Proceedings World Geothermal Congress 2023
Beijing, China, April 17 – 21, 2023

Research, development & innovation and competitiveness of the geothermal sector in Europe

Philippe Dumas[1], Fausto Batini[2], Javier Urchueguia[2].

[1] EGEC, place du champ de mars 2 – 1050 Brussels, Belgium

[2] ETIP Geothermal

p.dumas@egec.org

Keywords: research, innovation, competitiveness, value chain, project achievements, European Technology and Innovation Platforms (ETIPs), strategic documents.

ABSTRACT

Geothermal heating and cooling (H&C) and power is a growing sector in Europe, with sustained growth rates in installed capacity all over Europe. This growth is carried by a lively and active European geothermal industry, were historical actors and new players alike are at the forefront of innovation. Thanks to a rich and strong know how, the presence of many large companies and a widespread bedrock of SMEs, Europe is among the leading industrial actors globally in geothermal.

Despite its relative prominence, nevertheless, the European geothermal industry is faced with harsh competition from other geographical areas. That is particularly true in export markets, where the European geothermal sector must constantly prove its competitiveness to obtain projects. Beyond competition within the geothermal sector, there is also the question of the capacity of the European geothermal sector. An issue that questions the very structure of the European market, the robustness of its geothermal sector and the capacity of the existing regulatory framework to lay out a levelled playing field.

Moreover, Europe must develop new, innovative solutions to answer the next technological challenges for an accelerated deployment of geothermal across the continent. A next generation of geothermal technologies is needed to remain number one in the world.

The Research Agenda and Roadmaps produced by the Geothermal European Technology and Innovation Platform (ETIP) present a clear strategy for developing the research, development and innovation projects required to answer the challenge of the future.

These documents outline the research priorities that must be developed between now and 2050 if the Vision for the future of the sector is to be achieved.

This paper will present the roadmap, status of its implementation with a monitoring of the first project results and an assessment of the European industrial competitiveness in this sector.

1. INTRODUCTION

In order to decarbonise the electricity, heating, and transport sectors and reach a climate neutrality by 2050, Europe needs a wide range of renewable technologies, including geothermal systems. Geothermal will be a key energy source in the European decarbonized energy mix. Indeed, geothermal is a unique energy source that can provide a significant share of electricity, heating and cooling, thermal storage and minerals such as lithium. It is a source of energy which is renewable, local and continuously available as it is not dependent on climate conditions. Europe has pioneered the exploitation of geothermal resources for over a century and the EU still maintains a leading role due to research, innovation and the development of new technologies allowing the production of geothermal power as well as heating and cooling everywhere.

The quantitative development of the European geothermal market in the next ten years is expected to be fuelled mainly through the exponential deployment of shallow geothermal systems, the increased growth of deep geothermal systems for heating & cooling dor different applications and the launch of new electricity projects.

But several technological challenges need to be addressed for an accelerated deployment of geothermal across Europe by developing innovative solutions.

The geothermal panel of the European Technology and Innovation Platform on Renewable Heating and Cooling (RHC-Platform) was established in 2009, following an initiative of EGEC, and it became integrated to the RHC-Platform from 2010. In April 2013 the RHC-Platform launched its first Strategic Research and Innovation Agenda for Renewable Heating and Cooling (RHC-SRIA). The geothermal sector created a European Technology and Innovation Platform on Deep Geothermal in March 2016, and the European Commission (DG Research), officially recognised it as an ETIP in July 2016. The ETIP runs since that date with the support of a secretariat managed by EGEC.

From January 2023, the two ETIPs have been merged into one single ETIP on geothermal.

The European Technology and Innovation Platforms (ETIPs) have been recognised by the European Commission as a tool to strengthen cooperation with Stakeholders under the Strategic Energy Technology Plan (SET-Plan).

In the SET plan, Europe has set its ambitions for renewable energy technologies, including geothermal. To support those goals, the Deep Geothermal Implementation Working Group (DG-IWG) joins currently fourteen European countries, EGEC, ETIP-DG, ETIP renewable heating and cooling, and the research community, represented by European Energy Research Alliance- Joint Programme Geothermal Energy (EERA-JPGE). The IWG has supported the increase of the European and national budgets for geothermal RD&I projects. More than 100 million Euros per year were dedicated to RD&I projects in recent years, and an additional 40 million euros were spent on GEOTHERMICA projects every second year. The IWG is a forward-looking group that aims for innovation and momentum to the European geothermal sector..

