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1.1 Overview of technologies

1.1.1 Geothermal for electricity generation (base load and flexible)

Geothermal power can be produced thanks to various technologies according to different geological conditions. High temperature resources represent most of the existing capacity, with three key markets: Turkey, Iceland and Italy. Both Iceland and Italy mainly use “traditional geothermal” generation, from very high temperature fields and “conventional” steam turbines. Turkey however, where geothermal development has mostly happened over the past 10 years, makes greater use of binary turbines.

High temperatures technologies: a mature European sector

A mature technology, first used in 1904, conventional geothermal electricity production extract hot water in the form of steam from beneath the surface of the earth and runs it through a turbine which generates electricity. “Dry steam” or “flash” turbines may be used according to the resource.\(^1\)

\(^1\) Dry steam turbines: the geothermal brine is nearly entirely in the form of steam (mainly water vapour under pressure and high temperature). It is passed through a turbine very similar to steam turbines for conventional thermal technologies.
The geothermal resource must be of high temperature (typically >180°C). Quite widespread in Iceland and in Italy – where it was first demonstrated, Turkey being another important actor, conventional geothermal has a more limited potential in the rest of Europe. Volcanic islands such as Guadeloupe for France, in Acores for Portugal, the Canaries in Spain have extensive resources.

Medium temperatures technologies: unlocking the potential of geothermal electricity

Dual – or binary – cycle facilities operate with geothermal resources at 100°C to 180°C. Also called “organic Rankine cycle” (ORC) or Kalina cycle, this technology allows the development of lower temperature geothermal resources. This allows such technology to be deployed more widely across Europe. New developments in the fluids used for ORC open the prospect to generate geothermal power from resource temperatures as low as 80°C, further expanding the potential of this energy source.

Next generation of technologies: geothermal power everywhere

Enhanced Geothermal System (EGS) is the most recent and at this stage least mature geothermal technology. Usually associated with ORC turbines, EGS consists of improving a geothermal reservoir to render it suitable for commercial exploitation. This usually implies increasing the energy output by facilitating the water flow, either by adding water to the reservoir or increasing the porosity of the rock, using the natural features of the underground.

A major effort to introduce EGS could create a substantial base-load electric power production, as geothermal energy is available at any time of the day or year, regardless of climate, weather, etc. EGS systems could be established in all EU countries.

As for the development of projects utilising superhot geothermal resources (temperatures up to 500°C), there are so far only demonstration projects being initiated and none are operational as of 2019. Such technology has a significant potential for the development of large geothermal power plants, or for the supply of renewable high temperature heat for industrial processes.

1.1.2 Geothermal for heating and cooling

Geothermal Heat Pumps

Geothermal heat pumps extract the geothermal energy stored in the ground or aquifer, typically up to 500 m depth and at temperatures up to 25°C. Heat pumps are usually enabling the extraction of geothermal energy from the ground and raise the temperature

Flash turbine: the geothermal brine is in two phase, one gaseous (steam), one liquid (extremely hot water). The liquid phase is passed in a flash chamber where it passes to the gaseous states. The steam then passes through a turbine to produce electricity.
to the level required by the heating systems. With this type of geothermal system, it is also possible to directly use the water or brine as a cooling source to lower the ambient temperature of a building during warm periods. The type of heat pumps used for such geothermal systems can often be used in reverse to extract the heat from the air inside the building and injecting it in the ground – hence cooling the building.

Low temperature geothermal system coupled with an enabler can be deployed at a wide array of scales from around 15kWth to several MWth. Smaller systems usually utilise shallow resources and supply heat for single family houses. Larger units can either be a solution to cover the heating needs of very large buildings or to supply heat for a district heating. In between, large buildings such as hospitals, universities, office buildings or blocks of flats may use medium to large geothermal heating systems.

A very identifiable trend in the use of very low temperature geothermal systems is an increasing development of larger geothermal HP systems, notably coupled to neighborhood scale district heating.

**Deep geothermal for heating and cooling**

The second (low and medium temperature, ranging from 25 °C to over 100 °C) extracts the heat from ground and groundwater at higher temperature. On average these correspond to greater depth, but the depth varies greatly depending on the geological conditions. The heat of the geothermal fluid is typically extracted via a heat exchanger, and then used for district heating, agri-food processes or other uses. A heat pump may also be used to bring the temperature to the needed level (e.g. from 75°C to 80°C to meet the technical requirements of a district heating network).

Geothermal for heating and cooling may supply energy for various types of uses:

- district heating or combined heat and power installations;
- agriculture (horticulture, aquaculture, drying);
- industrial processes;
- balneology;
- absorption heat pumps for cooling purposes.

In order to maximise the value of their investments, geothermal power plant operators are also increasingly valorising the heat they produce. Indeed, after the electricity production process, a significant amount of energy remains available in the geothermal fluid. Combined production of electricity and supply of geothermal heat for district heating or as process heat for the industry is developing with examples in Tuscany, Alsace, Iceland…

**1.1.3 Extraction of materials from the geothermal brine: an emerging use**
Increasingly, geothermal project developers are looking at various ways to increase the profitability of projects. Beyond the sale of energy, innovation has allowed the geothermal industry to consider the potential of extracting materials from geothermal brines.

Geothermal brines are the fluid that carries the energy to the surface via the geothermal well. They are mostly made up of water (sometimes up to drinking water quality), and usually contain various dissolved elements such as silica, salt and other materials. Originally mostly perceived as a technical challenge, the minerals contained in the brine are more and more seen as an opportunity to extract rare minerals in an environmentally friendly way.

**Lithium made in Europe**

Developing innovative technologies, several projects are now ongoing, aiming to extract lithium from geothermal brines. Globally many projects have started over the past few years, with several in Europe that have a high potential. In some cases, geothermal lithium projects in Europe have been justified primarily based on the economics of lithium extraction.

In the medium to long term, other minerals such as rare earth may also be produced from geothermal brine. Other existing uses of material extraction include the sale of silica to the cement industry, CO2 to the food and beverages industry, or some other minerals for cosmetics.

### 1.1.4 Justifying an investment in a geothermal project

Geothermal projects are developed to meet a need for energy. The justification for the project may be entirely economic (geothermal is for a specific need the cheapest energy option), offering local economic development. Other elements may also factor in from the need for energy security (a major driver of geothermal development in the second half of the 20th Century), environmental concerns or the specific benefits of geothermal energy such as cogeneration of electricity and heat or the capacity to provide flexible, dispatchable and baseload energy supply. In terms of business models, notably regarding cash flows, key differences exist between the various geothermal technologies, though many nuances exist.

- Incomes from the sale of energy: geothermal investments may be undertaken with the objective to earn a profit from the sale of energy. This may be heat or electricity. In many cases, considering the typical business models of geothermal projects,
long term power purchasing agreements may be contracted or operational aid secured. This guarantees cash flow once the power plant is operational.

- Reducing energy costs: geothermal projects have minimal operation costs compared to many alternative energy technologies (in particular fossil), which may make them profitable to reduce energy expenditures. Typically corresponding more to geothermal heating and cooling projects, investors may develop a geothermal project (geothermal heat pumps or district heating and cooling according to their needs and resources) and recoup the costs over time on their energy bills.

Beyond the pure economics of geothermal energy projects, many other business models and income streams may justify geothermal investments. The emerging need to market flexibility in the electricity market is for instance a promising income stream for geothermal power plants (but also for geothermal energy storage projects and geothermal heat pumps able to participate in demand-response schemes). As seen above, the prospect to market some minerals contained into geothermal brine is another possible economic case in favour of geothermal projects.

Overall, however, geothermal energy remains to a large extend an emerging technology in many markets. All geothermal technologies typically face market structures that are tailored to incumbent fossil fuel technologies for energy production, and not often suited to the needs of geothermal technologies to justify a business model.
1.2 Cost structure

Geothermal energy projects are rather capital intensive, which requires addressing the challenge of financing. As with many technologies, geothermal costs tend to fall when the technology progresses along its learning curve and market matures. The structural dynamics of the energy market, in particular for heating and cooling, tend however to
favour technologies with higher operational expenditure (typically fossil technologies), which creates a market imbalance which is detrimental to geothermal technologies.

