



GEO THERM-FORA Deliverable D4.2

## Report on major market trends

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Funded by  
the European Union

|   |   |                  |                                 |
|---|---|------------------|---------------------------------|
| <b>Project Full Title:</b>                        | Support stakeholder’s fora on geothermal systems  |                  |                                 |
| <b>Project Acronym:</b>                           | GEO THERM-FORA  |                  |                                 |
| <b>Title:</b>                                     | Report on major technological trends  |                  |                                 |
| <b>Lead beneficiary:</b>                          | CNR   |                  |                                 |
| <b>Contributing beneficiaries:</b>                | EGEC, GFZ   |                  |                                 |
| <b>Related work package/<br/>Related task(s):</b> | 4   |                  |                                 |
| <b>Submission date:</b>                           | 22/10/2024  |                  |                                 |
| <b>Security class:</b>                            | Public  |                  |                                 |
| <b>Dissemination level:</b>                       | all Partners  |                  |                                 |
| <b>Status:</b>                                    | Final   |                  |                                 |
| <b>License information:</b>                       | CC_BY_4.0   |                  |                                 |
| <b>Recommended Citation:</b>                      | Manzella, A.; Dumas, P., Cittadini, G.; The Horizon Europe GEO THERM-FORA project: Deliverable D4.2 - Report on major market trends |                  |                                 |
| <b>ORCID:</b>                                     | Authors Orcid (or different Author Identifier)  |                  |                                 |
|   |   |                  |                                 |
| <b>Revision history</b>                           | Author  | Delivery date    | Summary of changes and comments |
| <b>Version 01</b>                                 | EGEC  | 17 June 2024     | Table of contents agreed        |
| <b>Version 02</b>                                 | CNR   | 5 September 2024 | Final draft                     |
| <b>Final version</b>                              | CNR   | 22 October 2024  | Final version                   |

| <b>Approval status</b>         |      |             |            |           |
|--------------------------------|------|-------------|------------|-----------|
|                                | Name | Function    | Date       | Signature |
| <b>Deliverable responsible</b> | CNR  | Task leader | 31/05/2024 | X         |
| <b>WP leader</b>               | EGEC | partner     | 17/06/2024 | X         |
| <b>Reviewer</b>                | CNR  | WP Lead     | 05/09/2024 | X         |
| <b>Reviewer</b>                | EGEC | Partner     | 01/10/2024 | X         |
| <b>Project Coordinator</b>     | EGEC | coordinator | 22/10/024  | X         |

Funded by the European Union from the Horizon Europe programme under the grant agreement n° 101075400.

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## Table of contents

|       |  |    |
|-------|--|----|
| 1     | Executive Summary .....  | 4  |
| 2     | Overview about market development in Europe .....  | 5  |
| 3     | Market trends in Europe.....   | 6  |
| 3.1   | Electricity.....   | 6  |
| 3.2   | Heating & Cooling .....  | 6  |
| 3.2.1 | Geothermal District Heating & Cooling .....  | 6  |
| 3.2.2 | Geothermal Heat Pumps .....  | 7  |
| 3.3   | Thermal storage .....  | 7  |
| 3.4   | Minerals .....   | 8  |
| 4     | Global market and competition.....   | 9  |
| 4.1   | Global Market .....  | 9  |
| 4.2   | European competitiveness .....   | 10 |
| 5     | Market trends in the value chain.....  | 13 |
| 5.1   | Trends in project development.....   | 13 |
| 5.1.1 | Resource identification and assessment .....   | 13 |
| 5.1.2 | Resource development and drilling.....   | 14 |
| 5.1.3 | Resource exploitation, operation and maintenance .....                                     | 14 |
| 5.2   | Market of equipment, components and services.....  | 15 |
| 5.3   | Market for materials and minerals .....  | 16 |
| 5.4   | Geothermal industrial Ecosystems .....   | 17 |
| 5.4.1 | Concept of Industrial ecosystems.....  | 17 |
| 5.4.2 | Industrial valleys .....   | 17 |
| 5.4.3 | Key equipment for geothermal technologies and manufacturing .....                          | 19 |
| 5.4.4 | Mapping geothermal value chain in Europe .....   | 21 |
| 6     | Conclusions.....   | 27 |
|       |  |    |
|       | Figure 1 Main critical raw material needed for renewable energy sources .....              | 16 |
|       | Figure 2 ETIP geothermal vision of industrial geothermal valleys .....                     | 18 |
|       | Figure 3 Greenhouse for Spirulina cultivation heated by geothermal, Chiusdino, Italy ..... | 22 |
|       | Figure 4 Mapping the membership of GeoEnergy Celle e.V .....                               | 23 |
|       | Figure 5 Location of geothermal powerplants in Iceland.....                                | 24 |
|       | Figure 6 Map Licenses for geothermal energy of the Netherlands - 2023 .....                | 25 |

## 1 Executive Summary

This report presents the recent market developments in geothermal technologies and the outlook for the market in 2030.

In 2022, a devastating war erupted in Ukraine and made energy security central to European energy policy. Inflation is again a major characteristic of the European economy, driven by the explosion of the cost of hydrocarbons on energy prices. It led to higher interest rates and then lower buildings construction and renovation rates.

In reaction to these geopolitical and macroeconomic disruption, the energy transition is back at the highest level of policy making, with more importance than ever.

The EU recently adopted a Net Zero Industry Act (NZIA) and gives specific attention to geothermal as one of the eight strategic net zero technologies. The EU's Commissioner for Energy, Kadri Simson, has called on Europe to "harness geothermal energy's potential. For too long the benefits of this sector have not been well understood – now is the time to learn."

Geothermal is as the unearthed energy gem as a key solution to supply base load electricity, heating and cooling for all consumers, critical raw materials such as geothermal lithium. Moreover, geothermal energy shall be regarded as the bedrock of the energy transition in Europe and in the world.

We are facing a significant moment of growth and anticipation for the European geothermal market. 2023 was a year of significant transformation for geothermal. Moving from a niche market, constituting just 2-3% of the energy mix, towards becoming a major player in Europe's energy landscape. This development blends perfectly with our goal of supplying sustainable, local and reliable energy to all inhabitants and industry of Europe and beyond.

The journey from niche to mainstream energy demands a robust framework based on critical components. First and foremost, we need effective and streamlined permitting rules. These regulations must facilitate the development of geothermal projects.

Financial resources are another pillar of this transformation. Investing in geothermal energy is investing in securing Europe's energy future.

A consolidated supply chain is equally vital. The geothermal sector must continue building and maintaining a resilient supply chain that can support the expansion of this energy across Europe. From technology providers to service companies, every link in the chain must be strong and reliable.

Moreover, the growth of geothermal energy also depends on the availability of a qualified workforce. As the sector expands, geothermal offers opportunities to re-skill and up-skill workforce in collaboration with regions and from the oil&gas industry, and the next generation of professionals is getting ready to drive innovation in the geothermal field.

The geothermal exploration of new regions of Europe represents an exciting challenge. We have the technologies at our disposal, but now we need to replicate best practices across the borders. Sharing knowledge and experiences will be key to overcoming geological and technical aspects in order to support the continued growth of geothermal networks in Europe.

## 2 Overview about market development in Europe

Geothermal projects are growing all over Europe. Nowadays, they deliver electricity to 11 million consumers and heat and cool about 20 million people and 400 cities and factories.

The geothermal heating and cooling sector continues to grow in traditional markets: individual buildings, districts of 5,000 inhabitants, and greenhouses. But new markets are being reached: new technologies, e.g., geothermal smart heat networks (5th generation) and deep closed loop and thermal storage systems, and new countries or new regions.

