Competitiveness of the Development of business model blueprints for geoHC networks industry

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1 Introduction

The need to transition towards sustainable energy solutions at the city level has intensified the exploration of geothermal heating and cooling (geoHC) networks, particularly in Europe where ambitious climate goals need innovative approaches to heat and cold supply for cities and villages. Geothermal energy stands out compared to other renewable energy sources for its ability to provide stable, reliable and uninterrupted electricity and heat. In particular, geoHC networks offer significant potential to decarbonise the heating sector, which remains one of the largest consumers of energy and a major contributor to carbon emissions. This report provides an overview of standard sustainable business models within this sector, assessing the competitiveness of traditional and innovative business models as well by considering both brownfield and greenfield territories of the continent. These models can be broadly categorised depending on the characteristics of the geothermal energy developers and the heat end-users, the level of community participation, and the extent of the energy market. By understanding these models, it would be possible to identify and share best practices, as well as find the solutions to the challenges, hence fostering the widespread adoption of geothermal energy solutions.

The report aims to illustrate the advantages of geoHC networks through case studies and real-life examples, which will be useful for policymakers, investors, and other industry players. The first chapter integrates the results of a review of sustainable business models within the geoHC networks industry, already collected and analysed in a report on the status of business models relevant to geoHC networks (Deliverable 4.1). In this part, the analysis of the available business models and their efficiency, as well as the challenges and prospects they face, is presented. Chapter two focuses on the analysis of the current trends in the geoHC networks sector in Europe, including the existing technologies and the market. After looking at the projections for the sector, the chapter proceeds to examine the geoHC technologies and their potential for effective business models as well as the geoHC market in Europe.

In the subsequent chapter, this report presents 5 blueprint business models customised for brownfield and greenfield developments within the geoHC networks sector. The first model (local public company) analysed is where the geoHC project is initiated by the municipality and may involve collaboration with private entities within a structured legal framework to facilitate its development. The second business model (public-private partnership) involves the development of geoHC projects with collaboration from the start between private companies and public entities. It is then considered the business model focused on self-consumption where industrial partners independently develop and manage the projects to meet their own heating needs. The analysis continues with the decoupled business model characterised by separating the project development into phases: underground exploration and production, surface systems development and heat and cold sales. Finally, the report touches on the business model developed in the framework of energy communities, where building owners and individual consumers collaborate to create sustainable energy solutions.

Based on the 5 business models identified, specific recommendations are then elaborated targeting policymakers, investors, and project developers engaged in advancing geoHC networks. It outlines policy initiatives for market expansion, investment strategies to mitigate financial risks, and best practices for stakeholder engagement.

Finally, the last chapter offers tailored recommendations specific to European countries, accounting for the diverse socio-economic and regulatory environments across the continent. Based on the policy readiness evaluation scheme from Deliverable 5.1, this chapter provides tailored recommendations for the countries analysed (Austria, Denmark, France, Germany, Italy, Poland, UK). This section also identifies the opportunities for collaboration between public and private entities, outlines regulatory frameworks supportive of geoHC deployment, and underscores strategic investments.

2 Key findings of the review of sustainable business models for geoHC networks

2.1 Overview of sustainable business models in the geoHC sector

Over the past decade, the number of operational geoHC systems in Europe has doubled to 400, adopting both traditional and innovative business models [1]. Challenges in securing demand, financing infrastructure, and managing project risks have encouraged the development of new business approaches. While geoHC technology is mature and competitive, the capital-intensive nature of installations, particularly drilling wells (1-3 €Mio/MWth), remains an obstacle. Nonetheless, low operational costs (about 2%) make them attractive with production costs averaging around 60€/MWh thermal in Europe[2].

2.2 Analysis of existing business models and their effectiveness

The two conventional business models include:

- A district heating (DH) company collaborating closely with Energy Service Companies (ESCOs) to transition to a decarbonised heat supply. Here, the primary marketing strategy involves integrating renewable heat supply (potentially with labels or certificates) with energy-saving services to expand the range of offerings and decrease energy consumption.
- A geoHC project developer, whether public or private, aiming to introduce a new DH system utilising geothermal heat and cold supply. Here, consumers need to be persuaded of the benefits of renewable energy sources, which are local, reliable, and cost-effective.