### 1.2.1 Deep geothermal cost structure

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment costs</td>
<td>Geothermal project development costs vary considerably as they depend on a wide range of conditions, including resource temperature and pressure, reservoir depth, location, drilling market etc. See below the capital costs per geothermal technology.</td>
</tr>
<tr>
<td>Operation and Maintenance costs</td>
<td>O&amp;M costs in geothermal plants are limited as they do not require fuel. 1-2%/year</td>
</tr>
<tr>
<td>Commercial costs</td>
<td>Commercial costs associated with developments also need to be considered. These include financing charges (including fees and interest), interests during construction, corporate overhead, legal costs, insurances. For geothermal, risk insurance is a crucial issue. The uncertainty on the geothermal resource has an outsized impact on the risk profile of the project. Mitigating this risk through derisking scheme lowers the cost of financing the project.</td>
</tr>
<tr>
<td>System costs</td>
<td>Being base load and flexible, geothermal doesn’t require extra grid infrastructure and storage. Offering also underground thermal energy storage, geothermal can save system costs.</td>
</tr>
<tr>
<td>Externalities</td>
<td>Geothermal is a renewable energy with very low GHG emissions so external costs of pollution damage are negligible</td>
</tr>
</tbody>
</table>

*Table 1. Technology costs for geothermal*

Investment costs are usually the largest segment of a geothermal project’s cost structure. They cover:

- **Exploration phase**: identification of the geothermal resource, environmental impact assessments, preliminary work.
- **Drilling**: this represents over 50% of the total cost of a project. Before the drilling of the first exploration well, it is usually not possible to know precisely what the capacity of the plant will be (which is notably informed by temperature and flow) and hence the possible revenues for the project.
- Building the installation: Building the installation represents between a third and half of the total cost for electricity projects. At this phase there are few uncertainties relating to the viability of the project, which may ease financing.

The cost structure of geothermal projects highlights their capital-intensive nature. Typically, as noted below, a geothermal flash power plant would have a cost range between EUR 60-80 million for a 20MWe installation. For a 5MWe project for a low/medium temperature installation (typically EGS plants) the cost would be expected to be between EUR 35-60 million.

This capital cost structure underlines structural differences from one type of installation to the other: while field development represents around 50% of the cost of a flash plant, it amounts to up to three quarters of that of a low/medium temperature binary plant. In absolute terms, the cost of developing a low/medium field costs up to four times as much as the development of a flash field on a EUR/MWe basis.

Figure 1: Cost range for the development of a 20 MWₑ conventional high temperature plant with a flash turbine. The graph shows the cost range for the different steps in field development and the construction of the power plant.
Figure 3: Cost range for the development of a 5 MW_e (or thermal 25 MW_th) EGS plant. The graph shows the cost range for the different steps in field development and the construction of the power plant with a turbo-generator.

Table: Costs of geothermal power plants (2019 costs, source: SU-IWG-DG)

<table>
<thead>
<tr>
<th>Plants</th>
<th>Capital Costs</th>
<th>Production Costs</th>
<th>Clarifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 MWe high temperature plant (Flash turbine)</td>
<td>€33-62 million in total</td>
<td>38/52 €/MWh</td>
<td>€1.65-3.1 million/ MWe Power plant construction: turnkey costs for Utilities in Italy and Iceland</td>
</tr>
<tr>
<td>10 MWe medium temperature plant (Binary turbine)</td>
<td>€42-57 million in total</td>
<td>140-180 €/MWh</td>
<td>€4.2-5.7 million/ MWe Costs will vary according to the increased amount for power plant construction and installation.</td>
</tr>
<tr>
<td>5 MW electric EGS plant (or thermal 25 MWth)</td>
<td>€35-50 million in total</td>
<td></td>
<td>€7-10 million/ MWe 1. power plant equipment: €10 – 15 million 2. power plant installation and infrastructure (civil works, connection to grid etc.): € 10 – 15 million</td>
</tr>
</tbody>
</table>
Figure 4: Cost range for the development of a 10 MWth geothermal DH (doublet) systems, producing 40,000 MWh/year (investment cost = €1.3-2 million/MWth). Capital costs do not include costs for the installation of the district heating grid (about €1 million/km).

Figure 5: Cost range for the development of a 10 MWth geothermal DH (doublet) systems, assisted with two large heat pumps of 4 MWth.
Figure 6: Cost range for the development of a 5 MW\(_e\) and 20 MW\(_{th}\) CHP plant (including a turbo-generator).

Figure 7: EUR, based on a 50kW\(_{th}\) geothermal heat pump installations

Geothermal resource risk: a major factor to be addressed for a successful market uptake

Exploration is necessary to identify potential geothermal resources. However, beyond exploration, the bankability of a geothermal project is threatened by geological risk:
- The short-term risk of not finding an economically sustainable geothermal resource after drilling;
- The long-term risk of the geothermal resource naturally depleting rendering its exploitation economically unprofitable.

Mitigating this risk is crucial for the profitability of a geothermal project. At the technical level, this includes improved exploration techniques. Non-technical measures that have proven effective include sharing geological data from existing projects. A widely proven solution to facilitate market uptake of geothermal energy against this challenge however is the establishment of geothermal derisking schemes.

Geothermal projects are very capital intensive and require a significant share of the investment to be invested before the exact parameters of the resource are known. On the figures above, this corresponds to expenditures for resource identification and exploration and drilling. In the case of projects requiring stimulation or reservoir engineering, there is significant uncertainty on the potential capacity and output of the project until this task has been successfully completed. This means that between 25% and 50% of a geothermal project cost must be invested when there is a very high level of uncertainty on the success of the development. The consequences of such uncertainty often are higher capital costs (i.e. higher interest rates) or incapacity to access private financing. As noted below, a suitable support framework for geothermal energy project accounts for the specificities of the cost structure of geothermal projects and the risk linked to geological uncertainty to minimise the cost of capital.

Considering the large upfront investment necessary to launch a geothermal project, the cost of capital is a key factor in the final price of geothermal heating and cooling or of geothermal electricity.

### 1.2.2 Geothermal heat pump

The risk component is much smaller for geothermal heat pump projects. Indeed, they are much less dependent on the temperature and flow rate of an aquifer (although this may be the case for some open loop projects, notably at large scale). For these projects, as in geothermal district heating and cooling, drilling and borehole heat exchanger construction represents the largest part of projects development costs. The heat pump, usually installed to enable the heat extraction, is another important segment.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost Range (EUR/MWh)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic heating (10-15kW)</td>
<td>81 - 126 € / MWh</td>
</tr>
</tbody>
</table>

² Figure from Ademe, *Coût des énergies renouvelables et de récupération*, 2019.
One of the main factors in the price of geothermal heat pump systems is the maturity of the market, including the competition among geothermal heat pump systems developers – which are often SMEs closely related to H&C equipment installers. In mature markets, where geothermal heat pumps are a well-established technology, costs will be much lower and system development quicker and more reliable. In emerging market, costs progress along the cost curve as installers acquire more experience, the skilled workforce expands and more actors enter the market. The higher penetration of the technology also has a direct impact in creating a deeper market, as mouth-to-ear experience sharing has a major impact on market uptake for H&C technologies (consumers have a high risk aversion to invest in a technology on which they are not sure they can rely for their H&C needs)³.

### 1.2.3 Cost reduction: experience and progressing along the learning curve

Geothermal electricity: a steep learning curve for innovative technologies?

<table>
<thead>
<tr>
<th>Levelised cost of Geothermal Electricity</th>
<th>Costs 2019 Range (€/kWh) Average (€/kWh)</th>
<th>Costs 2030 Average (€/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity Conventional – high T°</td>
<td>0,03 to 0,06</td>
<td>0,04</td>
</tr>
<tr>
<td>Low temperature power plants</td>
<td>0,10 to 0,17</td>
<td>0,15</td>
</tr>
<tr>
<td>Enhanced Geothermal Systems</td>
<td>0,20 to 0,30</td>
<td>0,16</td>
</tr>
</tbody>
</table>

*Table 2. Levelised costs of geothermal electricity (Update of Strategic Research Priorities for Geothermal Technology (2012, European Technology Platform on Renewable Heating and Cooling)) - updated*

Where high-temperature hydrothermal resources are available, in many cases geothermal electricity is competitive with newly built conventional power plants. The levelized cost of conventional geothermal power tends to be competitive with an average cost of 40 EUR/MWh in 2019 in Europe for new installations. There are also prospects for further cost reduction, and we can expect LCOEs around 25-30 EUR/MWh in 2030 in

³ Front Project.
Europe. The low availability of resources for conventional geothermal however limits the prospect for large development in the region.

Binary systems can also achieve reasonable and competitive costs in several cases, but costs vary considerably depending on the size of the plant, the temperature level of the resource and the geographic location. Typically, they range between 100 EUR/MWh and 170 EUR/MWh. With technological progress a halving of the typical LCOE can be expected by 2030 to produce baseload electricity at 70 EUR/MWh (in LCOE, not accounting for grid services such as flexibility, cogeneration of heating and cooling or other possible income streams for the power plant).

EGS costs cannot yet be assessed accurately because of the limited experience derived from pilot plants. As an emerging technology it is still fairly high up its learning curve. Significant improvements in the cost structure could be reached, from LCOE typically around 250 EUR/MWh for the first projects between 2007 and 2015, estimated at 200 EUR/MWh for projects around 2020 to 100 EUR/MWh in 2030.