Sales and new installations of geothermal heat pumps (GHP) have been strong across nearly all countries (growth of ca 12%), with a new record in annual sales: about 155,000 units in 2023. In terms of overall capacity installed, the market was still dominated by Germany, the Netherlands, Finland and Sweden, representing half the installed geothermal heat pumps in Europe and nearly half the annual sales. However, market growth is influenced by many factors. If we take, for example, the case of Germany, despite a positive first trimester, 2023 saw sales slightly declining. On a macro-level, factors impacting the GHP market in Germany were primarily the current increased interest rates and their impact on the building construction and renovation markets, together with high electricity prices and taxation in comparison with fossil gas. This is valid not only for Germany but for the whole of Europe.

The number of new geothermal district heating projects also continued to grow. 8 new district heating and cooling projects were commissioned last year in the European Union: 1 in Germany, 3 in Finland, 1 in the Netherlands, 2 in Romania and 1 in Slovakia. 2023 saw fewer plants put into operation than during the last years, especially in comparison with 2022 and 2021, with 14 new installations being inaugurated. Three reasons can explain this situation: 1) Delay in project development due to slow permitting, disruption in supply chain or longer drilling and commissioning phases; 2) Harder competition with fossil fuels; 3) Longer project development duration with projects in greenfield areas and project portfolio approach.

Geothermal electricity continued its march towards market maturity in key markets such as Italy, Croatia, Germany and Turkey, even though changes to the Turkish incentive framework caused uncertainty for project developers. About 50 geothermal power plants are under development at different stages: exploration, drilling or connecting to the grid. 8 new projects have started development in 2023. The renewed interest in base load and local electricity supply makes geothermal energy a valuable option. Geothermal is proven to provide a stable and secure supply of power while meeting base load demands and being able to supply 10% of our EU electricity demand.

## 3 Market trends in Europe

### 3.1 Electricity

As of 2023, Europe boasts an installed capacity of over 3.5 GWe in geothermal electricity, distributed among 143 operational plants. These facilities collectively generate approximately 20 TWh/year, with the EU specifically contributing about 7 TWh/year. Despite its potential, regulatory uncertainties pose a substantial challenge. While EU legislation acknowledges geothermal energy as eligible for public funding, concrete implementation has been delayed, particularly impacting countries like Turkey and Italy, where reforms to financial incentives and awaited subsidy schemes (FER 2) have slowed progress. The COVID-19 pandemic further complicated matters by causing delays in permitting processes and disrupting supply chains crucial for geothermal projects. Concurrently, the war in Ukraine exacerbated these challenges, particularly in terms of equipment availability and inflation, thereby straining project financing efforts. The resulting higher interest rates have significantly raised upfront capital costs, disproportionately affecting smaller developers in the geothermal sector.

In the broader context of the EU's energy landscape, overall electricity demand has declined, influenced by industrial sector reductions, although there has been a modest increase in demand from sectors such as electric cars and heat pumps. Geothermal energy stands out amidst these trends for its role in supporting decarbonisation efforts and offering a stable energy supply that aligns with the EU's goals to reduce reliance on fossil fuels.

#### Market Outlook to 2030

- **Project Development:** Approximately 50 geothermal power plants are under various stages of development across Europe, with Germany and Turkey leading in terms of project pipeline. Significant interest is noted in countries like Croatia, France, and Italy, while emerging markets like Spain and Greece are expected to begin geothermal electricity production.
- **Technological Trends:** The industry experiences a shift towards larger plants using mature binary technologies and small-scale combined heat and power (CHP) plants.

### 3.2 Heating & Cooling

#### 3.2.1 Geothermal District Heating & Cooling

Geothermal district heating and cooling (DHC) systems experienced steady growth in 2023, with a notable increase in new projects in preparation.

By the end of 2023, there were 401 geothermal DHC systems in Europe, with 298 in EU Member States. Europe's total installed geothermal heating and cooling capacity reached 6 GWth across 29 countries, with more capacity expected as projects in Bosnia, Ireland, Latvia, Luxembourg, and Malta come online. Eight new systems were commissioned in the EU, adding 33.9 MWth to European geothermal heating and cooling capacity. Around 64 new projects were announced, with significant developments in Germany, the Netherlands, and Croatia.

France remains the leader in geothermal district heating capacity in the EU, second only to Iceland in Europe. In 2023, new geothermal systems were installed in Finland, Romania, Germany, the Netherlands, and Slovakia.

#### Market Outlook to 2030

316 projects are under active investigation across Europe, which could add over 744 MWth to the existing 5,608 MWth capacity. Leading countries like Germany, France, and the Netherlands are

developing projects in greenfield areas, while Hungary and Poland have set ambitious national objectives. Newcomers like Finland are also showing significant growth potential.

In summary, the geothermal DHC market in Europe is poised for substantial growth, driven by policy support, technological advancements, and the need for sustainable energy solutions. The focus on lower temperature systems and innovative business models will be key to overcoming current challenges and achieving ambitious future targets.

### 3.2.2 Geothermal Heat Pumps

In 2023, EU sales of GHPs reached over 154,300 units, marking a notable 11.7% increase from 2022. Despite a 5% decline in the overall heat pump market in 2023, GHPs continued their growth trajectory. However, challenges included stagnant growth in mature markets like Germany and Finland.

GHP systems in Europe are predominantly used in residential buildings, with capacities of 15 kWth or less. Medium-scale units, ranging from 25 to 100 kWth, serve large buildings, while large-scale systems, between 100 kWth and 5 MWth, are utilised for district heating and industrial purposes.

Regarding country-specific market growth, Sweden led with 35,470 new installations, reflecting a 26% growth. Germany saw a slight decline with 30,700 units sold, a 1% decrease, yet it remains the second-largest market in the EU. The Netherlands emerged as the third-largest market, with 22,220 units sold, experiencing an 11.1% increase. Finland demonstrated robust growth with 11,772 units added, a 24% increase. These top markets accounted for 55% of total sales.

By the end of 2023, the total stock of GHPs in Europe had nearly reached 2.32 million units. This growth was driven by concerns over energy security and affordability following Russia's invasion of Ukraine.

#### **Market Outlook 2027 and 2030**

The REPowerEU plan aims to double annual sales by adding 10 million hydronic heat pumps by 2027 and 30 million by 2030. The role played by GHP has yet to be clear, and current growth rates suggest meeting these targets may be challenging.

## 3.3 Thermal storage

Underground Thermal Energy Storage (UTES) involves storing heat below ground for varying periods and retrieving it as needed for heating or cooling. This technology utilises closed-loop geothermal systems, such as borehole heat exchangers, or open-loop systems, like geothermal wells.

UTES offers significant advantages over other storage methods. One of its main benefits is cost-effectiveness. According to IRENA, it is one of the most economical storage solutions, with costs ranging from 0.1 to 35 USD/kWh. Additionally, compared to other storage technologies, UTES has minimal impact on surface land use.

There are several UTES technologies. Borehole Thermal Energy Storage (BTES) uses boreholes to store energy, primarily for applications in large offices and public buildings. Aquifer Thermal Energy Storage (ATES) stores energy in aquifers for seasonal heating and cooling, and it is widely used in countries like the Netherlands and Sweden. Cave Thermal Energy Storage (CTES), also known as "minewater," utilises underground reservoirs for heat management, with applications in various European regions. Other forms include Tank Thermal Energy Storage (TTES) and Pit Thermal Energy Storage (PTES), which use tanks and large reservoirs, respectively, for heat storage.

Moreover, repurposing abandoned coal mine shafts in projects across Canada and Europe, including the Netherlands, Spain, and the United Kingdom, underscores the innovative approaches to geothermal energy and thermal energy storage.