The evolution of business models in the geothermal sector has been influenced by several key factors. Firstly, European legislation enacted since the 1990s to liberalise electricity and gas markets has been significant. Additionally, the climate and energy packages of

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[1] EGEC (2023), Market Report 2022 based on ADEME report "Coûts des énergies renouvelables et de récupération en France »

[2] SAPHEA (2024), Status report on business models relevant for geoHC networks (D4.1_Business-Model-report.pdf (egec.org).

2020 and 2030 have fostered the development of renewable energy through supportive policies. Finally, the current European economy has been characterised by the inflation of recent years, driven by rising hydrocarbon costs.

With the shift towards developing geothermal projects in greenfield areas after brownfield projects, there are challenges due to limited information for developers and customers. Currently, several considerations need to be taken into account:

- Adopting a demand-side project approach to define heat demand before assessing available resources.
- Exploring multi-purpose uses of geothermal heat, such as cogeneration and trigeneration, to maximise revenue potential.
- Implementing underground thermal storage to integrate industrial or municipal waste heat and capitalise on market opportunities.

Consequently, new public-private partnerships (PPPs) and privately structured models have emerged, along with various decoupled models. These models involve shared ownership, financing, risks, and profits between the public and private sectors [3].

	Business models for geoHC networks
1	A private-public partnership
2	A joint venture - private-public partnership
3	A local project company established with a partnership between the municipal entity and the geothermal developer
4	Private self-consumption model
5	Secondary private self-consumption model
6	Private collective contract model
7	A special decoupling model
8	A new type of decoupling: subsurface and surface developers
9	Energy communities

Table 1: Business models for geoHC networks [4]

[3] SAPHEA (2024), Status report on business models relevant for geoHC networks (D4.1_Business-Model-report.pdf (egec.org).

[4] During a cross-thematic workshop organised by SAPHEA, experts and representative from the industry confirmed that PPP are the most adopted business model in geoHC projects.

As confirmed during a cross-thematic workshop organised by SAPHEA [5], PPP appears the most used business model in geoHC project development. The new business models that have emerged recently are indicated at the bottom of this ranking, arousing however the interest of experts and industrial representatives concerning their potential application.

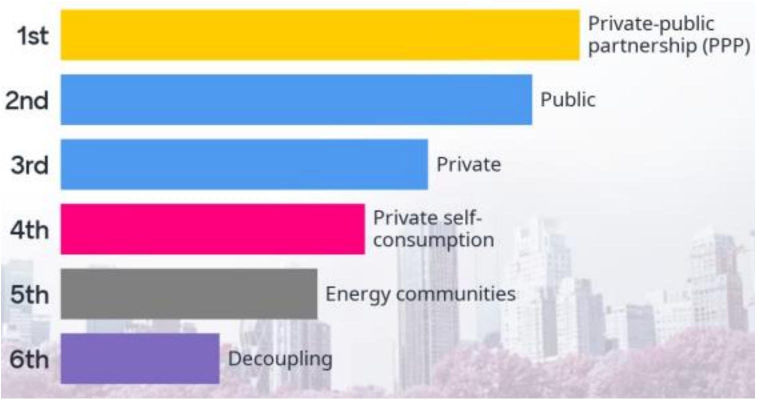


Figure 1: Ranking of the most adopted business models according to experts and industry representatives (2024)

Source: SAPHEA cross-thematic workshop

2.3 Identification of challenges and opportunities

The structuring of business models in geothermal projects is strongly influenced by financing, risk appetite, and regulations. Additionally, factors such as existing heat grid systems, project management organisations, and the entities involved (public, private, and individuals) also play significant roles.

By looking at this evolving landscape it is possible to identify six new key drivers shaping innovative business model developments in geothermal projects:

- Efficient plant operation is critical for project success, necessitating the need for short-term revenue collection and guarantees to cover initial investments. Implementing heat purchase agreements (HPAs) can address this challenge.
- HPAs serve as pricing contracts that streamline the business model process.
- Identifying geothermal resources is essential for project development, especially as more projects are expected in greenfield areas, requiring extensive exploration.