Beyond LCOE estimates, there are several factors that affect cost reduction for geothermal electricity technologies:

- Experience (in drilling, reservoir engineering)
- Technology advancement (esp. in drilling)
- Standardization of projects: would have a strong impact on lowering the cost of EGS, thus far are mostly demonstration projects
- Competition between developers and service companies (i.e. demand driven).

A larger portfolio of demonstration projects would provide valuable data to project developers on techniques, failure rates, processes, and it would allow more companies to acquire expertise, initiating a more competitive field.

For all technologies, access to reliable and granular geological data would greatly increase the early stages of project development. There are further cost reductions that may be reached with increased deployment (notably for drilling, production).

Considering the weight of capital costs in geothermal electricity projects, the reduction of the cost of capital itself is key to reduce the cost of geothermal electricity. While this depends on the maturity of the technology, several policy and financial instrument can have tremendous impacts, notably derisking schemes.

### Geothermal for heating and cooling: cost reduction dependent on market maturity

<table>
<thead>
<tr>
<th>Levelised Costs of Geothermal Heat</th>
<th>Costs 2019 (EUR/kWh)</th>
<th>Costs 2030 Average (EUR/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal Heat Pumps</td>
<td>0.05 to 0.150</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Geothermal for heating and cooling covers widely different technologies that can meet different uses. However, geothermal for heating and cooling will tend to be more cost effective when good geothermal resource is readily available and/or in colder climates – with a longer heating season. Geothermal heat pumps can however be very relevant for warm climate as well, being a very efficient solution for providing cooling as well as heating.

Climate conditions must be accounted for when considering a geothermal project’s cost as the demand for heat is much more variable geographically than that of electricity. However, beyond the quality of the geothermal resource and the risk factor, the main factor for cost reduction in geothermal for heating and cooling is market maturity. Typically, markets with small capacity tends to be more expensive than more liquid ones for conventional projects.

Another key prospect for cost reduction in geothermal heating and cooling projects is the use of the geothermal resource at various temperatures, extracting more value from the same amount of energy produced. This can for instance include the use of higher temperature for industry, then the use of energy is a low temperature district heating and finally using the remaining heat energy for processes such as de-icing roads.

### 1.3 What impacts the cost of a geothermal project?

The cost of a geothermal project varies significantly according to many factors that are go beyond the geothermal resource itself. As the geothermal market remains quite fragmented and complex, there are elements that factor the cost of a project.

- Geothermal energy projects tend to use equipment and workers that are also utilized by the oil and gas sectors, for instance for drilling. There is therefore a direct link between oil and gas prices and the cost of drilling for a geothermal project. Indeed, globally, the O&G sector is by far the largest user of drilling rigs (over 70% of drilling rigs in Europe are used for O&G activities). A high oil price, which incentivises drilling for more oil, translates in higher drilling cost for geothermal because there will be more competition to use the available rigs.

- The high drilling cost, especially in deep geothermal energy projects, could be further reduced by deploying innovative drilling technologies that are more cost-

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4 Geothermal applications for various processes (industrial, agricultural and tertiary) include for instance: balneology, greenhouses, agro-industrial processes etc.
efficient in bigger depths, with cost per depth increasing linearly, not exponentially (as it is the case with conventional drilling).

- Geothermal for electricity is often compared in terms of cost (per MW or per MWh) with solar PV or wind power. While these comparisons make sense to acknowledge the competitiveness of the two latter technologies, they do not usually accurately represent the differences between the energy sources. Geothermal power can indeed reach capacity factors of up to 100% and has proven to be flexible and dispatchable production sources that can provide grid services. These grid services have a value that is not always reflected in the cost per capacity when comparing different renewable sources. In that regard, the integration of system costs, and not only LCoE should be considered by policy makers and investors.

- The geothermal sector remains a smaller market that of other energy source, which leads to a fragmentation of the supplier markets, which may be the source of higher prices in emerging markets as manufacturing capacity is lacking. With the deployment of more geothermal projects, this lack of manufacturing capacity will cease to be a factor driving up costs in new markets and be a source for cost reductions in the European geothermal market as a critical mass of capacity is reached.

- Geothermal energy is still an emerging energy source across many European markets, and RD&I are required to allow Europe to fully tap into its geothermal energy potential for heating and electricity production. In that regard, the cost of projects demonstrating innovative technologies or processes may not be fully reflective of the cost of geothermal energy once this technology reaches a higher degree of maturity.

- The availability of a geothermal derisking scheme has a strong influence on the cost of geothermal projects, as it reduces the risk for private investors in a project (and therefore the return they require in exchange for their investment).
Financing geothermal energy projects: support schemes and financial instruments

“The right scheme for the right market maturity.” This could be the maxim for financing geothermal energy projects as the geothermal sector is far from being uniform in terms of maturity and technology readiness across geographical, technology lines and uses.

As figure 3 below illustrates, to incentivize the scalability of geothermal technologies, the exposure to market conditions should not anticipate their market maturity, and instead accompany the technologies towards this goal. Suitable support schemes and financial instruments allow for the cost reductions necessary for a technology to reach the market and for the consolidation of an emerging renewable industry in a market that remains very favourable to incumbent fossil technologies.
2.1 The central role of geothermal derisking

Geothermal projects face an atypical financial risk profile as they have to compound with “geological risk”, or the fact that there is significant uncertainty regarding the quality of the resource (temperature, flow, minerality…) until the first well has been drilled – and therefore that a large amount has been spent\(^5\). The figure 5 below draws an outline of the

\(^5\) See figures 1 & 2.
investment risk along the development of a geothermal project. It underlines that much of the investment has to be spent before the risk decreases significantly. A solution to facilitate the financing of geothermal projects considering this factor is to set risk insurance schemes.

![Figure 9: Investment risk: a key challenge (representation of the level of risk of a geothermal project against cumulative investment) (EGEC)](image)

As usual when it comes to financial instruments and support schemes, it is necessary to tailor the instrument to the needs of investors to maximise its impact. As detailed in the figure 5 below, there are many options for mitigating the resource risk linked to developing a geothermal project. However, some options are more suitable than others according to the market and the technology considered. Indeed, a private insurance scheme would not be attractive to developers (or indeed to insurers) in a small market where risk is high, information unavailable and there are few projects undertaken – so insurers cannot diffuse the risk throughout a portfolio. In this case a grant-based scheme may be required to help set the basis for a geothermal market, create the right level of expertise and knowledge of the resource. Conversely, public grants are an inefficient way to mitigate risk in a deep and mature market with a lot of projects.
Figure 10: Waterfall structure of Commercial Readiness Indicator and Risk Mitigation Schemes dependency (GEORISK)

Where circles represent the relevant Risk mitigation scheme (RMS) at the given Commercial Readiness Indicator (CRI) level.

I. Grants
II. Convertible grants
III. Repayable grants
IV. Public insurance scheme
V. Public-Private Partnership
VI. Private RMS

Additionally, following auxiliary mechanism could be present in the market:

- Blue Circle represents a zone, where Contingency Grants is represented.
- Green Circle represents a zone, where Loan Guarantees is represented.
- Purple Circle represents a zone, where Private-Private Partnerships is represented.

The figure 6 highlights the many nuances of geothermal derisking schemes:
• **Grant based derisking:** grants are awarded by public authorities to project developers to cover the investment costs (or part of the costs) before the risk can be decreased (e.g. exploratory well, drilling…). In new markets, unconditional grants may be more relevant to attract developers, while as the market matures, other form of grants can be suitable for a lesser impact on public finances, for instance repayable grants in case of success, or even convertible grants (if the project is successful, the grant is converted into a loan which has to be paid back including some possible interests).

• **Public insurance schemes:** Public authorities guarantee a pool of geothermal projects against failure (for instance providing 90% of payback for eligible costs such as drilling in case of total failure to the project developer). Such insurance scheme requires a degree of market maturity that allows the insurer and developer to have sufficient knowledge of resources and project development that risk is already lowered.

As market maturity increases with the knowledge of resources and the portfolio of insured projects, the private sector may increasingly be involved in insurance schemes. Some entirely private risk insurance schemes have already been established for geothermal energy, but with limited success due to a lack of market liquidity.

### 2.2 Auctions: global overview

Auctions are often used to allocate funding to geothermal energy projects – and renewable project by extension. They are particularly widespread for geothermal outside Europe. Auctions for renewable energy projects are defined as follow by the IRENA\(^6\): “Renewable energy auctions are also known as “demand auctions” or “procurement auctions”, whereby the government issues a call for tenders to procure a certain capacity or generation of renewables-based electricity. Project developers who participate in the auction typically submit a bid with a price per unit of electricity at which they are able to realise the project. The auctioneer evaluates the offers on the basis of the price and other criteria and signs a power purchase agreement with the successful bidder.”