2. ACTIVITIES OF THE SUPPORT FORA

Reducing by 55% of the EU greenhouses gas emissions by 2030 is an unprecedented challenge which will need growth of all renewable technologies, including geothermal. Geothermal energy is already successfully deployed in many European countries. It is an affordable option in many geologies. Technological progress and targeted policies can bring Europe closer to an optimal utilization of our geothermal resource. We have witnessed a resurgence of interest in geothermal, after nearly a decade of only little augmentation in capacity, both for electricity and for heat supply (mainly via district heating). A substantial number of projects (150 power plants and 350 heat plants) has been developed throughout Europe. Geothermal energy is becoming a key player in the European energy market.

However, the current market conditions are hampering the market growth of geothermal; and many technical and non-technical barriers still need to be removed. A new generation of geothermal technologies is needed to answer the challenges of the next decades of the European energy system.

If Europe wants the energy transition to be successful, we have to think about an optimal scenario in terms of cost and affordability for the consumer. Geothermal will then be a key enabler, a local and stable source of renewable energy, and its role could be crucial in the future energy system.

2.1 The geothermal panel (RHC Platform)

From 2014, the geothermal R&D plan was implemented. Several geothermal research projects were co-funded by the European Programme Horizon 2020 in the framework of this implementation plan. The implementation of the geothermal technology roadmap was monitored by reviewing ongoing and achieved research projects and by assessing the impact of the first results on the key performance indicators. Future trends are also identified, by highlighting areas in which relevant projects are being developed, which could have an expected major impact on a given KPI. This analysis was performed by research area, as identified in the Geothermal Technology Roadmap. The research agenda 2013 identified the state-of-the-art, the research objectives and the critical targets (e.g. in terms of performance increase / cost reduction) required to realise the potential of geothermal HC technologies defined in the Vision's document 2010. To implement the research activities a Roadmap was released in 2014. The implementation of this first set of R&I activities lasted until 2019. Then an exercise to update the SRIA was launched and the updates research agenda was presented in 2021. It offers to present new recommendations for research, development and demonstration funding in the timeframe of the 2030 Energy and Climate Framework. It provides stakeholders with a structured and comprehensive view of the research, development and demonstration activities able to meet diverse profiles of demand in the short (by 2023), medium (by 2030) and long term (after 2030).

In 2019, the steering committee launched the process to update the SRIA published in 2012. The new agenda was released during an online event in September 2020.

This SRIA on Geothermal heating and cooling identifies a path forward, developing high performance, cost-effective and sustainable shallow and deep geothermal technologies that can expand the production of heating and cooling, while reinforcing EU industrial capacity and leadership in the sector. It continues the work of the 2019 Technology Roadmap on Deep Geothermal published by the ETIP on Deep Geothermal (ETIP-DG), which launched the 2030 objectives and the related Implementation Plan. The mission, goals and actions described here for 2030 and the future date of 2050 build upon the Vision and the Strategic Research and Innovation Agenda for Deep Geothermal (SRIA).

This document is also complementary to the one provided by the Implementation Working Groups on Deep Geothermal and Energy efficiency (Buildings and Industry) active within the Strategic Energy Technology Plan (SET Plan).

All these challenges require an update of our research agenda to synchronize them with our current needs and to amplify the synergies with other renewable energy sources (RES) technologies, a scope of increased importance. This is the aim of the current document, which shall set the basis of a further successful development of the geothermal sector in Europe and worldwide, in its aspiration to make a more substantial contribution to the sustainability of our energy sectors and our Society.

The SRIA is intended for policy makers, funding institutions, manufacturers and energy market actors, research institutions and other stakeholders.

2.2 The ETIP DG

ETIP-DG has identified its R&I priorities in a Vison (2018), a SRIA (2019) and a Roadmap (2019). Since 2020, this Roadmap is implemented by several R&I projects. To outline the key RD&I trends impacting the structure of the deep geothermal industry:

Prediction and assessment of geothermal resources: A better understanding of complex and deep geological processes will enhance the predictability of underground conditions; deep exploration technologies will have high resolution imaging capacity and data modelling will be fully integrated; geothermal resources beyond those already in development will be characterised in greater detail in order to optimise their use and increase energy production. The overall objective of R&I in exploration is to reduce the costs of exploration technologies and increase the probability of successfully characterising geothermal resources prior to drilling and during geothermal development.