## 3.4 Minerals

The utilisation of geothermal brines extends beyond energy production to include the extraction of valuable minerals like lithium, silica, zinc, manganese, and rare earth elements, among others, for commercial purposes. This dual benefit offers economic potential and contributes to efficient geothermal resource management. For instance, silica removal from geothermal brines, as demonstrated in sites like Ohaaki in New Zealand and Hellisheiði in Iceland, addresses scaling issues in infrastructure such as injection wells, pipelines, and surface facilities.

Scaling up initiatives in mineral recovery from geothermal activities into large commercial ventures requires further development to ensure economic and environmental viability. Regions like Cornwall, the Upper Rhine Graben, and Italy hold significant potential for exploiting geothermal mineral by-products. The European geothermal industry has already invested more than €50 million into this sector.

In 2021, the production of battery grade lithium from geothermal brines was demonstrated in Europe within the EuGeLi (European Geothermal Lithium) project by ES and ERAMET.

First results from the estimation and evaluation of geothermal lithium deposits in the Upper Rhine Rift show significant lithium contents of up to 200 mg / L in the deep geothermal brines from Strasbourg to Mannheim.

### **Market Outlook 2027 and 2030**

In April 2024 in Germany, Vulcan has started the production of the first lithium chloride (LiCl) from the Lithium Extraction Optimisation Plant (LEOP) of Landau. This existing geothermal plant retrofitted became the first EU geothermal lithium, electricity, heating and cooling production plant in the EU. More projects in Germany are being developed by Vulcan and other ones such as the UnLimited Project, by EnBW in Bruchsal Geothermal Power Plant (Upper Rhine Valley in Germany).

In Italy, CNR mapped the potential in an article published in September 2022. ENEL signed a partnership with Vulcan which has already a license there. Altamin has also three exploration licenses for geothermal lithium in Italy.

In France about ten permits for geothermal lithium explorations have been attributed in Alsace to Arverne/Lithium de France, ES and Vulcan.

Moreover, in the Southwest of the United Kingdom, the ongoing Cornish Lithium project is looking to valorise geothermal resources for energy and lithium production in a former mining area.



## 4 Global market and competition

### 4.1 Global Market

In recent years, the world has witnessed a significant uptake in the use of renewable energy sources, driven by an increased awareness of climate change, the imperative to reduce greenhouse gas emissions, and the pressing challenges posed by energy scarcity. Geothermal energy, once primarily exploited for electricity generation, has undergone a remarkable evolution, diversifying its applications across the energy landscape, particularly in the sector of sustainable heating and cooling solutions. As of the latest data available from 2023, the cumulative installed capacity of geothermal energy stands impressively at more than **16 GWe**. The top 10 countries in geothermal energy are responsible for 93% of the total installed capacity worldwide. The following 20 countries collectively contributed 1.1 GW to global geothermal capacity.

The global geothermal industry has undergone diverse development trajectories due to differences in the geological landscape, market dynamics, and regulatory framework.

#### Global developments for electricity generation

In 2023, the global geothermal sector experienced an increase of **281 MWe** in installed capacity. This growth underscores geothermal energy's continued momentum and growing significance in the global energy landscape as nations worldwide seek to transition towards cleaner energy sources.

The United States (US) led the pack in geothermal capacity with 3,900 MWe, followed by Indonesia at 2,418 MWe, which saw a last-minute addition for the Sorik Marapi project. The top 10 countries in geothermal energy now command approximately **93%** of the total installed capacity worldwide. Notably, an additional 20 countries collectively contributed 1,125 MWe to the global geothermal capacity. This highlights the increasing international interest and commitment to leveraging geothermal energy as a sustainable and reliable power source.

In the US, the GeoVision report identified the opportunities for geothermal in the country, with the possibility of reaching 60 GWe of installed capacity by 2050 with the required technological improvements. Indonesia has set an ambitious target of achieving 3.3 GW of installed geothermal capacity by 2030, signalling a strong commitment to accelerating investment in renewable energy. To facilitate this goal, the Indonesian government issued the Presidential Regulation for the Acceleration of Renewable Energy Development for Power Supply in 2022, introducing a tariff ceiling framework for renewable energy sources and specific incentives tailored to support the development of geothermal energy projects.

The Asia-Pacific region contributes 6 GWe to the total installed geothermal capacity for electricity generation, around 37% of the worldwide share. As of 2022, seven countries in the Asia-Pacific region—China, Indonesia, Japan, New Zealand, Papua New Guinea, the Philippines, and Thailand—have established operational geothermal plants.

Kenya ranks among the top ten geothermal electricity-producing countries globally, where geothermal energy represents 29% of the national electricity installed capacity and a notable 47% of the electricity consumed as of 2019. Kenya's rapid growth in electricity capacity results from policy supporting private investments and significant public financing and risk mitigation funding.

The application of favourable Feed-in tariff schemes (FiTS) also plays a crucial role in advancing geothermal industries, as the positive examples of Japan and Turkey clearly indicate.

Latin America has abundant geothermal energy resources, ideal for clean energy production, industrial decarbonisation, and energy security. However, only 2 GWe are currently utilised out of a potential 33 GWe, with Mexico, Costa Rica, and El Salvador accounting for about 75% of this capacity. Rystad Energy forecasts a rise in geothermal investments in the region, from \$570 million this year to \$1.3 billion by 2027, driven by an increase in operational capacity from 950 megawatts electrical (MWe) to over 1.4 GWe, spurred by announced projects and government targets.

### Global development for geothermal heating and cooling

The adoption of geothermal heating and cooling solutions has grown significantly in recent years, reaching nearly **110 GWth** in 2022, a remarkable increase of over **50%** since 2015. Particularly in Europe, there has been a noticeable shift in the political landscape surrounding heating and cooling practices, driven by stricter mandates for sustainable construction practices and other factors. Consequently, geothermal energy has emerged as a key component of various decarbonisation strategies, displacing fossil fuel technologies from the market.

In emerging geothermal heating and cooling markets like **Latin America and Africa**, efforts are underway to enhance the enabling framework. For instance, countries such as **Chile** are improving their regulatory environment. The 2004 Geothermal Concession Law was amended by several decrees regulating extraction and streamlining the concession-granting process. In 2021, the Chilean Energy Ministry established an online platform to make permitting more accessible. Other countries, like **Ethiopia**, have recently established new regulations governing electricity generation, heating, and cooling. The Geothermal Resources Development Proclamation entered into force in 2016 and was amended in 2020 to facilitate registration and licensing processes.

However, in many nations where policies and frameworks for geothermal electricity generation are already in place, there is a notable absence of similar support for developing geothermal heating and cooling.

Geothermal energy plays a significant role in heating and cooling applications across Africa and the Middle East, boasting an installed capacity of 475 MWth. Beyond conventional uses like swimming and bathing, diverse geothermal heating and cooling applications are evident throughout the regions, such as fish farming, greenhouses, agricultural drying, milk processing, irrigation, deployment of heat pumps and an egg hatchery.

In North America, the geothermal heating and cooling sector is predominantly characterised by Geothermal Heat Pump (GHP) applications, which have experienced sustained expansion over the past decade. Representing 98% of the installed geothermal heating and cooling capacity in the US and 99% in Canada, the GHP sector is expected to grow in both residential and commercial applications.

## 4.2 European competitiveness

Competitiveness is a key challenge for geothermal energy to become one of the main contributors to the European climate and energy targets. The geothermal energy sector needs to build a more robust competitive market to compete with the fossil industry, its key competitor. To become even more competitive, the costs of geothermal technologies need to be reduced by fostering research and knowledge of innovative technologies.