The Agency notes that auctions are an interesting mechanism thanks to their flexibility, the possibility to discover the “real price” thanks to competition between bidders, transparency and greater certainty regarding prices and supply. However, there is a significant risk of delays and under delivery, as well as high transaction costs linked to the bidding process. In top, system costs and value of the energy source are not incorporated.

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For geothermal projects, auctions can make sense provided there are enough actors involved in the market and able to take part in the bidding process. It is therefore a financing scheme that is best suited for more developed markets, having the value of geothermal integrated in the process.

The auction process provides policy makers with a great degree of flexibility in the design of the requirements. Auctions may be technology neutral or specific, focused on capacity or energy production, and include requirement for resource availability, diversity of portfolio or dispatchability. According to the parameters of an option – and the resource and market maturity – geothermal projects may or may not be competitive.

Outside Europe, there have been successful example of auctions for geothermal electricity:

**Indonesia:** The auction was launched with a highest reference price of USD 155/MWh (USD 0.155/kWh) by the Energy Ministry. The consortium of PT Hitay Southwestern Energy and PT Dyfco Energy has won the auction for the Mount Talang Geothermal Working Area with an offer price of electricity of $0.1275/kWh.

**Mexico:** During the 2nd Renewable Energy Auction in 2016, the GFE company was awarded an auction for developing a geothermal plant (25MW) at an expected cost of USD 0.039/kWh and receiving USD 0.0375/kWh. This plant is an extension to an existing facility.

**Kenya:** The feed-in-tariffs in place until 2018 have been replaced by an auction scheme. While geothermal received around USD 0.088/kWh (or USD 88/MWh) as a feed in tariffs, it is expected that upcoming auctions could result in support level twice as low, reflecting the significant maturation of the Kenyan market over the past decade.

Typically, geothermal projects are competitive in the auction process when there is a well-established geothermal sector and when there is requirement for energy availability (i.e. flexibility, dispatchability or baseload production). Another feature of the auction process where geothermal projects may be very competitive is when the auction does not distinguish between the supply of heat and electricity. In this case, geothermal heating and cooling projects may be very competitive.

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7 Energy Ministry ministerial decree no. 17, 2014.
8 *Daily Nation, Kenya bets on cheaper power to fire its key growth engine, 11/02/2018*
### 2.3 Support schemes during operation

**FEED-IN TARIFFS, FEED-IN PREMIUMS: OVERVIEW OF NATIONAL SUPPORT FRAMEWORK (WITH A FOCUS ON GEOTHERMAL ELECTRICITY)**

<table>
<thead>
<tr>
<th>Country</th>
<th>Type</th>
<th>Eligibility period (years)</th>
<th>Description of the scheme</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Feed-in Tariff</td>
<td>13</td>
<td>7.22 c€/kWh (if application in 2019)</td>
</tr>
<tr>
<td>Belgium (Flanders)</td>
<td>Investment subsidy</td>
<td></td>
<td>Granted to SMEs, for investments of at least EUR 3 million, in Flanders</td>
</tr>
<tr>
<td>Belgium (Brussels)</td>
<td>Quota System</td>
<td></td>
<td>Geothermal eligible as part of the portfolio</td>
</tr>
<tr>
<td>Belgium (Wallonia)</td>
<td>Investment subsidy</td>
<td>-</td>
<td>Case by case basis, up to 20% of the investment by a large company, 50% by a SME.</td>
</tr>
<tr>
<td>Croatia</td>
<td>Feed-in Premium, Subsidised loans</td>
<td>N/A</td>
<td>Level of supported determined by the government, it is set through tendering.</td>
</tr>
<tr>
<td>Denmark</td>
<td>Tax reduction</td>
<td></td>
<td>RES exempt from taxes on energy products, royalties, levies</td>
</tr>
<tr>
<td>Finland</td>
<td>Investment subsidy</td>
<td></td>
<td>Up to 40% for project &gt; EUR 5 million</td>
</tr>
<tr>
<td>France</td>
<td>Case by case support</td>
<td></td>
<td>New electricity projects are not eligible for a feed in tariff or premium.</td>
</tr>
<tr>
<td>Germany</td>
<td>Feed-in Premium</td>
<td>20</td>
<td>25 c€/kWh (plants can only be eligible if they are able to respond to balancing needs)</td>
</tr>
<tr>
<td>Germany</td>
<td>Low-interest loans (KfW Renewable Energy Programme Premium)</td>
<td></td>
<td>Low interest loans (up to 80% of financing) or repayable grants for CHP plants.</td>
</tr>
<tr>
<td>Greece</td>
<td>Feed in premium</td>
<td>20</td>
<td>Sliding premium, awarded through tenders. 139 EUR/MWh for plants below 5MW capacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>108 EUR/MWh for plants above 5MW capacity</td>
</tr>
<tr>
<td>Country</td>
<td>Support Scheme</td>
<td>Details</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Iceland</td>
<td>Investment subsidy</td>
<td>Up to 50% of the project finance</td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>Feed-in Tariff</td>
<td>20 For plants up to 0.5 MW, Three tariffs between 4.2 c€/kWh and 11.5 c€/kWh (depending on load profile) For plants 0.5MW&lt;x&lt;1MW, “green” Premium of 10 c€/kWh (tendering procedures)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Feed-In Premium</td>
<td>25 Technology neutral tendering for plants &gt;1MW, Premium set by tender with maximum value of 10.3 c€/kWh</td>
<td></td>
</tr>
<tr>
<td>Italy</td>
<td>Currently no defined framework for support to geothermal electricity in Italy. Discussions are ongoing to limit future support to conditions on environmental impact.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Netherlands</td>
<td>Feed-in-premium</td>
<td>15 Typically 5.3 c€/kWh of heat (some higher tariff for specific type of projects)</td>
<td></td>
</tr>
<tr>
<td>Poland</td>
<td>Tendering scheme</td>
<td>15 Plant awarded a guaranteed price over 15 years (technology neutral, competitive process)</td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>Feed in Tariff</td>
<td>12 For plants up to 3MW, average value of 270 EUR/MWh</td>
<td></td>
</tr>
<tr>
<td>Romania</td>
<td>Quota system</td>
<td>N/A Geothermal electricity counted with multiplier 2x (3x for high efficiency CHP)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Investment subsidy</td>
<td>Up to 15 million EUR in grant (up to 45% of project cost) for developing “less exploited sources”</td>
<td></td>
</tr>
<tr>
<td>Serbia</td>
<td>Feed in Tariff</td>
<td>12 8.2 c€/kWh</td>
<td></td>
</tr>
<tr>
<td>Slovakia</td>
<td>Feed-in Tariff</td>
<td>15 108.7 EUR/MWh</td>
<td></td>
</tr>
<tr>
<td>Slovenia</td>
<td>Investment subsidy/Loans</td>
<td>Tenders to award investment subsidies for projects (up to 50% of investment) Subsidised loan up to EUR 6 million with a rate of at least 1.3%.</td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>Quota system</td>
<td>15 Geothermal is eligible as part of portfolio</td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>Feed-in Tariff</td>
<td>20 Plants &lt;5MW: 37.3 c€/kWh Plants &lt;10MW: 33.6 c€/kWh</td>
<td></td>
</tr>
</tbody>
</table>
Many European Countries propose feed-in tariffs or premiums to support geothermal electricity production. This type of support schemes on operation, which became widespread after the adoption of the Renewable Energy Directive in 2009, reduce the uncertainty linked to electricity market price fluctuations for the sale of renewable electricity. For facilities with baseload production profiles such as geothermal, feed in tariffs and premium can have a very strong impact in guaranteeing the potential income of a project. As we have seen above, the guaranteed income does not erase the need for a form of derisking to mitigate the resource uncertainty. This highlights the need to articulate support frameworks and incentive schemes for an effective market uptake according to the requirements of a given technology.

Feed in tariffs are notably suitable to promote the emergence of a new technology within an electricity market, by decoupling its income from the market price (as the producer receives a fixed income per MWh produced, it also incentivises to produce as much as possible regardless of the electricity market price). This is valuable when there are barriers to entry, or when the electricity mix is characterized by a dominance of amortised, heavily subsidised assets (e.g. old coal, natural gas or nuclear plants).

For the development of geothermal power in new markets, either feed in tariff or premium can be suitable, depending on their design. As a capital-intensive energy technology, with low variable cost and baseload production profiles, demonstration geothermal facilities would not benefit from exposure to price volatility. Instead a support scheme that guarantees a stable amount in exchange for production reduces the costs of developing new geothermal projects by reducing income uncertainty – and therefore the cost of capital with a significant impact on total project cost.