Resource access and development: The extraction of heat from underground will be maximised thanks to improved well designs, new drilling technologies, new sensors and monitoring techniques, and safe and sustainable flow enhancement. In addition, reduced drilling costs will be possible as a result of new or high-performance drilling techniques. Another basic challenge is drilling deeper and/or reaching very high-temperature resources. There will be safe, rapid and automated technologies providing access below the ground. The lifetime of boreholes and system components will be prolonged by using materials and pumps that are tailored for deep geothermal wells, as well as real-time monitoring and an in-depth understanding of reservoir and thermal loop processes. Geothermal energy storage will be efficient, fully integrated into energy systems, and responsive to demand R&I goals such as these, which will also be tied to environmental requirements, can serve as a reference for the majority of European geothermal reservoirs, which often occur in densely populated areas and are characterised by low-to-medium temperature conditions.

Heat and electricity generation and system integration: When it comes to energy conversion processes, geothermal plant surface systems and the integration of geothermal heating, cooling and electricity supply into the energy system, the challenge is maximising generation at the lowest lifetime cost. The net efficiency, performance and cost-effectiveness of production systems are to be optimised, extending the temperature range of different geothermal energy applications. The conversion of heat to electricity and cooling will only be constrained by physical laws and production will be sustainable and fully responsive to demand. Hybrid, multi-source and multipurpose high efficiency systems embedding geothermal technology will become the European standard.

The shift from R&I to deployment (environmental, regulatory, market, policy, social, human deployment): The aim is to develop regulatory, financial, political and social solutions that can be implemented in order to overcome barriers obstructing the deployment of innovation in the sector, the broad deployment of geothermal energy solutions, and increased uptake all over Europe. This must be done in parallel to the technological research described above if geothermal energy is to become one of the main contributors to European climate and energy targets. This includes supporting the establishment of a legislative framework that will sustain geothermal deployment, penetration and profitability while guaranteeing that resources are properly managed. This framework should also provide low environmental impact technologies, define economic evaluation criteria (including technical and economic risk assessment), and foster partnerships between companies and consumers by strengthening mutual trust as a result of ethics and security.

Knowledge sharing (data harmonisation and coordinated organisation of data and information, shared research infrastructures): Establishing an open-access policy to geothermal information (including standard exchange formats) will ensure open and easy access to data and information. This should be achieved through the progressive harmonisation of national data in order to facilitate data discovery and data mining. It is also vital that demonstrations of capacity building, industrial technology transfer, and scientific and academic partnerships based around joint expertise take place throughout Europe, with the shared goal of developing high quality, competitive and sustainable geothermal energy projects.

Information, communication and analytical capabilities will receive large-scale support. The amount and types of underground data available will be expanded, globally organised and made easily accessible. Terms of reference for reporting and computing geothermal potential, production and capacity will be harmonised; data sharing will improve scalability and the extrapolation of information, improving the ability to forecast techno-economic parameters and influencing energy planning. Solving these challenges will grant the geothermal sector enormous capability with regard to the key societal challenges of our energy future and will significantly improve our ability to maintain the safety, security, wealth, and prosperity of Europe. The overall Mission of the Research, and Innovation Agenda is to elevate the Deep Geothermal sector so that it might contribute to the Clean Cities and Communities of the Future, where a combination of renewable energy sources (including geothermal) provide for local electricity, transport, and heating/cooling supply for both tertiary and industrial buildings, with underground thermal storage facilities and electric vehicles integrated into the system.

2.3 The ETIP Geothermal

ETIP DG & geothermal panel of the ETIP RHC- become ETIP Geothermal from 2023. To fully represent the geothermal technologies for Research & Innovation and reflect the technology trends and the market development, ETIP DG and ETIP RHC become ETIP Geothermal. This proposal was made by the ETIP DG Steering Committee in October 2022 and has been approved by all members during the 2022 Annual meeting in December 2022. The geothermal panel of the ETIP RHC also gave its approval on the 1st of December 2022 about this change of name. So from January 2023, the ETIP geothermal is established

3. R&I ACTIVITIES

Geothermal is a renewable energy source which is local, manageable, and flexible. The main applications for geothermal energy are:

Geothermal heat pumps: About 23 GWth of geothermal heat capacity has been installed in the EU to date, with more than 2 million units. Geothermal heat pumps can be installed in any location and size (from 10 kWth to 500 kWth) to supply heat, cold and hot water. Theie efficiency for heating is usually higher than 4 and for cooling, often free-cooling, the performance can be higher than 20.