## Heating and cooling

Technological developments have allowed the exploration and development of former out-of-reach geothermal resources. New technologies will make it technically and economically feasible to implement geothermal projects where the earth's temperature is too low. Many solutions can be adopted to do so, such as enhancing heat extraction, drilling deeper, or using heat pumps to raise the temperature.

| Heating and cooling competitiveness overview |  |
|--|--|
| <b>Heat Pumps</b>                            | The European Heat Pump supply chain is to a large extent European, and European companies are global leaders.  |
| <b>Equipment</b>                             | The manufacturing of equipment for geothermal heating and cooling (heat pumps and district heating) is to a large extent European based.   |
| <b>Services</b>                              | 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.   |
| <b>Drillers</b>                              | 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. |

## Electricity

The use of geothermal heat for producing electricity is the most flexible way to make a clean renewable energy product with major sustainability benefits. It is easily transportable over long and short distances and readily available for end-users. With the suitable flexibility market, geothermal electricity can become more competitive, including in areas where it remains an emerging technology at this stage. Enhanced technical solutions will boost the development of electrical potential. For example, technologies for enhancing heat extraction at depth will be optimised and proved at a large scale, and safety precautions will be standardised.

| Geothermal electricity competitiveness overview |   |
|---|---|
| <b>Services</b>                                 | The EU geothermal industry is a net exporter of services for geothermal power plants. It is particularly competitive in innovative solutions, thanks to the robust market of innovative technologies domestically successful. |
| <b>Equipment</b>                                | Equipment use in geothermal power plants in Europe are largely manufactured domestically.   |

## Becoming even more competitive

- Market conditions and trends

The European geothermal industry has a strong leadership degree but needs a robust internal market to consolidate, notably when it comes to exporting its services. Overall, the key competitor is the fossil fuel industry. For deep geothermal project development, there is competition for the use of equipment and services, with the price being tied to the cost of oil and gas.

The key competitors in the deep geothermal industry are the US, Japan, and China for project development and equipment manufacturing and New Zealand for exporting services. Competition in the shallow industry comes not from other countries but from other sectors, notably natural gas.

- Research and Innovation trends

Innovation is a key resource for the competitiveness of the European geothermal industry. Innovation allows for reducing the costs of developing geothermal systems, improving their performance and competitiveness against fossil fuels, which benefit from a dominant position. However, considering the similarities between upstream oil and gas and geothermal production, the geothermal sector benefits from innovation for oil and gas in the long term. It also represents an opportunity for a just transition of the European oil and gas industry.

## 5 Market trends in the value chain

Geothermal technologies are defined by the supply of electricity, heating, cooling, and hot water. They also include thermal underground storage and the supply of raw materials extracted from the geothermal brine.

For these technologies, project development passes through the following five stages:

- 1) Site investigation;
- 2) exploration for resource assessment;
- 3) drilling and subsurface engineering for resource development;
- 4) utilisation and management of the resource to generate electricity and h&c;
- 5) operation and maintenance for a sustainable management of the resource and
- 6) decommissioning after the end of life.

### 5.1 Trends in project development

**As a heavily capital-intensive investment, the value chain of the geothermal sector is overwhelmingly concentrated around the project development phases.** Four themes are shaping the next generations of projects:

**Increasing capacity** also by diversifying and multi-purposes applications, e.g., in Combined Heat and Power projects and supply of minerals such as lithium, potassium etc., to increase economics;

**Adapting the depth** to be accessed, taking advantage of increased efficiency of production at lower temperatures;

**Adopting right number of wells:** multiple wells, new drilling design with sub-horizontal wells, advancing from the concept of a single production well to a doublet (production and injection wells) and then to three or more wells which are rotated in use, to improve the sustainability of the production system and resource performance;

**Expanding Greenfields,** moving from the vicinity of known areas and expanding the geothermal asset with new exploration techniques;

**De-risking approaches:** on top of the topics highlighted above, which also contribute to de-risk geothermal projects, it must be noted the project portfolio approach to de-risk development with several projects in a same area.

Altogether, the geothermal value chain may be subdivided into several subsectors, which correspond broadly to a given aspect of geothermal projects, from exploration to well completion and operation.

#### 5.1.1 Resource identification and assessment

Exploration services are expanding in use and time, and investments are enlarging, especially to explore greenfield areas.

Advanced services for Earth observation, geological and geophysical data integration, 3D seismic, and mapping-while-drilling are ambitious targets that improve reservoir understanding and enhance well placement to improve return, especially in complex reservoirs. Geothermal projects are utilising 3D seismic data more frequently and moving toward cloud and digital solutions to deliver 3D profiling of reservoir objects. 2023 and 2024 are seeing a record number of 3D seismic campaigns.

Artificial intelligence (AI) should allow a deeper data treatment of these exploration campaigns.

The design of acceleration areas in all EU Members States should lead to better identification of the potential and further assessment of the geothermal resources.

On shallow geothermal market, traffic light systems for geothermal heat pump systems already exists in some countries and must be replicated.

### 5.1.2 Resource development and drilling

Unlike short-lived oil and gas wells, deep geothermal wells must last decades (50 years) under constant use and harsh conditions and require well material (casing, cement) that can survive for years at high temperatures and potentially saline fluids. The expanding DHC market is resulting in novel and competitive companies developing and operating projects. Geothermal deep drilling is quickly advancing in specialisation of directional drilling facilities, monitoring downhole electronic equipment, and resilient material (use of fiber-glass, epoxy in the casing for a well lifetime of 40 years, and re casing and lining for extending well lifetime to 40 more years).

Following recent exploration campaigns, it is expected to have an increased a record number of deep wells drilled in Europe from 2025 to 2030.

Typically drilling phase represents from 30% to 50% of the cost of geothermal electricity and heat projects and more than half of the total cost of the next generation of geothermal systems. Moreover, the success rate in drilling for geothermal projects is about 50% in green fields and 75% in operated fields. Drilling in the deep geothermal sector requires essentially the same services and equipment and mobilises similar actors and workers as the onshore drilling in the oil & gas sector.

The resource development requires a range of suppliers (rigs, bits, equipment, casing materials, chemicals, pumps etc.), services companies and drilling contractors

An innovative market approach has been recently developed in Europe with joint Ventures established between developers and rigs owners, and with companies providing turnkey solutions integrating the geothermal value chain (from manufacturing of equipment to drilling, construction and operation). These solutions could be more attractive to consumers eager to use geothermal energy, but not to acquire themselves the skills necessary for development.

### 5.1.3 Resource exploitation, operation and maintenance

Geothermal plants are marked by long lifetime, over 50 years of operation with a sustainable exploitation and management of the resource.

2023 marks the 110 year anniversary of the very first geothermal power plant.

In 1913, the first geothermal electricity plant started its operation in Larderello, Italy. It was composed of an alternator Ganz 250 kW, three-phase 50 Hz, and a voltage of 4500 volts coupled with a Tosi Parsons turbine of 350 horsepower.

A handful of geothermal power plants were installed in Europe up to the 1970s. They were in Italy, Iceland, French Guadalupe, and Turkey. They were all high-temperature plants using flash/dry steam turbine technology.

The development of new turbine technologies, such as the binary cycle (i.e. Kalina and Organic Rankine Cycle-ORC), was a game changer as it allowed low and medium-temperature geothermal power plants to be commissioned. Countries such as Austria, Germany, Portugal, Croatia, and Hungary have installed geothermal power plants over the last 20 years using these technologies.

Regarding the lifetime of these plants:

- oldest geothermal powerplant still in operation is from 1986
- 4 running plants are from the 80's, 17 ones from the 90's and 32plants run from the 2000's
- so 21 powerplants are more than 25 years old and 53 plants are more than 15 years old

Geothermal district heating and cooling systems continued their steady growth trend in 2023 and witnessed a boom in the number of new projects in preparation. By the end of the year, a total of 401 systems were in operation, 298 of which were in EU Member States. Typically, doublet systems for geothermal DH systems have more than 30 years of operation. When a well is less productive, it may be possible to drill a new one, and triplet systems (several examples in the Paris area) increase the lifetime to more than 50 years.