A major issue that has emerged from the perspective of the geothermal industry relates to the management of the changes in support scheme framework, especially regarding the evolution of the feed-in tariffs. Although it is indeed necessary to lower the amount awarded as a tariff as the market progresses toward maturity, this must be done while preventing disruption in the geothermal markets, which remain inherently fragile across Europe. Typically, as geothermal energy projects take between 5 to 10 years (for innovative electricity projects) to be commissioned, rapidly evolving frameworks with little predictability pose a significant challenge to geothermal developers.
In some European markets, the implementation of a feed-in-tariff for renewable heating and cooling has been a successful strategy to support the deployment of geothermal energy projects. The feed-in-tariff or premium for heating and cooling has been a crucial factor in enabling the rapid deployment of privately led geothermal heating and cooling projects in the Netherlands over the past decade. When adequately targeted, feed-in-tariffs can be a winning solution in the heating and cooling sector as well as in the electricity sector. The Dutch case shows that tailoring the schemes to SMEs with high energy costs can be beneficial: such actors have the incentive to benefit from the tariffs and the capacity to invest in order to recoup their costs in the short to medium term. Such private investor-led investments (even when a FiT/FiP is available) however requires the availability of some form of geothermal derisking scheme to incentivize SME developers to deploy geothermal systems.

Feed-in-premium or tariffs for heat require the availability of the right business model, as heating and cooling equipment (unlike electricity generation) is often owned and operated by the consumer, which may be much less sensitive to operation costs in her investment decisions. For the Netherlands, greenhouse operators could assess the benefits they could get from developing a deep geothermal system, and raise the capital needed for the investment costs. At the level of a household however, even if the payback appears obvious, not all homeowners are able to invest in a geothermal heat pump system on this basis alone. This explains the prevalence of tax rebates or investment aid, to maximise deployments despite the usually more limited investment capacity of household. Some business models, for instance on the ESCO model used in the energy efficiency space, or similar to the leasing one in the car industry could be a solution in that regard, and enable households to tap into the benefits of operation aid to geothermal heating and cooling.

Communication between the industry and the authorities is crucial to ensure the change in the tariff framework is commensurate with the market’s evolution, and that it does create a situation of uncertainty which stops on project developments.

**Takeaways:**

- Relevant schemes to reduce income uncertainty for developers, can be implemented in heating and cooling and for electricity.
- Stability and predictability of framework is crucial considering the long development period for geothermal projects.

### 2.4 Different uses of grant-based financing:

Grant based financing is a stable of public support to renewable energy project, notably when it comes to the support of innovative technologies, demonstration projects or high-
The grant, usually a fixed amount of money awarded by a public authority to a project may cover a large share of the total costs or be a marginal part of the financing scheme. Different types of grant financing usually serve different purposes.

- Direct grant financing happens when a grant is provided to a project in order to finance it. The money awarded is given to the project operator without financial conditionality (such as equity or reimbursement), but some conditions may be set to ensure the money is properly used. It is a form of financing particularly suited for very innovative projects (typically H2020 in the EU), or for projects carried by public authorities themselves (e.g. ESIF). Examples of projects that benefited from ERDF grants include the United Downs project in Cornwall in the UK – first geothermal electricity project in the country, and the city of Schwerin in Germany. The Heat Fund (in France is a major and successful example of a large scale facility providing grants to geothermal energy projects (usually at a larger scale) in order to correct the market imbalances due to the dominant position of gas or nuclear energy in the heat market.

- Repayable grant: a repayable grant is typically a grant that has to be repaid if certain conditions are met. In some cases, the grant may have to be repaid if the project is not successful, which is notably the case for grant financing awarded as part of the NER300. In other, the grant would only be repaid if the project is successful, which is quite a suitable scheme to reduce investment risk and helps in the early stage of marketability.

- Convertible grants are a more innovative type of financial instrument that is designed to ease the market development of innovative technologies. The funding, awarded as a grant, can be converted in another type of financing (equity, debt…) once the project attains a certain degree of success (this may the successful completion the drilling phase for a geothermal project for instance).

In general, in the European Union, grants do not cover the entirety of the funding needs of a projects and other sources of capital would often be needed for 50% of the total investment costs. However, grants are usually designed to decrease the cost of capital – which increases with the risk. This is intrinsically the case when part of the project is funded for “free”. The fact that grants can come in at the early stages of the project to provide funding for project development (ELENA, EHIA…) or for high risk stages of the project (such as drilling an exploratory well for a geothermal project) can provide benefits in terms of cost of capital that far outweigh the actual size of the grant. The European Union, in the name of a more efficient use of public funding, is increasingly developing financial instruments that use grants as a risk mitigation tool, developing repayable or convertible grants, or funding crucial parts of projects. The structure of the Innovation Fund, which replaces the NER300 in directing ETS funds to innovative renewable energy projects, reflects this trend, with the possibility to have part of the support validated (i.e. the grant does not have to be repaid) through milestones and not only in terms of performance of the project.

**Takeaways:**
• Very relevant in emerging markets as a way to reduce the geothermal risk and increase knowledge of resources.
• Relevant mechanism to enable derisking a low level of market maturity, notably to finance the parts of the project that carry the highest financial risk (drilling, exploration).
• Effective in favouring the market uptake of geothermal heat pumps provided the framework is well designed, stable and reflects the benefits of this technology compared to alternatives.

2.5 Green Bonds

Green bonds have been widely adopted by a large array of actors as a mean to finance environmentally friendly projects, notably for renewable energy investments. A green bond is emitted against an underlying asset that contributes to environmental priorities such as carbon emissions reduction. Some criteria are established for guaranteeing that the green bond is used in a way that delivers the advertised benefits. For geothermal for instance, an emission threshold of 100gCO2/kWh from direct emissions is set. Two plants have been deemed eligible and been financed through a green bond: Contact Energy in New Zealand (2016) and AP Renewables Inc in the Philippines.

This type of financing is especially relevant for commercially mature projects. Moreover, the emission of a green bond for project financing may be challenging for a small to medium sized developer.

Green bonds are also relevant as a mechanism to raise capital for financing schemes: for instance, a Bank may emit a green bond to finance a scheme for small scale loans for individual geothermal heat pumps in a given area. Similar practices have already taken place for energy efficiency financing.

Takeaways:
• Relevant schemes for utilities, large scale investors for financing a single large project or for a portfolio
• Can finance electricity, heating and cooling projects of all sizes, for instance as the capital that allows the emission of small business or households loans for renewable heating and cooling investments
2.6 VAT

The Value Added Tax is quite strictly regulated by the EU Directive on VAT. It can however be an incentive for investing in geothermal energy projects and has been used as such in some cases. Despite strict rules on the VAT, which should be fairly uniform across the EU to avoid market distortion, it is possible to apply lower VAT rates for heat supplied in District Heating, notably in the case of district heating in some countries (Czech Republic, Slovakia…).

The directive also states that Member States may apply a reduced rate for “provision, construction, renovation and alteration of housing, as part of a social policy;” (which may arguably be applied to geothermal district heating or geothermal heating systems).

More generally, tax policy can be used at the national level to encourage investment in geothermal projects – of all types – through tax breaks or tax credit. This is notably the case in France with a tax rebate on energy efficiency and renewable energy investments in individual housing.

Takeaways:

- Low efficiency of this measure in favouring the market uptake of geothermal in its current application, as fossil fuels can also benefit from reduced VAT rates.
- Overall a necessary tool to allow fair market conditions for geothermal compared to other technologies – not considering other market imbalances.

2.7 State aid: current framework and upcoming review

To ensure that the pursuit of the decarbonization of the European economy respects the principle of competition in the market, the EU Competition authority published in 2014 State Aid Guidelines for energy and the environment that indicates which rules Member States should follow when providing support.

As a rule, state aid is indeed forbidden in the EU market, but there are some exemptions that are explicitly laid out. The main rules are:

- EU public support is always deemed to be compliant with State Aid rules;
- “Member States intending to grant environmental or energy aid will have to define precisely the objective pursued and explain what is the expected contribution of the measure towards this objective”;

• The aid must generate additionality (enable an environmental improvement that would not happen should there be no state aid) and the benefits should be measurable when possible;
• The state aid can only be provided to fix market failures linked to negative externalities, positive externalities, asymmetric information or coordination failure;
• The aid should be appropriate, or proportionate, to the benefits it yields.

By defining what is possible for support renewable energy projects, and therefore geothermal projects, the state aid guidelines play a key role in the financing framework for geothermal projects. As the current set of guidelines were set in 2014 to allow the EU to meet its 2020 objectives, an upcoming revision of the guidelines will define the framework for Renewable energy support schemes after 2020 up to 2030.

This review should happen in the continuity of the current framework, while including the provisions on support schemes adopted as law by the European Union in the Renewable Energy Directive 2018:

• allow for specific support schemes for innovative renewable technologies (for instance EGS, notably in new markets)
• allow for technology specific support that allows a diversification of the energy mix according to the local resources – where geothermal energy has a key role to play to balance the intermittency of other sources;
• enable the promotion of renewables in heating and cooling (in line with RED Article 23);
• allow the derisking of geothermal energy projects;
• forbid strictly any subsidies to fossil fuel energy.