Geothermal District Heating plants: 5 GWth with 300 geothermal district & cooling heating systems have been installed in 30 European countries (example: France, Hungary, Germany and the Netherlands). Some of them are using highly efficient large heat pumps.

Geothermal heat for Industry, Agriculture and Services: The installed capacity in Europe of geothermal heating from medium to low temperature sources supplied to industry and services exceeds 5 GWth. The potential is very large for other European countries. Geothermal can supply heat for low to medium process heat in the industry such as Gypsum, Paper and Food & Beverages, chemicals and cement.

Geothermal electricity plants: EU has more than 1 GWe installed producing around 7 TWh. It produces electricity and combined heat&power, by using the flash and binary turbines. Italy has the largest number of geothermal electricity plants providing baseload renewable electricity at nearly 100% capacity factor. Geothermal can also provide flexible generation to the electricity system, ramping up and down the output in a matter of seconds.

Geothermal lithium (and other minerals: silica…) production: The global race for the lucrative geothermal lithium market is on. France and Germany are in competition with China, US, Canada and New Zealand to develop intellectual property rights and extraction techniques for this critical feature of batteries.

Geothermal can also offer underground thermal energy storage (UTES) solutions at shallow and deep depth, and for different temperatures, providing a crucial solution to the deep decarbonisation of the economy with economic and scalable seasonal energy storage. It can be done via aquifers (aquifer thermal energy storage: ATES), largely developed in the Netherlands, and via boreholes (borehole thermal energy storage: BTES).

Research, development, and innovation (RD&I) are needed to develop renewable technologies, accompanied by market uptake measures. Major investments in geothermal research and innovation are necessary to develop and deploy the next generation of geothermal technologies and to answer the challenges for the transformation of our energy system towards a decarbonisation of our economy. The added value of a joint European RD&I framework is very clear in the geothermal sector where engineers and manufacturers all over Europe are facing similar challenges to develop and operate efficient systems and to reduce costs.

A large part of the RD&I from Industry is dedicated to innovation at a high level of technology readiness. The total number of private projects for geothermal RD&I is hard to estimate. However, it can be assumed that the private sector represents one third of the total investment for RD&I in geothermal in Europe. The geothermal sector benefits from RD&I investments in other sectors such as geosciences (oil&gas), deep drilling, turbines and heat pumps.

4. COMPETITIVENESS OF THE SECTOR

Costs reduction of geothermal technologies can be reached via technology development and innovation, economies of scale but also through competition between market actors, the most experienced and innovative enjoying growth and new business. Also, geothermal energy plants deliver a range of system services (energy storage, flexibility, potentially environmental products such as emission reductions) that are in demand by the marketplace. Hence to value geothermal energy products and services, it is crucial to adopt an approach that goes beyond a levelized cost of heat or electricity (LCoE) methodology but instead adopts a quantification of the value of geothermal energy related products. However, for the time being and in line with the targets of the Deep Geothermal Implementation Working Group, we continue to talk about cost reduction in terms of levelized cost of heat or electricity.

4.1 Learning curve and potential cost reduction: Beyond the LcoE approach

The competitiveness of the deep geothermal sector must be consolidated by first developing a fair basis of cost comparison between energy sources which goes beyond a limited LCoE approach, taking into account actual system costs and external factors. It should be noted that deep geothermal projects have low systems costs and negligible externalities, which means that the LCoE accounts for almost the full costs for the project.

Estimating the value of geothermal in the energy systems is a next step on approaching the costs of a technology.

This potential cost reduction is linked to the third strategic target of the targets from the SET Plan's Deep Geothermal Implementation Plan. The target is set at a maximum production cost of 10 €ct/kWh for electricity and 5 €ct/kWh for heat by 2025.

These cost targets apply to all types of deep geothermal projects, including EGS and super-hot geothermal systems (> 350°C). As of 2019, the levelized cost of energy (LCoE) for electricity production varies between 30 and 150 €/MWh (between 3 and 15 €ct/kWhe). The higher values are typical for binary plants tapping into medium temperature resources.

The LCoE for flash plants typically is lower at an average value of about 40 €/MWhe. The selling price for heat in existing geothermal district heating systems is usually around 60 €/ MWh, and within a range of 20 to 80 €/MWh. The price depends on the local geothermal situation, socio-economic conditions and pricing policies. In addition, district heating networks account for a significant share of the total costs for a geothermal district heating system.