[5] SAPHEA organised a cross-thematic workshop on the 9th of September in Paris (France), where innovative solutions for integrating geothermal district heating and cooling into European cities and industries were showcased. Presenters discussed current case studies from Spain and France, as well as new funding opportunities. Participants engaged in open discussions about the latest technologies and the challenges and opportunities facing geothermal energy in Europe. This session provided a vital platform for dialogue on the future of geothermal energy. Some of the experts gathered at the SAPHEA workshop had already been consulted in the elaboration of the blueprint business models, collecting their inputs and comments to acquire a broader and complete perspective on business trends. The information included has therefore been processed in order to represent a variegated pool of key stakeholders of the geoHC sector.

- De-risking schemes are crucial for project financing, particularly for geoHC projects serving small communities or industrial processes. These schemes mitigate risks associated with resource temperature and flow rate.
- Energy market liberalisation introduces demand-side risks, with clients potentially disconnecting from the grid. Public funding for heat infrastructure is then necessary to de-risk surface development and secure long-term heat purchase agreements.
- Changes in district heating regulations require geothermal projects to adapt to evolving revenue security. Diversifying revenues through heat, electricity, storage, and minerals extraction offers new financial prospects, contingent upon supportive regulatory frameworks. Permitting processes also play a vital role, necessitating streamlined timelines of approximately 2 years for project development.

The current market dynamics in the EU's electricity and heat sectors present challenges for geothermal energy to compete with traditional technologies, which historically operated in protected, monopolistic environments. These conventional technologies benefited from shifting costs and risks onto consumers rather than sharing them with suppliers and operators. Unfortunately, the internal market still lacks transparency and efficiency. A look at the status quo allows the identification of several challenges hindering the development of geoHC in Europe.

Firstly, many countries continue to regulate electricity and gas prices, which do not reflect the true costs of generation, hence negatively impacting the competitiveness of renewable energy sources, in particular geothermal. Additionally, fossil fuel and nuclear industries receive significant subsidies, consumers receive insufficient information and opaque billing practices are put in place further distorting the market.

As technology advances and developers gain experience, the likelihood of successful geothermal reserve discovery and cost reductions will increase. This will enable developers to better manage and transfer project risks (technical, economic, commercial, organizational, and political), paving the way for private funding. Until then, establishing a pan-European Geothermal Risk Insurance Fund is an attractive public support option.

In addition to barriers like the availability of geological data, regulations on energy, environment, mining, permitting processes, and supply chain issues, the high upfront costs and risks associated with geothermal resources are significant challenges. For geothermal projects, the upfront capital expenditure (CAPEX) typically constitutes 80-

90% of the total project cost which is then coupled with the risk profile of geothermal resource identification and may require additional exploration or development investment. There is a risk of not finding an expected or economically sustainable geothermal resource after the initial drilling, and there is also the long-term risk of the resource naturally depleting, making its exploitation unprofitable.

Mitigating these risks is therefore crucial for the profitability of geothermal projects. Risks can be minimised with improved exploration techniques and better data availability. However, a widely proven solution to facilitate geothermal energy market uptake is establishing financial de-risking schemes such as insurance, grant schemes, or public-private partnerships. In mature markets, these can take the form of private insurance and public-private partnerships, while in less developed markets, public and public/private risk instruments are required. Grant schemes are particularly suitable for markets with little information about geothermal resources and few reference projects. Best practices for upfront cost support and risk mitigation exist in France with the SAF Environment Fund and in the Netherlands with the Geothermal Heat Guarantee Scheme. [6].

3. Presentation of market and technology trends in Europe

3.1 Description of heating & cooling demand by 2030 and 2040

Europe has recently witnessed progress in the deployment of geoDH networks as a renewable energy solution positive for the environment, due to their significant reductions in greenhouse gas emissions. To identify efficient business models for geoHC projects it is essential to firstly analyse the major trends that the energy sector will experience in the following decades.

By looking at the EU's total energy consumption in 2019, buildings represent a relevant part of energy usage contributing to 40% of the total consumption[7]. Within this framework, heating represents the factor absorbing most of the energy consumption within buildings (figure 1). Around 248.2 million tonnes of oil equivalent (Mtoe) were recorded in residential buildings while non-residential ones consumed about 128.6 Mtoe

[6] Georisk (2019) Report reviewing existing insurance schemes for geothermal.