Takeaways:

• The State Aid framework is not a barrier to the market uptake of the geothermal industry currently;
• Proposed revisions of the framework carry opportunities and risks;
  o Opportunities: further establishing a level playing field through the application of strict state aid requirement to fossil fuels, and favouring the establishment of a level playing for renewables – notably in heating and cooling.
  o Risks: that renewables and fossil fuels are considered equal, despite the dominant position of fossil fuels in the market, and the continued stream of public subsidies received by the fossil fuel industry.
2.8 Financing demonstration projects: RD&I

All technologies pass through the same stages of the innovation cycle: from basic research through development, demonstration, deployment, and commercial market uptake. During these phases public funding for the continuing industry-led research, development and deployment is needed.

Under Horizon 2020, geothermal has been among the most supported technologies, as highlighted in the figure 6 below. Some EUR 113 million have been awarded for supporting geothermal RD&I projects between 2014 and 2017 at the European level – much of this funding in the form of grants.

Figure 11: Repartition of H2020 funding under INEA as of Jan 2020 (source: European Commission)

Another financing instrument existing at EU level is the NER300 programme, so-called because Article 10(a) 8 of the revised Emissions Trading Directive 2009/29/EC contains the provision to set aside 300 million allowances (rights to emit one tonne of carbon dioxide) in the New Entrants’ Reserve of the European Emissions Trading Scheme for subsidising installations of innovative renewable energy technology and carbon capture and storage (CCS). In December 2012 for instance, the European Commission awarded NER300 funds to the Geothermal South Hungarian Enhanced Geothermal System (EGS) Demonstration Project. The Hungarian project is one of the 23 innovative renewable energy technology projects funded according to the outcome of the first call for proposals under the NER300 programme. This led to the launch of the first plant for producing
electricity from geothermal in Hungary – inaugurated in 2017. The NER300 supported 4 geothermal projects. In 2020 it will be replaced by a so-called Innovation fund, which has the same purpose.

The level of support received by geothermal is supported by the advantages it provides to the energy system (renewable baseload, no need for back up, alleviating the need for transmission and distribution infrastructure etc.).

While conventional geothermal power is already a competitive energy source, low-temperature systems and EGS will become competitive within a few more years if substantial research, development and demonstration (RD&D) resources are allocated to those technologies. Likewise, geothermal heating and cooling also need RD&D funding to further improve the efficiency of the systems and to decrease installation and operational costs.

As debate is ongoing as to the shape that Horizon Europe, the facility replacing Horizon 2020, should take, it appears imperative that it continues to prioritise emerging renewable sources such as geothermal. The public support, notably at the European level, for geothermal has proven effective in unlocking innovation and opening new markets to geothermal energy.

**Takeaways:**

- EU R&I financing is a valuable funding channel for geothermal energy projects, having substantially contributed to the emergence of recent innovation.
- Over the coming programming periods, the funding should increase to enable the emergence of innovative geothermal energy technologies and accelerate their market uptake.
3.1 Private Financial institutions

The deployment of geothermal energy technologies at scale is dependent on the availability of private financing.

a) Actors

There are several categories of actors that provide private financing to geothermal energy projects, each with its own specific characteristics. However, private investors are looking to balance the risk and profitability of their investments, usually reflected in a metric such as the cost of capital. Different types of investors will have a different tolerance to risk: for instance, a large financial institution with a diversified project portfolio may be more willing to invest in a riskier geothermal project than a small investor that would entirely rely on said project.
<table>
<thead>
<tr>
<th>Category of private investor</th>
<th>Type of geothermal projects supported</th>
<th>Type of financing provided</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local banks</td>
<td>Geothermal heat pumps (individual, large buildings, business…), district heating…</td>
<td>Loans</td>
</tr>
<tr>
<td>Private equity</td>
<td>Geothermal developers, manufacturers, large projects (district heating, electricity)</td>
<td>Equity financing</td>
</tr>
<tr>
<td>Pension funds</td>
<td>All</td>
<td>Any, through private financial institutions such as banks or PE</td>
</tr>
<tr>
<td>Investment banks</td>
<td>Refinancing, manufacturers, utilities, large scale project financing</td>
<td>Loans, equity, complex financial products</td>
</tr>
<tr>
<td>Households</td>
<td>Geothermal heat pumps, district heating</td>
<td>Private investment, heat bills payment</td>
</tr>
<tr>
<td>SMEs</td>
<td>Geothermal heat pumps, district heating/heat for processes, small electricity projects</td>
<td>Private investment (equity), corporate PPA</td>
</tr>
<tr>
<td>Utilities</td>
<td>All (typically larger projects)</td>
<td>Private investments, project finance (typically structured by involving other investors)</td>
</tr>
<tr>
<td>Citizens/energy communities</td>
<td>All, usually projects within the community</td>
<td>Crowdfunding (loans, grant, equity…)</td>
</tr>
</tbody>
</table>

**b) Instruments**

Various instruments allow geothermal project developers to gather the necessary capital for their geothermal project. Instruments can be deployed at various scale: there is for instance significant differences in the loan provided to a household for installing a geothermal heat pump in their home by a local bank, and the loan provided by an investment bank to a utility for the financing of several large scale geothermal projects in export markets. The financial instruments usually provided by private financial actors to geothermal projects include:

- **Loans**: the provision of a sum of money that must be paid back to the investors (at an interest). Loans are an attractive option for developers in the current financial conditions of low interest rates. However, they require a robust derisking framework and a degree of maturity in the geothermal energy market as investors want to minimise their risks.
- **Equity**: in providing equity, private investors become directly involved in the projects, and do not receive a return if the project is not profitable enough. As a riskier form of financing, it is usually provided either directly by developers, or
at later stages of the project where the geothermal risk has been mitigated to a large extend.

- Corporate PPAs are an emerging financing instrument for geothermal project developers. By securing the demand for the geothermal energy produced, developers ensure its income, which in turns reduces the financial risk profile of the project. Corporate PPAs are emerging rapidly as the evolution of public operational support framework is exposing developers to more financial risks.

There is no single private financial instrument that is inherently better for geothermal energy technologies. Moreover, beyond direct financing, some financial instruments can be directly relevant to the market uptake of geothermal energy projects. For instance, securities backed on the provision of geothermal energy, harmonized within the framework of the EU sustainable finance taxonomy, can allow to direct new financing to the geothermal sector. However, such complex financial products are only emerging in the renewable sectors and need a harmonized set of standards to prevent greenwashing.

### 3.2 Corporate sourcing of geothermal energy

Corporate sourcing of energy is used by corporations or public authorities to secure their supply of renewable energy. More conventionally they have been used – notably in beyond the EU in markets such as the US – by utilities to source power capacity, for instance from renewables. The benefit of corporate sourcing is to provide certainty for both parties: the energy producer has a higher certainty on income with a stable customer at a predetermined price. The consumer benefits from certainty on price in the long term. Corporate sourcing of energy may take various contractual forms. It may correspond to Power Purchasing Agreements (PPA, where an agreement is made for the long-term sale of energy by two parties), to a joint venture or event to a corporation investing in its own geothermal project. Often associated with renewable electricity, corporate sourcing can also be used for heat supply to industry, agri-food or for space heating.

Corporate sourcing can moreover be a key factor for the development of a geothermal demonstration project, either by providing support in the context of a joint venture for a demonstration project (e.g. the ECOGI project in France about the supply of geothermal heat to a biorefinery for process heat), or by reducing the financial uncertainty for project developers, and hence reducing capital costs.

This business model may involve a direct connection between the plant and the customer as in the case of the heat supply from the Rittershoffen plant. They can also be virtual PPAs where the energy - usually electricity - is fed at one end of the grid and consumed at the other. In the latter case, sound certification of the electricity consumption, for instance with guarantees of origins is necessary to avoid a double counting of the renewable energy produced throughout the energy system.
Geothermal energy, as a flexible baseload source of energy, is particularly suitable for the needs of a PPA, as it can respond to variations in demand and is available when needed. For this reason, there are several examples of geothermal PPA across the world and in Europe.

Iceland

In 2014, Landsvirkjun, Iceland’s national power company signs power purchasing agreements with the industrial actor PCC BakkiSilicon for 35 MW of hydroelectricity capacity and 58MW of geothermal electricity. The purpose of this agreement is to provide electricity for a plant to produce silicon metals. The value of geothermal power for this type of customer is the guarantee to have a stable electricity source (geothermal plants have capacity factors up to 100%) with stable prices in the long term.

USA

In the United-States, PPA are much more widespread than in Europe. They are quite common for large companies, especially when they are looking to shift their electricity supply towards renewable energy. They are also prevalent for municipalities or utilities/electricity suppliers. There are indeed nearly 1 GW of geothermal capacity contracted as PPA to such actors as of 2016 for an average price per MWh of USD 75.88.