The economic potential for geothermal electricity generation in Europe in 2030 and 2050 has been estimated as part of the GEOELEC project, using an LCoE value of less than 150 €/MWhe for 2030 and less than 100 €/MWhe for 2050.

4.2 Technology Perspectives for Heating & Cooling generation development

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

Over the last decades, the supply and return temperatures of DH networks have been reduced. Since modern, energy efficient buildings and new heating systems allow rooms to be comfortably heated at supply temperatures of 40°C and less, the operative temperatures of the DHC network can be further reduced.

Third and fourth generation DH and DHC networks will be developed, and it will be possible to integrate low temperature geothermal resources in district heating in urban areas anywhere in Europe.

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

4.3 Technology Perspectives for Electricity generation and Combining heat & power development

The use of geothermal heat for producing electricity is the most flexible way to produce a clean renewable energy product with major sustainabillity benefits; a product that is easily transportable even over long distances and ready for use for the end-users.

Enhanced technical solutions will boost the electrical potential development:

- The utilisation of geothermal resources will be optimized, with a focus on increasing efficiency and reducing LCoE for low temperature binary plants;

- The existing high temperature technologies (heat exchanger, flash/steam plants) will be improved, even through disruptive ideas on cycle design, novel materials, and more;

- Technologies for enhancing heat extraction at depth will be optimized, proved at a large

- scale, and safety precautions will be standardized;

- The unique capability of geothermal energy to operate in hybrid mode with other renewable energy sources (photovoltaic, concentrated solar, biomass and biofuels) will be intensified, with an overall increase in total energy conversion factor;

- New technologies will enable us to access and manage deep and extremely hot resources, whose productivity will be ten times higher than in existing hot systems;

- Cutting-edge technologies will be extensively assessed for producing from untapped resources that pose peculiar issues, such those off-shore, close to magma shallow intrusions, depleted or unproductive hydrocarbon fields and more.

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

- Increasing the efficiency, and reducing losses and internal consumption;

- Improving reliability and durability (resistance to corrosion, abrasion) of equipment;

- Extending the economic resource base by breakthroughs in technologies for subsurface access and heat extraction from the underground;

- Reducing the overall cost for CCHP generation.

4.4 Global Competition

Globally, for the geothermal industry key competitors are:

- Deep geothermal: US, Japan and China for projects development globally and manufacturing of equipment and New Zealand for exporting services.

- Shallow geothermal: competition does not come from other countries, but from other sectors (notably natural gas which has a dominant position on the H&C market) and less efficient technologies such as air heat pump that benefit from the same support framework.

Overall, the key competitors of the geothermal industry are the fossil fuel industry. In the H&C sector this is due to the structure of the heat market.

For deep geothermal project development, there is a competition on the use of equipments and services (e.g. drilling rigs) with the price being tied with the price of oil & gas<

Electricity:

- Flash turbines: leading manufacturers are Japanese companies

- Binary: European companies are very competitive despite important global competition (US, emergence of China)

- Services: Europe is a net exporter of services for geothermal power plants, and is globally competitive. The EU geothermal industry is particularly competitive in innovative solutions, thanks to the robust market of demonstrating innovative technologies domestically.

- Equipment: the equipment used in geothermal power plants in Europe are largely manufactured there.

- The generation of geothermal electricity can be very competitive, for instance it is the baseload resource for the central Italy (thanks to the important installed capacity in Tuscany). With the right flexibility/capacity market, geothermal electricity can become more competitive, including in areas where it remains an emerging technologies at this stage.

- Global race for lithium: globally, there is a race towards the development of an economic geothermal lithium value chain and technology. The USA are typically investing significant public and private R&I funding on bringing geothermal lithium technologies to market, notably in view of export to markets such as Latin America, Europe.

The European geothermal industry is competing on this field, securing innovation, looking to establish rapidly demonstration and commercial projects. Public R&I support is however necessary considering the magnitude of the global competition and the geopolitical implication of a secure lithium and other critical raw materials (e.g. in the US, USD 8 million of public R&I funding have already been invested in geothermal rare earth production technologies)

Heating and Cooling:

- Heat Pumps: The European Heat Pump supply chain is to a large extend European, and European companies are global leaders.

- Equipment: the manufacturing of equipment for geothermal heating and cooling (heat pumps and district heating) is to a large extend European based.

- Services: the European geothermal industry is a global leader in the provision of services for the development of geothermal district heating projects, and for geothermal heat pumps.