[7] Eurostat (2022) Energy consumption in households, Energy consumption in households - Statistics Explained (europa.eu).

equivalent during the same period [8]. The industrial sector is another major consumer of energy, using around 125 Mtoe for heat and, in some cases, for cold industrial processes. This considerable energy usage highlights the need for efficient heating and cooling solutions tailored to industrial requirements. Altogether, the heating and cooling sectors represent 50% of the final energy consumption in the EU, which amounted to 940 Mtoe in 2022.

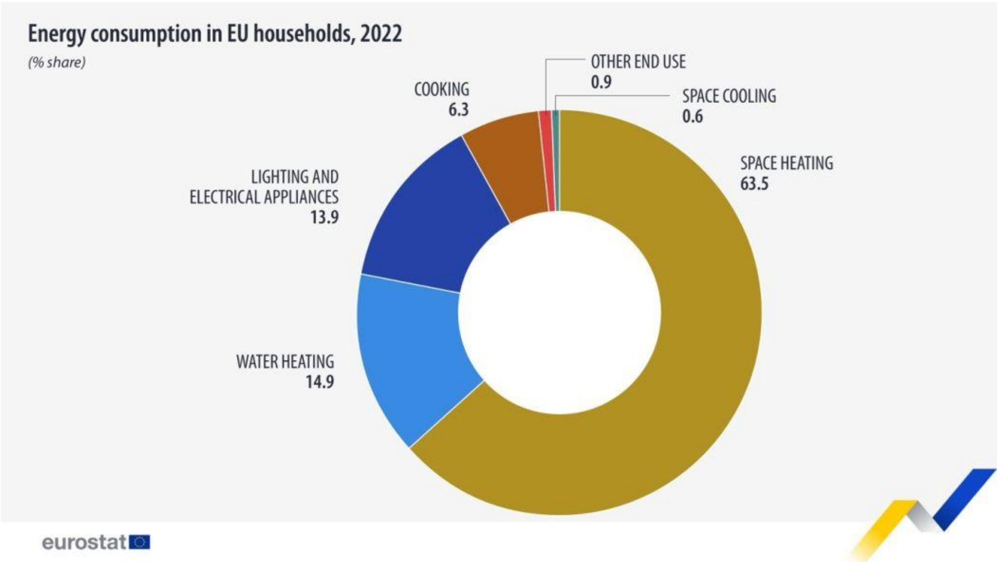


Figure 2: Energy consumption in EU households, 2022.

Source: Eurostat

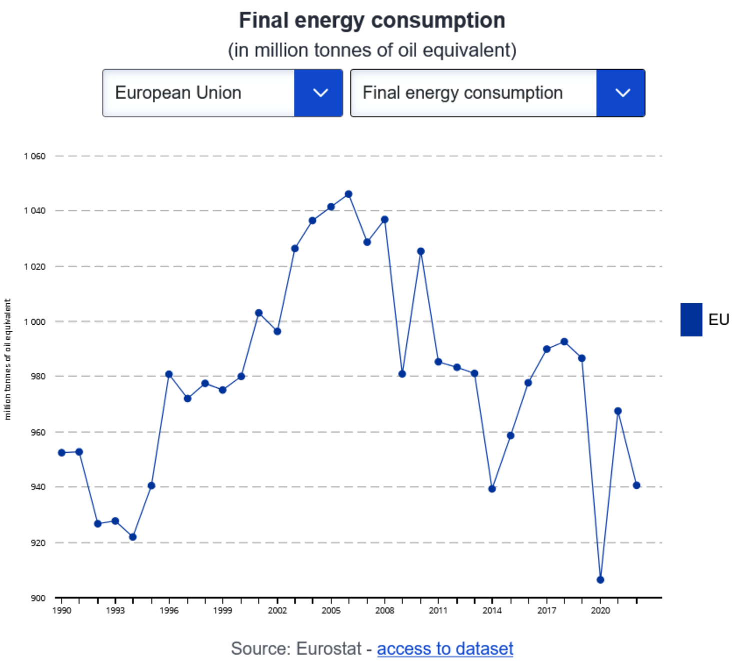


Figure 3: Final energy consumption, 2023.

