and are more efficient for cooling in hot summers. Geothermal energy is not dependent on climate, therefore able to cover energy needs all year round.

Geothermal is a local resource that fosters local development. It creates both direct and induced employment, through ad-hoc industries such as the agro-food industry (greenhouse heating, agro-drying). It also boosts tourism through recreational uses such as for bathing and swimming.

Picture: new geothermal plant in Pico Alto

GEOTHERMAL ENERGY IN THE AZORES ARCHIPELAGO

The Azores Archipelago has set quite the successful example in demonstrating what can be achieved with geothermal energy. With a power production from geothermal that presently meets 42% of the electrical consumption of São Miguel Island, and over 22% of the total demand of the archipelago, the Azores have shown that geothermal energy can provide a local, stable, and clean energy source that can help EU islands achieve the energy transition.

Clean and reliable electricity in pico alto

The new geothermal plant in Pico Alto in Terceira island, which started operations in August 2017, demonstrates the successful application of a more sustainable and efficient power generation energy model for small islands with isolated grid.
Although geothermal plants located on islands or remote areas have been equipped with traditional flash power systems, Pico Alto utilises a binary system that provides a sustainable and reliable source of electricity to more than 56,000 inhabitants, meeting up to 10% of the island electricity needs.
The utilization of geothermal as a baseload renewable energy source, available 24/7, has brought the island a stable electricity supply and economic savings thanks to a reduced reliance on imported fossil fuels.
ORC provider Exergy, that built the power plant, estimates that 4 MWe of green electricity produced in one year operation of the plant will allow to save 18.768 tCO2/year and 5998 TOE/y.

ECONOMIC

> Local economic development

Geothermal is a real local sources of energy producing power and heat for the cities and the rural communities. Geothermal allows also economical local development with many indirect positive effects such as jobs creation.

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.

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.

> New industrialization

Renewable heating and cooling technologies can replace gas for industrial processes. For example, this can be the case in the sector of food and tobacco production, which is the third biggest industrial consumer of gas (around 16%)[1]. Indeed, the sector's industrial processes only require temperatures up to 400°C, and more than 50% of its heat demand is lower than 100°C. This could be easily covered by geothermal and other RHC sources[2].

Geothermal energy has been used extensively in the agricultural industry for the last three decades, notably for commercial out-of-season production of vegetables, flowers and fruits. The case of the Netherlands, where geothermal is gradually replacing gas in greenhouses illustrates this example very well (see the box below).

GEOTHERMAL HEAT PLANTS IN HORTICULTURE

Where: The Netherlands
What: Geothermal heat for greenhouses

Objective: The Dutch horticulture sector is one of the top global leaders in terms of innovation and trade with international partners. Being a stable pillar of the Dutch economy, horticulture represents around 400.000 jobs and accounts for a yearly production value of €8 bn. Relying extensively on natural gas, the sector's energy costs represent about 20% to 30% of its total production costs. Therefore, one of today's challenges for Dutch horticultural companies is to achieve a more efficient and sustainable use of energy, notably through the uptake of renewables such as geothermal district heating.

Key data: There are today 9 geothermal systems operating projects in the Dutch horticultural sector representing an installed capacity of 100 MWth. 2 new deep geothermal projects are planned in the next 3 years accounting for an additional capacity of more than 30MWth. The development of geothermal in horticulture is very promising as the country has a good potential in terms of geological resource were the sector is most dynamic.

Benefits: Although it is still a rather new technology in the Netherlands, geothermal installations offer many advantages. They provide a great opportunity to significantly lower energy costs and protect companies from volatile natural gas prices. Geothermal systems are also particularly attractive thanks to a favourable regulatory framework combining existing insurance scheme for geological risks and competition-based support schemes (i.e. SDE+, "Encouraging Sustainable Energy Production").

[1]European Commission, "In-depth study of European Energy Security", Commission SWD (2014)330, 2.7.2014, p.39.
[2]European Technology Platform, "Strategic Research and Innovation Agenda for Renewable Heating and Cooling", 2013, p.52.

Geothermal energy can also supply heat for industrial processes. There is notably the example of a bio-refinery from France. By the middle of the century further R&D and other enabling policies enable deep geothermal technology, notably through innovative Enhance Geothermal Systems, to be fairly widely available for higher temperature heat demand for industry.

ENHANCED GEOTHERMAL SYSTEMS FOR INDUSTRIAL PROCESSES

Where: Rittershoffen France
What: ECOGI- Geothermal heat plant for a bio-refinery

Objective: This geothermal project was initiated in 2011 and is on-going. It is designed to deliver power of 24 MWth to the "Roquette Frères" bio-refinery in Alsace, in order to cover around 25% of the process heat needed on this industrial site.

Key data: The project is supported by ADEME, the Conseil Régional d'Alsace and SAF Environnement. The drilling of the first vertical well started in autumn 2012. The well reached a final depth of two and a half kilometres end of 2012 within a deep fractured basement.
The reservoir temperature met predictions, with temperatures above 160°C. A second well was drilled in 2014, and the plant will be in operation in the coming months.

Replicability: The development of enhanced geothermal systems, a proven technology since 2007, opens new routes for providing, amongst other things, medium and high temperature heat for industrial processes across Europe. More support for deploying this innovative technology is, however, needed.

GLOBAL LEADERSHIP

The EU is a major actor of the global economy, and the early start of the European Union in the energy transition allowed it to be among the world leaders on renewable energy. In particular, geothermal energy is one of the sector where Europe is a major industrial player in terms of technologies, manufacturing capacity and capacity to export, notably in such dynamic markets as Latin America or East Africa. Over the coming decades, as the world engages more deeply into the energy transition and as the development of lower income countries happens directly through renewable, geothermal's value is exploited worldwide, and carried by a strong domestic market, the European geothermal industry can be a world leader, thanks to cutting edge technologies and the experience in the development of many projects in Europe for the supply of renewable electricity and heating and cooling.

The voice of geothermal in Europe

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