2023 was the second consecutive record-breaking year for Geothermal Heat Pump (GHP) Sales. More than 154,300 units were sold in the EU in 2023. This was a 11.7% increase on 2022 sales.

Reporting market data for GHP requires some explanations about its difference with other HP technologies. There are no GHP systems with very small units, only for hot water or only for cooling. The majority of the units in operation, 2,3 million systems, have a capacity of 15 kWth or less and are used for individual residential buildings. The market of small-scale geothermal HP units (15-25 kWth) for heating, cooling and domestic hot water is progressing for collective and some tertiary buildings. Medium-scale units (25-100 kWth) for heating and/or cooling and/or sanitary hot water are used for larger collective and tertiary buildings. We account for 600 units of large fields of boreholes with a capacity greater than 50 kWth and 200 large open-loop systems with a capacity greater than 100 kWth. Large-scale systems (100 kWth – 5 MWth, up to 20 MWth) for district heating and industrial process heat are more detailed and reported in the previous chapter about geothermal DH.

A geothermal heat pumps systems, tapping resource at shallow depth, have a lifetime over 50 years, while the HP can be changed after 20 years.

Geothermal projects tend to have relatively low Operation & Maintenance (O&M) costs compared to other energy technologies. For deep geothermal, O&M costs represent about 2% of capital costs. It includes personnel costs (for remote control, regular routine inspections, start up / shutdown of the plant and during maintenance), routine maintenance costs (replace or clean equipment such as valves, pumps, the generator, etc), and consumables for the operation (filters, oil and chemicals). However, more and more manufacturers of equipment are looking at solutions to mitigate O&M impact, notably by developing productions that do not react with the brine, from coatings to epoxy/fiberglass tubing.

## 5.2 Market of equipment, components and services

Both the Covid-19 pandemic in 2020 and the Russian attack on Ukraine two years later demonstrated the EUs dependence on third countries for raw materials, components, equipment and security of energy supply. In the geothermal sector, disruptions in the supply chain occurred especially at the start of the pandemic. Supply of equipment for drilling or heat pumps components was delayed for some months, with a growing demand for geothermal DH and HP systems.

High gas and electricity prices, and concerns about security of energy supply due to the war in Ukraine, increase the demand for geothermal heating systems. The exponential growth in the geothermal heat pump market in some countries between 2022 and early 2023 and the late delivery of some equipment caused delays in drilling of up to 10 months for example in Germany.

To scale up the manufacturing of clean energy technologies in the EU, the European Commission proposed the Net Zero Industry Act (NZIA) in March 2023. It was adopted in 2024 identifying geothermal as one of the strategic net-zero technologies. This selection was based on technology readiness level, contribution to decarbonisation and competitiveness, and to the resilience of the energy system. The objective is that for all strategic net-zero technologies identified in the NZIA, manufacturing capacities in the EU approach or reach 40% of domestic deployment needs by 2030.

The EU is considered to be a net exporter of many services and equipment for geothermal technologies, including organic Rankine cycle (ORC) and heat exchanger manufacturers, facility constructors and, to a lesser extent, flash power turbine manufacturers. However, some sectors are dominated by non-EU companies, including pumps, valves, and control systems. Exploration and drilling services are expanding, also aided by the interest of the oil and gas industry.

For the geothermal heat pump sector, the production of HP is mainly European with companies assembling components. But for components such as the compressor as well as the electronic modules, they are currently produced outside of the EU, imports from China have doubled in 2021/2022. The United States are also developing their own domestic industry and have adopted a

support system through the Inflation Reduction Act that will facilitate the installation of heat pumps in the US and also exports to Europe.

### 5.3 Market for materials and minerals

Materials, including critical raw materials, are not considered a major issue for the geothermal sector. However, the dramatic increases in the cost of carbon steel (for well casings) and stainless steel in 2022 have impacted the project’s economic viability. On the contrary, the sector is becoming a producer of material from geothermal brines. With the increasing demand for batteries, the focus of mineral extraction from geothermal brines has been on lithium, and relatively high lithium concentrations have been reported for geothermal brines in several parts of Europe and other parts of the world. Approximately 20% of the EU demand for lithium by 2050 could be covered by geothermal production. A major focus of RD&D efforts is the efficient extraction of lithium and other metals from geothermal brines, and several methods, including membranes, ion exchangers, sorbents, and electro dialysis, are currently tested in Germany/France (Upper Rhine Graben area) and the UK (Cornwall). New opportunities are also being looked for in other areas, e.g., eastern Europe and Italy.

Globally, the demand growth for critical minerals has been strong. In 2023, lithium’s demand increased by 30%, experiencing the fastest demand increase in clean energy transitions. Nickel, cobalt, graphite and rare earth elements also saw significant growth, with demand expanding from 8% to 15%. In the case of lithium, this increase is largely driven by the expansion of the electric vehicle industry, with demand projected to increase tenfold by 2050 in the Net Zero Emissions (NZE) Scenario. While lithium has several industrial applications, the last decade has seen batteries become the main driver for global lithium demand due to its excellent electrochemical properties. In the short term, supply is expected to meet the current demand, but more projects are necessary to support the medium and long-term growth. Thus, ongoing investments are essential to develop new initiatives and meet future demand and diversification objectives (IEA, Global Critical Minerals Outlook 2024).

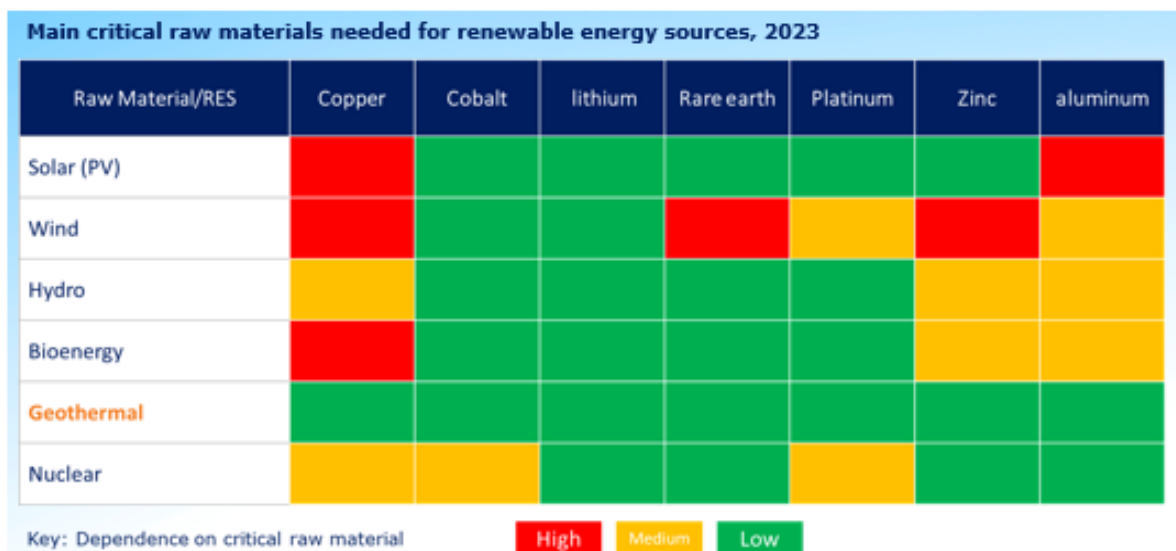


Figure 1 Main critical raw material needed for renewable energy sources

Source: The European House – Ambrosetti on International Environment Agency data, 2024



## 5.4 Geothermal industrial Ecosystems

### 5.4.1 Concept of Industrial ecosystems

Industrial ecosystem is a concept that maps the supply chain of a defined sector. It encompasses all players operating in a value chain: from the smallest start-ups to the largest companies being services companies, financiers, lawyers, manufacturers, developers, operators, from academia to research service providers and suppliers.