Source: Eurostat

[8] Eurostat (2023) Shedding light on energy in the EU – 2023 edition, Shedding light on energy in the EU – 2023 edition - Eurostat (europa.eu).

The other factor to be considered is the rapid expansion in the deployment of renewable technologies driven by the EU's increasing commitment to enhancing these technologies by 2030. The forecasts of the significant increase in the share of renewable energy sources indicate a potential market for geoHC networks which are an essential element of the heating and cooling strategy within the EU's renewable energy policy. To achieve this pattern of growth, it is probable that this will come with more innovative and supportive regulatory regimes to support long-term geoHC network investment. By 2040, more than 50% of energy is likely to be from renewables hence supporting geoHC networks in the EU energy landscape.

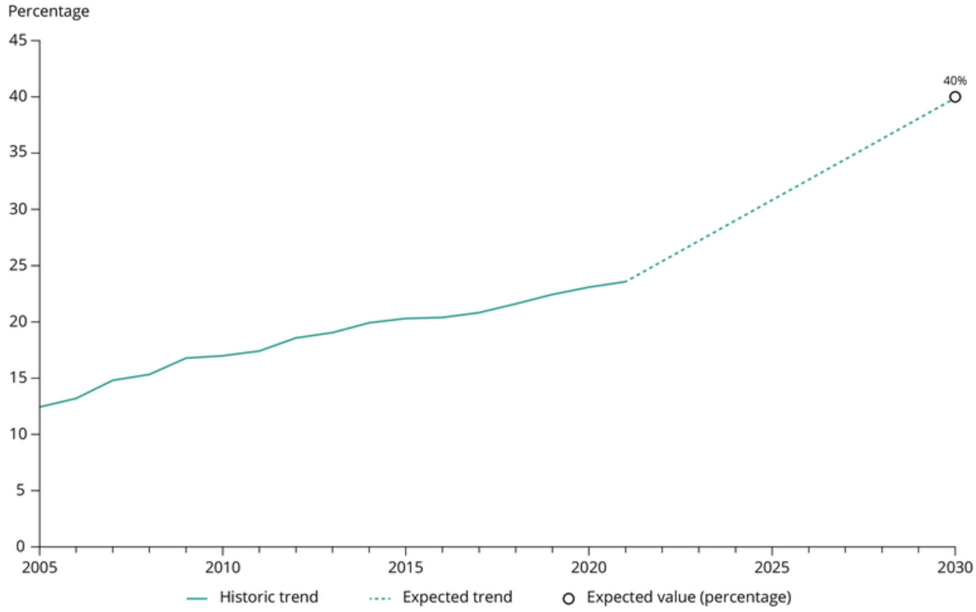


Figure 4: Historic and expected share of renewable energy sources in EU heating and cooling (%), 2023.

Source: European Environment Agency

Consistent investment will be required for the successful decarbonisation of the heat sector in Europe. The graph below (figure 4) shows that within the heat sector in Europe, there is a trend towards a more efficient and centrally managed system of district heating, highlighting the great potential for establishing new and efficient business models based on geoHC networks. Businesses specialising in geoHC solutions could capitalise on these trends by developing integrated solutions that align with the expanding district heating infrastructure.