- Drillers: Drilling for geothermal heating and cooling (deep and shallow) is usually undertaken by European drilling contractors, with a good degree of competition in the market, as there tends to be a high demand for drilling services compared to supply.

The European geothermal industry has a strong degree of leadership, but needs a robust internal market to consolidate, notably when it looks to export its services. Global competitors are quite active and supported by a robust network of export agencies (US, Japan), and China is become and increasingly strong competitor in the global geothermal market?

Innovation is a key resource for the competitiveness of the European geothermal industry. Innovation allows reducing the costs of developing geothermal systems, improving their performance, and therefore improving the competitiveness against fossil fuels which benefit from a dominant position and a large amount of structural subsidies (e.g. CEF financing gas pipelines). Meanwhile however, considering the similarities between upstream Oil & Gas and geothermal production, the geothermal sector benefits from R&I innovation for O&G on the on the long term. It also represents an opportunity for a just transition of the European oil & gas industry.

5. FINANCING R&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.

5.1 Project financing

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.

5.2 R&I funding in geothermal

During H20220 framework programme in the period 2014-2020, the funding was:

- total costs of R&I geothermal projects in the category Low Carbon Eeenrgy = 350 €mio, and EU contribution of 248 €mio so 70% EU contribution and about 35,5 €mio EU contribution/year
- SME instrument: 2.5 €mio EU contribution
- Other H2020 than LCE topics, geothermal projects: 124 €mio costs and 107 €mio EU contribution 86% contribution and 15 €mio/year

For the programme Geothermica, the calls 1 represented a total cost of 43,79 €mio, public contribution of 23 €mio and private cofunding of 20.79 €mio = 53% public co-funding

In the programme Interreg, the total costs was of 29.9 €mio, with a public contribution of 20.1 €mio and private contribution of 9.8 €mio = 67 % co-funding

In total, the R&I geothermal projects costs were about 500 €mio: the Public contribution of 350 €mio and 150 €mio from the private, so around 73 % public contribution. It represents about 52 €mio per year and about 180 projects funded in 7 years, circa 25 projects per year.

6. Conclusions

The geothermal sector is a diverse, highly innovative sector, which leads many different types of actors to be engaged in fostering the R&I priorities identified by the ETIPs Geothermal. Many of these actors are engaged, usually in partnership with non-industrial actors such as the research communities in public funded projects, for instance programmes such as Horizon Europe or Geothermica. Meanwhile, as the geothermal sector remains very competitive, industrial actors also often carry out innovation in the various projects they are developing commercially as they seek to decrease the cost of producing geothermal energy. All industrial actors are therefore susceptible to engage in the implementation of the R&I priorities for geothermal.

Meanwhile, the geothermal sector, while not necessarily a very concentrated community, remains structured by key organisations and events, which constitute relays of the geothermal industry, where experience sharing happens, and cooperation emerge, fostering innovation. These institutions of the geothermal community are crucial in identifying the key industrial actors of the geothermal sector.

The global and European landscape of private investments in geothermal and other renewables is showing a rather decreasing trend for 2 years. The COVID pandemic has also an impact on the overall investment rate in geothermal energy and had also affected the R&I aspects of technology development.

Despite this trend, the EU should act to avoid the scaling back of private investment in the clean energy industry. It needs to better evaluate the impact of EU energy R&I funding, notably in the context of the REPowerEU plan, the EU economic recovery, ensure the alignment of EU and national priorities (under the Strategic Energy Technology Plan) in the NECPs, and boost private capital and innovation.

An effort to reverse this trend will have to be made by both: public and private sectors. This report also includes an overview of EU funding instruments that are available across the entire innovation value chain, with programmes for energy research, development and innovation (RD&I). This information is crucial for private actors that want to co-finance European or national R&I projects.

To sum up, aligning the SET Plan priorities with the economic recovery and involving private companies in delivering new geothermal technologies is key.

.

REFERENCES

The Geothermal Panel of the European Technology & Innovation Platform on Renewable Heating and Cooling: Geothermal Technology Vision (2010), SRIA (2012), Roadmap (2014) and updated SRIA (2021).

The European Technology & Innovation Platform on Deep geothermal: Vision (2018), SRIA (2018), and Roadmap (2019).

Acknowledgements (optional)

We wish to thank all Geothermal Panel and ETIP DG members and experts having contributed and the steering committees of both ETIPs.