For the geothermal sector, it must consider all geothermal technologies be it for heating, cooling, electricity generation, underground thermal energy storage or the extraction of critical raw materials. All project development passes through five stages and all stages have their specific requirements in expertise, components and materials: 1) Site investigation; 2) Exploration for resource assessment; 3) drilling and subsurface engineering for resource development; 4) utilisation and management of the resource; 5) operation and maintenance for the sustainable management of the resource; 6) decommissioning after the end of life.

The focus on industrial ecosystems was announced in the Commission Communication on “A new industrial strategy for Europe” (10 March 2020).

Following the mandate by the European Council in April 2020, the European Commission made a preliminary assessment of the liquidity and investment needs of the EU27 to cope with the COVID-19 crisis. During this preparatory work to inform the Recovery Plan, the Commission started by identifying 14 industrial ecosystems: Tourism, Mobility-Transport-Automotive, Aerospace & Defence, Construction, Agri-food, Energy Intensive Industries, Textile, Creative & Cultural Industries, Digital, Renewable Energy, Electronics, Retail, Proximity & Social Economy, and Health.

The liquidity and investment needed for these ecosystems, in the aftermath of the COVID-19 pandemic, was published on 27 May 2020 in the Communication “Europe's moment: Repair and Prepare for the Next Generation”. The European Commission is proposing the programme Next Generation EU of €750 billion as well as targeted reinforcements to the long-term EU budget for 2021-2027 to bring the total financial firepower of the EU budget to €1.85 trillion.

### 5.4.2 Industrial valleys

The NZIA regulation promotes the development of net-zero acceleration ‘valleys’ (territories that concentrate several companies involved with a certain technology). The objectives of those valleys are to create clusters of net-zero industrial activity so as to increase the attractiveness of the EU as a location for manufacturing activities and to further streamline the administrative procedures for setting up net-zero manufacturing capacity. They will contribute to the reindustrialisation of regions.

#### **Industrial Geothermal Valleys**

The following illustration from ETIP geothermal showcases its versatility and competitiveness for the security of the energy supply.

Geothermal industrial areas can guarantee Europe’s energy independence and energy security. A single geothermal energy plant can produce electricity, heating, cooling, and raw materials, such as lithium, with a zero-carbon process.

Geothermal industrial valleys represent a transformative concept poised to reshape Europe’s economic landscapes. These systems aim to support the transition of regions from conventional energy sources to sustainable, self-reliant hubs for geothermal renewable energy to supply local energy generation, distribution, and consumption. Geothermal resource manufacturing of geothermal equipment is already made in Europe, allowing local supply of components and materials for geothermal technologies with European steel, cement, and chemicals.



Figure 2 ETIP geothermal vision of industrial geothermal valleys

### 5.4.3 Key equipment for geothermal technologies and manufacturing

Project development have five stages:

- 1) Site investigation;
- 2) Exploration for resource assessment;
- 3) drilling and subsurface engineering for resource development;
- 4) utilisation and management of the resource;
- 5) operation and maintenance for a sustainable management of the resource;
- 6) decommissioning after the end of life.

During **the first two stages**, mainly software as well as seismic exploration and measurement tools are provided by engineering and services companies for shallow and deep geothermal projects. Software for site investigation and 3D modelling is predominantly supplied by EU companies while equipment for seismic exploration (sensors, vibrators, etc.) are manufactured by European and North American medium-sized, rather specialised companies. A variety of software tools are available for visualising geological data – usually developed for the oil and gas industry – and are increasingly taken up by the geothermal industry with a record number of seismic campaigns in Europe in the last year.

Seismic Acquisition Instruments are mainly produced by large subsurface services companies operating worldwide. In the market of geophysical services and software manufacturing, on top of large subsurface service companies, some SMEs are also operating. Public research laboratories also offer performance of measurements, analysis, processing and interpretation of data with the application of geophysical methods. For the geothermal heat pump sector, project designers are European SMEs operating essentially on a national market, but some also provide services in other countries in Europe.

Once the resource has been mapped and the well field designed, the project enters the **phase of drilling and subsurface engineering**. Typically, the drilling phase represents 30% to 50% of the cost of geothermal projects and more than half of the total cost of the generation of geothermal systems. The resource development requires a range of suppliers (rigs, bits, drilling equipment, casing materials, chemicals, pumps etc.), services companies and drilling contractors.

Shallow geothermal drillers are mostly SMEs with on average 1 to 3 rigs, active on a regional or national level only, but there is a growing number of companies with a larger fleet of rigs. Drilling contractors (supplying the rig and crew) in the deep geothermal market operating in Europe are only European. They mainly work in one country, but not all countries in Europe have drilling companies. On average, there are less than five companies per country with the exception of Germany where more are active domestically and abroad. Some project developers such as Enel Green Power (Italy), Lithium de France or Vulcan (Germany) have also acquired their own rigs to be less dependent and better manage drilling costs.

Drilling rig manufacturers for shallow and deep geothermal are European, the leading companies coming from Germany, Italy and the UK. These drilling rig manufacturers are also supplying drilling equipment, but for some of them (e.g. air compressor) Europe faces a tough competition by Chinese companies.

In geothermal HP sector, closed loop systems also require underground equipment such as polyethylene piping and propylene glycol. Equipment manufacturers for geothermal probes, connection pipes and manufacturers of their components (pipes, valves, collectors, etc.) are European companies operating all over Europe. For well cementing, project developers find cement producers in Europe.

In deep geothermal, high temperature cementing solutions are provided by global companies with an increasing competition from China. To increase productivity, filters are utilised for the geothermal brine. These filters are manufactured by specialised companies operating in oil, gas and geothermal such as Dutch, Swiss and German companies. As for electrical submersible pumps and downhole

pumps, some European and North American manufacturers are the top players in the global market. Many of them are also global manufacturers of valves, monitoring and control systems.

For these two phases of project development in the underground, large subsurface services companies active in oil & gas are also supplying services (exploration and subsurface engineering) and equipment to deep geothermal: exploration tools, drilling equipment and pumps. A growing number of SMEs mainly active in O&G are also now operating in geothermal. Some of these services companies are also providing engineering, procurement, and construction (EPC) for geothermal plants.

After drilling and subsurface engineering are completed, the geothermal project enters into the phase of **utilisation and management of the resource**. Key components in this phase at the surface are valves, pipes, heat exchangers, and turbines/generators in the case of power generation.

The large majority of the equipment manufacturers operating in the geothermal sector have their core business in the oil and gas sector or in the conventional power sector. It means that technological development and costs reduction of equipment used for geothermal are not mainly influenced by geothermal actors.

The European valve market is wide and mature. Most of the manufacturers are found in Italy, the UK, and Germany. There is also an increasing number of Chinese and Indian valve manufacturers.

As for pipes and tubulars there are enough manufacturers on the market to cover the European demand, currently over 10 manufacturers. Project developers are often looking for products made in Europe which are generally available. This increasing demand can also clear current concerns about factories of equipment such as for casing materials closing in the EU.

Europe has always been a strong market for heat exchangers and, globally, this market has been a leader for heat exchangers which are not only used in the geothermal sector. This region has notably the presence of most of the global leaders in heat exchanger manufacturing. Newcomers to the European geothermal market are large manufacturers coming from India and Japan, or very specialised SMEs in Europe able to answer project specific challenges of corrosion and scaling with steel and titanium. The key materials for the production of heat exchangers are carbon steel (Ukraine), titanium (Japan), gaskets (UK).