American corporations are also tapping into the stable power supply that geothermal can provide. It is notably the case of Apple, which pursued a 75 MW PPA with a geothermal power plant in Arizona, and additional agreements in Utah and California.

Mexico

In Mexico, as of 2016 geothermal energy was the third renewable energy source for supplying electrical capacity through corporate PPA behind wind and hydro. Among the subscriber to geothermal electricity through PPA are the mining company Minera Monteverde with a contract for a 52 MW capacity, the retail company Elektra and the telecom company Axtel.

Takeaways:

- Corporate sourcing of geothermal energy is a promising avenue for the geothermal industry. Suitable policy and regulatory frameworks are needed to enable the development of this practice.

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10 [http://www.thinkgeoenergy.com/geothermal-power-sought-by-apple-for-new-u-s-production-facility/]
• The framework for corporate sourcing of renewable energy needs to be flexible enough to allow the various types of schemes and business models that can be implemented.

3.3 Crowdfunding

Crowdfunding is an emerging resource for geothermal energy projects. Crowdfunding enables a project to raise a new form of capital, that comes with strings attached. Typically, geothermal energy projects enter crowdfunding financing to anchor projects within the community. The crowdfunding, while providing equity, is particularly relied on to foster community engagement. Indeed, the buy-in of the local community allows for a core of supportive citizens to signify their support of the project. By enabling the community to take financial ownership of the project, geothermal developers mitigate the risk of opposition as the involvement through crowdfunding guarantees transparency and accountability.

A key example of a crowdfunding project is the United Downs Deep Geothermal Project in Cornwall/ UK has successfully concluded its GBP 4.4 million fundraising campaign. The funding was thought in the form of bond financing through Abundance, a renewable energy focused crowdfunding platform. To a large extent, this project’s crowdfunding is driven by financial motives. Another example is the GéoMarnes Project by Engie in the Paris area, which is primarily driven by the desire to engage the community in the project (the crowdfunding is limited geographically and contributions by individuals are capped to ensure it is not coopted by large investors).
The financing of a geothermal energy project depends on many factors, chiefly technology, type of production and scale. The first takeaway of this publication should be that the right scheme is crucial for the success of geothermal project development. This is true for all geothermal technologies. Geothermal projects do not require more public support than other renewable technologies, they merely require support to
be provided at a level that is aligned with technology and market maturity. Besides, the financial instruments available to geothermal projects for private or public finance must also be adapted to the specific requirements of geothermal projects.

Due to the cost structure and the requirements of project developments, **geothermal energy project deployment benefits hugely from financing frameworks that emphasise derisking CAPEX.** This derisking framework can take many forms, from grant money in emerging markets for innovative technologies, to private insurance schemes in mature and liquid markets. Here again, tailoring the scheme to market maturity is crucial to ensure it is able to deliver.

Geothermal energy projects are in general looking at financial instruments that contribute to a reduced financial uncertainty. While this means on one hand derisking CAPEX, it also means securing income. In that regard, **operational support or long-term contracts are crucial.** For geothermal electricity projects, the framework is already well established for securing income on the sale of baseload electricity production. For heating and cooling, the availability of infrastructure is crucial for the geothermal project operator to ensure an outlet for the renewable heat or cold produced.

Finally, as the energy sector is increasingly competitive while fossil energy sources continue to benefit from massive and systemic subsidies, **geothermal energy developers are looking to new income streams to increase the profitability of projects.** These include the provision of flexibility services to the energy system, where schemes for the remuneration of this service need to be put in place. It also includes developing entirely new geothermal products, such as the extraction of strategic minerals like lithium from geothermal brines and signing long term supply contracts with battery factories.

To facilitate geothermal project financing, decision makers need looking at:

- Derisking capital expenditures through schemes tailored to market maturity;
- Reducing income uncertainty through public (FiT, FiP…) or private (enabling corporate PPAs…) instruments;
- Ensure the infrastructure is ready for the deployment of geothermal projects, notably for heating and cooling;
- Schemes to enable marketing the value of providing flexibility to the system by geothermal operators (for power production, storage, demand response…);
- Readiness of the regulatory environment for geothermal operators to propose new services such as mineral extraction from brine;
- **New business models are key for the market uptake of geothermal energy technologies, as their cost structure differs greatly from the prevalent ones in the current fossil technology dominated energy system which relies on not including externalities such as carbon costs, and discounting future costs (e.g. OPEX) compared to investments (CAPEX) when assessing the value of an investment.**
4.1 Comparability: the need for indicators that reflect the value provided by geothermal technologies

At the policy level, a strong emphasis is put on the levelized cost of electricity (LCoE). However, this measure of the cost of electricity is only a partial representation of the value of an electricity project. Typically, the LCoE does not reflect the need for electricity to be produced at exactly the same time it is needed, and therefore the specific value of flexible and dispatchable plants.

The LCOE is defined as follow:

$$LCOE = \frac{\text{total lifetime expenses}}{\text{total expected output}} = \frac{\sum_{t=1}^{n} \left( \frac{l_t + M_t + F_t}{(1 + r)^t} \right)}{\sum_{t=1}^{n} \frac{E_t}{(1 + r)^t}}$$

Where:

- $LCOE$ = average lifetime levelized cost of electricity;
- $l_t$ = investment expenditures in the year “$t$”;
- $M_t$ = O&M expenditures in the year “$t$”;
- $F_t$ = fuel expenditures in the year “$t$”;
- $E_t$ = Electricity generation in the year “$t$”;
Moreover, the sole focus on LCoE tends to ignore the possibility to extract value from heat production in thermal renewable plants (such as geothermal), which may represent a significant amount of heat able to meet the needs of whole neighborhoods. The value of this cogeneration should be reflected when comparing two projects – as well as the quantity of fossil energy displaced not only by the addition of electrical capacity, but by the substitution of fossil heating by renewable heat such as geothermal.

Missing in the above equations are factors that are therefore much more difficult to approximate within a single value, and are therefore often left aside when considering the LCOE of two different technologies:

- Value of the production of heat (compared to alternative when the heat is needed);
- Value of dispatchability and flexibility;
- Externalities (from carbon, air pollution, other environmental impacts).

European funded projects such as GEOENVI and GEOSMART are working to propose indicators that are more relevant to reflect the needs of the evolving energy sector.

**Externalities and carbon price: the blind spot of LCOE**

Externalities are notably emissions of GHG such as Carbon dioxide (CO2), Sulphur dioxide (SO2) and Nitrogen Dioxide (NO2), but also subsidies to fossil fuels and nuclear, electricity and gas regulated prices. They must be counted and ideally also the security of energy supply should be taken into account;

- Carbon emissions are counted through ETS (but only for the large energy plants)
- SO2 and NO2 emissions are not (except the example of the Swedish pool for No2)
- Gas price for heating: open market

The EU Emission Trading Scheme (ETS) has a conflicting objective of CO2 emissions reduction and promoting low carbon technologies. The current incertitude on its main goal creates the conditions of its ineffectiveness with a CO2 price that is not reflective of the targeted decarbonization trajectory.

The introduction of a system to reflect the price of carbon emissions, or more generally the lifetime carbon impact of alternative projects can also contribute to a better information
on the benefits of different investment options in renewable projects. The inclusion of system costs in the pricing of these projects could also reflect their real-world value more accurately. While geothermal projects remain more expensive on an LCoE basis, their value in terms of system services and supply of heat is usually not reflected in this indicator.

Another major distortion in the perceived cost of an energy source linked to LCOE – but also to similar methodologies for “levelized cost” – is linked to the discount rate. With the discount rate, a lower value is put on a cost in the future that in the present. The higher the discount rate, and the further away in the future the cost, the lower it is perceived in the present. This seriously minimizes the perceived cost of operating or cost expenditures in the future, such as the cost of carbon regardless of the price.

As illustrated above regarding the value of flexibility from geothermal technologies to the energy system, this service from geothermal energy can represent a very significant part of the LCOE of a project (from 5-100%+). Relevant indicators must include this dimension of geothermal technologies, especially as significant amounts of capital are being mobilized to invest in both renewable energy production and flexibility resources. Geothermal projects should be compared with technologies that can provide the same services (this is also true regarding the possible supply of combined heat and power).

4.2 Toward innovative schemes

a) grid premium for geothermal electricity?

4.2.1 Capacity and flexibility payments for geothermal power plants

Electricity production from geothermal energy is a renewable, dispatchable and flexible resource. The high capacity factor of existing geothermal plants show that they are currently able to meet the demand of baseload production. Tests on German plants also show that geothermal capacity can be ramped or down in a matter of seconds. These characteristics open the opportunity for geothermal power to benefit from support in the form of a grid premium or capacity remuneration.