For turbines, the major components include the impellers/blades, shaft/rotor, nozzles, inlet guide vanes, disks, and casings. The main manufacturing locations for binary cycle turboexpanders are Israel, the United States, Italy, and Germany. The flash cycle geothermal steam turbine manufacturing countries are Japan, Italy, the United States, France, Mexico, Russia, India, and China. Japan accounts for 82% of the geothermal steam turbine manufacturing market while Israel accounts for 74% of the geothermal binary cycle turboexpander manufacturing market. Italian turboexpander manufacturers have started to increase their share in the geothermal market with significant growth in the last couple of years.

For geothermal individual h&c systems, HP are always used for the heating. District level heating and cooling systems, heat pumps are increasingly used in projects to further increase the temperature. Heat pumps are assembled by European companies, but components may come from Europe and the rest of the world: compressor (using an electric motor), condenser, expansion device, and evaporator like a refrigerator, but also reversing valve / refrigerant, and the electronic components.

For commissioning DH and power plants, the construction is done by four categories of actors: the project developers such as electrical utilities, turbine manufacturers with an EPC department, EPC contractor (Technip, Clemessy Eiffage, etc.) or subsurface service companies in partnership with turbo-generator manufacturers. EPC is done by European companies.

Geothermal projects tend to have relatively low **Operation & Maintenance (O&M)** costs compared to other energy technologies. For deep geothermal, O&M costs represent about 2% of capital costs. It includes personnel costs (for remote control, regular routine inspections, start up / shutdown of the plant and during maintenance), routine maintenance costs (replace or clean equipment such as valves, pumps, the generator, etc), and consumables for the operation (filters, oil and chemicals). However,

more and more manufacturers of equipment are looking at solutions to mitigate O&M impact, notably by developing productions that do not react with the brine, from coatings to epoxy/fiberglass tubing.

#### 5.4.4 Mapping geothermal value chain in Europe

The Net-Zero Industry Act (NZIA) was approved with an aim to produce 40% of its annual deployment needs in net zero technologies by 2030. It will focus on key and specific components of each of the technologies listed in the NZIA.

##### **The made in Europe manufacturing of geothermal**

The geothermal sector in Europe benefits of a rather solid supply chain. For their key and specific components, enough European equipment and components manufacturers provide their products to the market. As an example, drilling rigs manufacturers for deep and shallow geothermal are European and we account more than 10 manufacturers of rigs.

Project developers, and public entities using public procurements and auctions are looking for products made in Europe, this could impact the manufacturing when geothermal will be further deployed.

The geothermal market deployment in Europe will be a game changer for more EU strategic autonomy.

Some issues must be highlighted:

- the value chain for deep geothermal technologies is today still dependent on the oil & gas sector: rigs availability, supply of equipment, drilling prices... and the O&G sector is global.
- There are concerns about factories of equipment, such as for casing materials, closing in the EU, so they will have to be imported in the future.
- Some specific equipment is not manufactured in Europe such as lineshaft pumps. For operating in European geothermal conditions, we don't find EU manufacturers so pumps are imported from USA.
- Some components of geothermal equipment assembled in the EU are not manufactured in Europe. The EU has always been a strong market for heat exchangers and, globally, this market has been a leader for heat exchangers. Issue concerns the material used for these components which are based on titanium, material not factored in Europe.

##### **Leading Geothermal valleys**

In this manufacturing of geothermal equipment and components made in Europe, some regions in Europe could already be considered as leading Industrial Geothermal Valleys:

1. Italy
  - a) Tuscany region

Tuscany region is for more than 100 years a leading region in geothermal. The first geothermal electricity plant was installed in 1913 in Larderello, Tuscany. Since then, nearly 1 GWe electrical capacity has been installed together with 25 geothermal district heating systems.

This industrial valley can be divided by on one side the geothermal industry and on the other side the local economy created around geothermal.

An ecosystem has been created with companies and public entities employing around 1,000 people directly, 2,000 people indirectly employed, and more with induced jobs (tourism, food and drinks, etc.)

created in the region around geothermal activities. Each megawatt of installed and maintained geothermal capacity creates 34 jobs<sup>1</sup>.

Enel Green Power is currently the operator of all the operating geothermal power plants in Italy. The local industry includes services engineering companies, project developers, and some equipment manufacturers. Historically, turbines provided to Enel Green Power were manufactured in Florence by Nuovo Pignone (now part of Baker Hughes group) and Ansaldo Energia based in Genova (Liguria region).

This geothermal valley has also an eco-system of companies operating in tourism (museum, moto and bikes tours), food (cheeses, cakes), drinks (beers), health and dietary products (spirulina algae-figure 3) supplied by geothermal energy.



**Figure 3 Greenhouse for Spirulina cultivation heated by geothermal, Chiusdino, Italy**

#### b) Lombardy region

The region of Lombardy is characterised by a full value chain for geothermal equipment. Two world leading turbines and large heat pump manufacturers are located in this region: Turboden (Brescia) and Exergy (Varese). These two companies assemble locally binary cycle with components manufactured by Italian suppliers based in an area of 100 km: pumps, generator, turbine, pre-heater, evaporator, tubes, filters, heat exchangers, air condensers.

This industrial valley shows an example of both equipment's and components manufacturers.

## 2. Germany

Germany is a leading country in terms of manufacturing geothermal equipment for heat pumps, district heating and electricity plants. For all project development phases, German companies are based in all regions and supply services, drilling, and equipment.

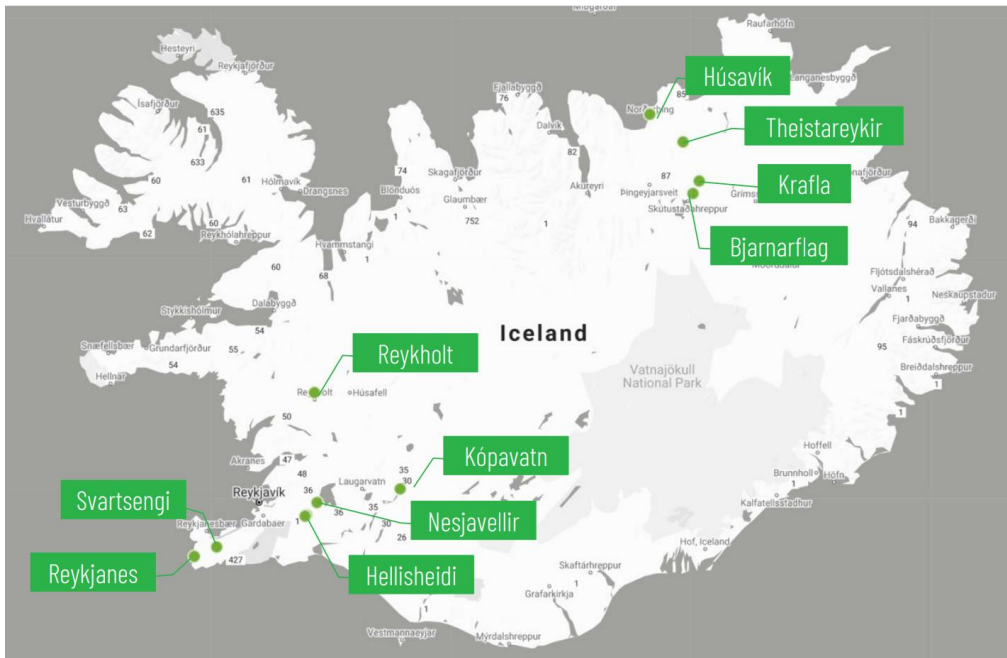
#### a) Bavaria and Baden-Württemberg for project development:

Historically project developers were focusing on Bavaria (the Molasse Basin) and Baden-Württemberg (the Upper Rhine Graben), but we can see now project developers in the whole country.

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<sup>1</sup> <https://www.enelgreenpower.com/learning-hub/renewable-energies/geothermal-energy/italy>





**Figure 5 Location of geothermal powerplants in Iceland**

Source: Iceland Renewable Energy Cluster

a) Reykjavik

Most of the Icelandic geothermal companies are based in the capital Reykjavik and in the surroundings. It includes services companies, project developers and a drilling company (Iceland Drilling).

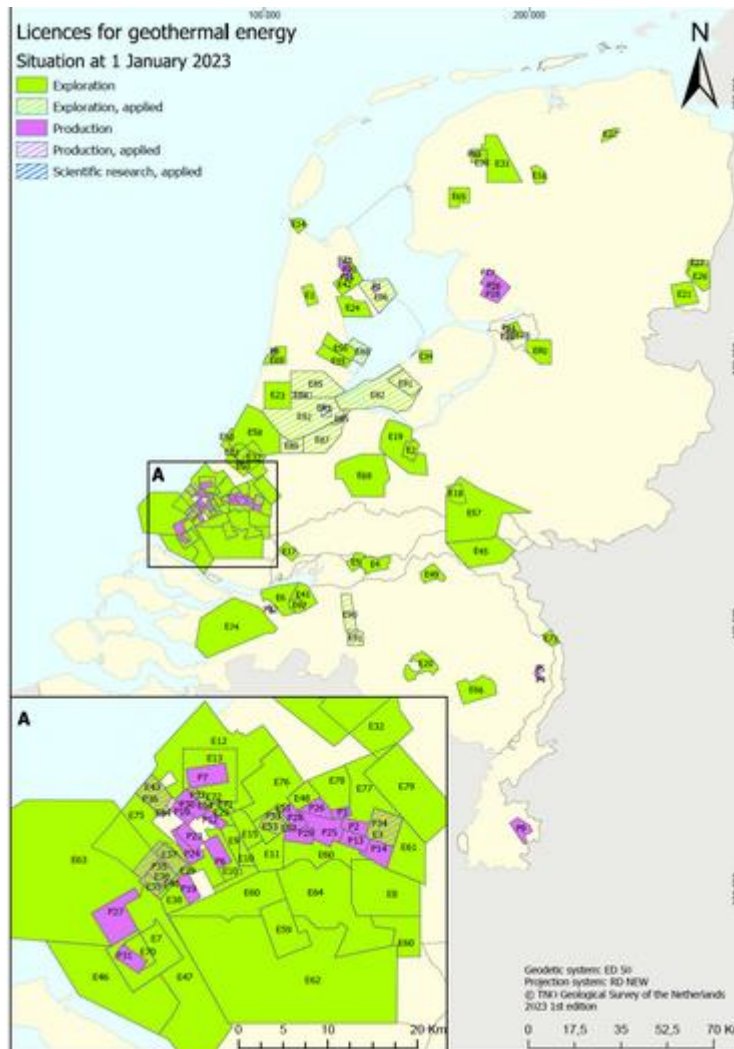
b) Reykjanes area

A Unique area can be highlighted in Iceland. As for Tuscany in Italy, one can find in Reykjanes peninsula a local economy created around geothermal. UNESCO, the United Nations Educational, Scientific and Cultural Organization, recognised Reykjanes as a UNESCO Global Geopark in 2015. The geothermal Combined Heat and Power (CHP) plant in Svartsengi provides energy to the Reykjanes Geothermal Resource Park, also known as the Blue Lagoon Geothermal Spa. A local eco-system was created with linked companies working in the fishing (fish drying facility and a fish farm) and tourism sector with a spa, skincare products and a dermatological treatment clinic. The industrial clustering now also includes a carbon recycling company producing methanol, a molecular farming company to produce proteins and growth factors from barley; and a data centre fully running on geothermal energy. There is a project to cultivate algae for biofuel production, and for an aquaculture plant.

4. Netherlands

In the Netherlands, geothermal projects are in operation mainly South Holland province, but projects are now developed all around the country (figure 6).





**Figure 6 Map Licenses for geothermal energy of the Netherlands - 2023**

The Netherlands has exploited fossil gas since 1959. From the exploitation of oil and gas, a Dutch industrial gas sector was established with a full value chain. The gas sector is well developed and includes production, transport, storage and trading companies, suppliers, service companies and drilling, as well as several interest groups public and private.

With such an expertise about the underground, the geothermal sector has benefited from this expertise from oil & gas. Dutch companies are based in all regions of the country, with a specific focus on the subsurface.

The Netherlands are not a real industrial valley but a national hub.

#### 5. Norway:

Norway has not developed many geothermal projects (2 deep geothermal heat plants) and the geothermal sector is still at a juvenile stage.

But from a unique expertise in oil since 1969, the Stavanger area can be considered as an eco-system for geothermal drilling. Stavanger is considered the Oil Capital of Norway, with the Norwegian energy company Equinor having its headquarters in the city. Several companies, most of which constitute a world-leading value chain of suppliers to the oil & gas, are also based around Stavanger. It includes international drilling majors, large mechanical manufacturing companies, energy project developers and operators, and engineering, ICT solutions, logistics and business services.

#### 6. Scotland (UK):

Similar to Norway with Stavanger, Scotland has with Aberdeen an eco-system around Oil & Gas with a potential technology transfer to geothermal. Since the discovery of North Sea oil in 1969, Aberdeen has been known as one of the offshore oil capital of Europe.

This industrial system includes engineering and manufacturing companies, drilling companies, production and workover equipment's providers, and projects developers/operators.

#### 7. France

France has a similar situation with Germany. With about 80 geothermal district heating systems in operation and 3 geothermal powerplants running, France has a rather mature market.

The equipment and components manufacturing for the whole supply chain of geothermal technologies is disseminated all over the territory. Some activities are seen around Nancy about transfer of technology from coal mining and subsurface activities to geothermal.

##### a) Paris, Alsace and Aquitaine:

But the operations are focused on three regions: Paris, Alsace and Aquitaine, where several geothermal companies are established but without been considered as an eco-system. It includes mainly services and engineering companies and geothermal project developers and operators.

##### b) Pau:

As for Germany with Celle, France could consider Pau as a drilling centre. The discovery of the Pau-Lacq gas field in 1951, saw the establishment there of French oil company Total and other oil&gas services and drilling companies. Some equipment manufacturers are also based in Pau. A drilling training centre was also created together with a Competitiveness cluster about underground industries.

#### 8. Sweden and Denmark:

Both Sweden and Denmark have a leading manufacturing industry for heating and cooling equipment and components. It applies for both district heating systems and individual heat and cold appliance. Sweden is a leading country in heat pumps and many heat pump manufacturers and manufacturers of heat pump components and based in this country. Denmark is leading in district heating systems. Leading services and equipment manufacturer for heating and cooling systems come from these two countries such as ABB, Danfoss, Grundfos, Alfa laval...

## 6 Conclusions

Geothermal energy already provides heating and cooling to more than 16 million inhabitants, and electricity to circa 11 million consumers.

IEA (December 2002) and ADEME (edition 2022) showed geothermal heating technologies as the more competitive sources. All consumers should benefit of it.

The present report on markets in Europe and worldwide shows you this by presenting the market trends and forecasts on development.

The geothermal sector in Europe benefits of a rather solid supply chain. For their key and specific components, enough European equipment and components manufacturers provide their products to the market.