In a system where there is an increasingly high share of intermittent electricity production (namely PV and wind power), policy makers are challenged to develop incentives to support technologies that are at the same time compliant with climate imperatives and contribute to ensuring the continuous supply of electricity to consumers. Some options such as capacity remuneration mechanisms (CRM) are being debated as part of the proposal for an electricity market regulation. The purpose of CRM is to provide a payment to a producer of electricity for its capacity to supply power at a given time, to meet imbalances that may arise between production and demand. Grid premium is a more general idea for remunerating flexible and dispatchable – and ideally prioritizing renewable - capacity if it has to be displaced by intermittent renewable production.
CRM or grid premium are an interesting support scheme perspective for geothermal energy, as it highlights the specific benefits that geothermal electricity production provides in addition to the simple “capacity” figure. Able to provide baseload power, or to meet sharp ramp or down requirements, the capabilities of geothermal power plants have a value for the stability of the system. A framework that captures this value and fairly distributes it to the geothermal plants can incentivize the development of a more robust electricity network and spur the development of flexible and dispatchable renewable capacity, notably geothermal electricity.

The value of the flexibility provided by geothermal power plants is difficult to estimate considering the current market structure where this service is not usually rewarded, and the abundance of publicly subsidized fossil flexibility resources (gas, oil power plants), in the price of which carbon externalities are not suitably included. However, some studies allow a conservative estimate of the value of flexibility of geothermal power plants between 15-50 €/MWh\textsuperscript{11}.

For a geothermal power plant selling its output at 40€/MWh, as can be the case in Tuscany considering costs, this may entail an average 10€/MWh net subsidy from the geothermal operator in flexibility costs to the rest of the system.

\textbf{4.2.2 Market flexibility through system integration}

On the other side, geothermal heating and cooling technologies can also derive financing from the provision of flexibility service. First, geothermal heat pump systems can contribute to demand response schemes, where the electricity consumption of appliances is adapted to the grid (i.e. run the heat pump when there is plentiful renewable supply from intermittent source and electricity is cheap, and not when there is more scarcity). Demand response is increasingly considered to reduce the cost of energy for consumers, while being one of the answers to the need for flexibility resources in a decarbonised electricity sector. Geothermal heat pumps are a valuable instrument in that regard because they allow an interconnection between the electricity and heating and cooling sector, while minimizing the impact on the grid. Indeed, geothermal heat pumps being the most efficient, heating the same area will require between 10-85% less electricity than any other alternative equipment\textsuperscript{12}. The deployment at scale of geothermal heat pumps allows to benefit from demand response for flexibility, while not minimizing the increase in the absolute quantity of electricity needed.

\textsuperscript{11} Approximated value based on the Committee on Climate Change study "Value of Flexibility in a Decarbonised Grid and System Externalities of Low-Carbon Generation Technologies", 2015.
\textsuperscript{12} Alternative electrically driven heating and cooling equipment including air heat pumps (which are 10 to 50\% less efficient in using electricity to produce heat than geothermal ones) and direct electric heating which uses at least 5 times as much electricity to produce the same amount of heat as a geothermal heat pump would.
<table>
<thead>
<tr>
<th>Value Metric</th>
<th>Residential Cooling</th>
<th>Residential Water Heating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue per peak capacity</td>
<td>$5/kW-year</td>
<td>$45/kW-year</td>
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<tr>
<td>Revenue per annual availability</td>
<td>$15/MW-h</td>
<td>$31/MW-h</td>
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<tr>
<td>Revenue per enabled capacity</td>
<td>$3.1/kW-year</td>
<td>$0.7/kW-year</td>
</tr>
<tr>
<td>Revenue per unit</td>
<td>$7.4/unit-year</td>
<td>$3.3/unit-year</td>
</tr>
</tbody>
</table>

Table 4. Value to load of demand response options (Source: NREL, analyzing the Arizona power grid)

The above table highlights the value that can be extracted from the provision of demand response services by geothermal heat pumps – although these figures cannot be translated as such to the European framework considering the greater use of cooling in Arizona and the much lower heating needs that in Europe. They however allow to approximate a range for the value of demand response from individual geothermal heat pumps ranging from 10 – 100+ €/month per household.

Simultaneously, geothermal technologies for heating and cooling also represent opportunities to store energy. This can be done over a few hours (typically what is done with demand response in geothermal heat pumps). But geothermal technologies also have a huge potential for seasonal storage of thermal energy. This is particularly relevant as heat represents about half of the European energy consumption, and winter heat demand may be up to 10 times the electricity peak load. Seasonal storage could therefore enable the European economy to avoid multiplying the size of its electricity capacity (including production and distribution networks) by several order or magnitudes. The right business models can enable seasonal storage from geothermal, for instance UTES or ATES technologies, to provide this service, for instance by storing solar thermal energy in summer, or even excess intermittent renewable electricity production, to deliver heat in winter.

b) Geothermal in a fair competitive market

The structure of the heat market impacts the deployment prospects for geothermal energy projects. A market defined by subsidised fossil fuels will be closed to geothermal energy projects, as there will be huge incentives for actors to reward low investment costs compared to operational costs. On the contrary, in energy markets built around fair competition, which implies including environmental externalities (carbon price) and the
value of various services provided such as flexibility, energy storage and so on, geothermal is much more competitive.

• **Fair competition**

Currently, the European heat market is designed around a privileged place for fossil gas, which benefits from a heavily subsidized and extremely granular infrastructure (transmission and distribution networks, publicly funded import infrastructure such as LNG terminals, pipelines), and economic rules and business models that benefit the low CAPEX high OPEX cost structure of fossil fuels (once the huge investment costs and risks for the infrastructure have been socialized through programmes such as the Connecting Europe Facility). For geothermal energy technologies, a restructuration of the heat market design allows to compete through a better access to the heat market via fair competition and the availability of the needed infrastructure for consumers to be able to access geothermal energy.

Gas is the only fossil fuel included in multiple EU regulations. Because of this privileged position it is able to continue to benefit from numerous public subsidies for infrastructure, appliances and consumption. Article 176 of TEFU calls for an internal energy market that ensures security of supply, interconnectivity as well as the promotion of energy efficiency, energy savings and renewable energies. The focus on an internal market for fossil gas goes against these requirements. It prevents the heat sector from delivering cost-effective, reliable and renewable heating, cooling and electricity services in Member States.

• **Heat market design**

The design of a heat market needs to shift the focus from the provision of a commodity to considering the heat market as a competition of service providers. Geothermal heating and cooling technologies can compete with fossil fuel alternatives in many cases, especially for uses with low (e.g. ~50-60°C for space heating) or medium temperatures (80-150°C for business processes). However there can only be fair competition if the comparison of the costs of the two energy sources includes all parameters, notably the cost of carbon and air emissions, the cost of subsidies embedded in the gas infrastructure and discounted from the cost.

Across the European Union, the consolidation of a fair heat market supposes the deployment of a suitable infrastructure to enable the competition of renewable solutions such as geothermal with incumbent fossil fuels that abuse their dominant position. Pricing of the carbon externality is a first factor to contribute aligning the dynamics of the heat market with the principles of fair competition. Mapping available renewable heating and cooling resources is another key requirement of fair competition. For geothermal energy for instance, this may mean a European financing of geothermal exploration campaign.

The heat market, beyond the need for fair competition in line with the European climate and energy objectives, goes beyond the sole comparison of the price of energy services. The value provided to the community is a factor that needs to be reflected by the heat
market as well. Geothermal district heating systems are a factor of resilience and mitigation of energy poverty, locking in a fixed price for renewable heating and cooling, with no additional expenses for the community. Geothermal projects are also responsible for important direct, indirect, and induced job creation, notably when they enable new businesses with the provision of renewable heat. Geothermal heat pumps can also contribute to increasing the value of buildings, ensuring low operational costs (i.e. heating and cooling bills).

- **Heat grid & infrastructure**

To enable a fair and competitive European heat market, which allows the market uptake of renewable heating and cooling technologies such as geothermal energy, infrastructure is a crucial factor. The fossil gas market is enabled by decades of public investments in an expensive infrastructure, from transmission pipelines to distribution networks. In recent years, the Transadriatic Pipeline, the NordStream and the tremendous buildup of subsidized LNG terminals are examples of the huge amount of public resources into fossil assets. They are also a testament of the vulnerability of the European Union to geopolitical disruption in fossil fuel supply. Renewable heating and cooling prevent these issues.

To be able to compete, renewable heating and cooling solutions such as geothermal require the availability the relevant infrastructure. This includes soft infrastructure such as the knowledge of resources available (e.g. financing geothermal exploration across Europe), and hard infrastructure such as the availability of heating and cooling grids and equipment to deploy geothermal energy projects (e.g. drilling rigs). There needs to be a shift at the European level on the understand of what constitutes an investment in the completion of the internal energy market (enabling the market uptake of renewable solutions, notably in heating and cooling), compared to what is undue state aid (financing any project that may lock-in fossil fuel consumption).
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