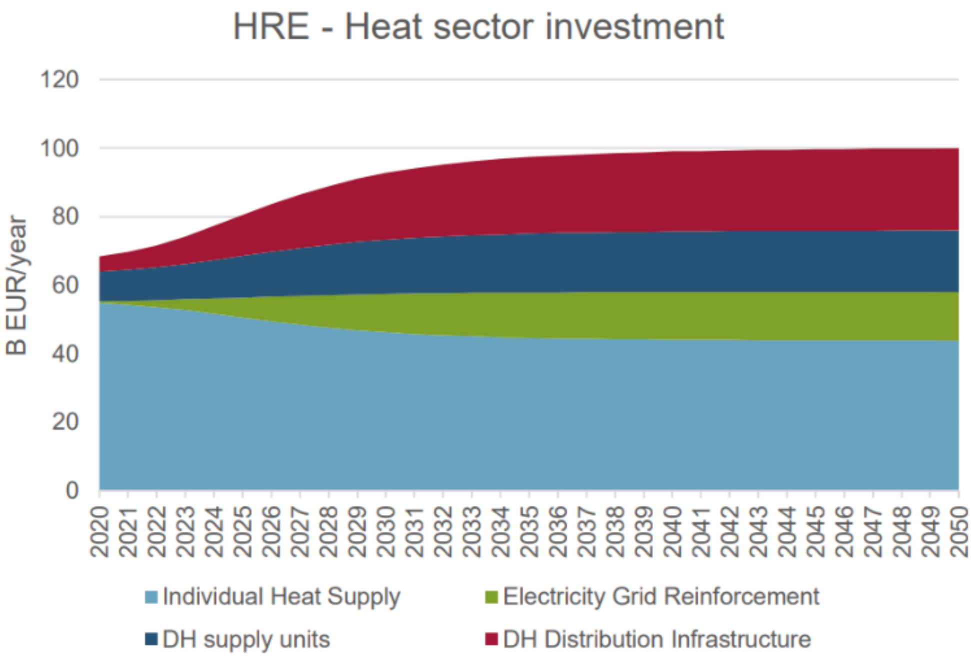


Figure 5: Annualised heat sector investment costs roadmap, 2024.

Source: European Commission

By 2030, the reliance on coal and natural gas is expected to decline, with the consequent increase in the use of electricity, biomass, district heating, and other renewable energy sources. In the following decades, electricity will probably become the dominant energy source, followed by district heating, biomass, and hydrogen. The patterns illustrated in Figure 5 show that there will be a significant decrease in the final energy demand for heating and cooling in the industrial sector by 2050, thanks to increased energy efficiency and cleaner energy sources. Businesses specialising in renewable energy technologies and the development of energy-efficient industrial processes will likely be advantaged by this transition towards decarbonisation.

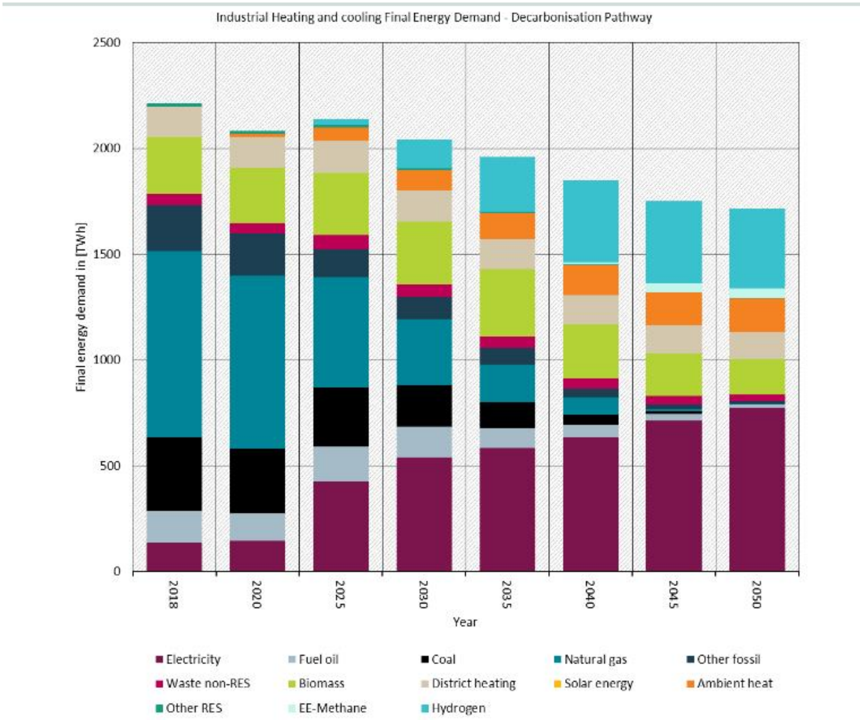


Figure 6: Final energy demand for H&C in the industry in 2050 in the pathway scenario (EU27), 2023.

Source: European Commission

The landscape of deep geothermal energy for geoHC in Europe is also witnessing substantial shifts that open up promising prospects for sustainable business models. These changes are driven by advancements in market dynamics and technological capabilities, strategic transformations among key industry players, and evolving regulatory frameworks. [9].

The increasing sophistication and acceptance of geoHC technologies in the market indicates a strong base for sustainable business concerns. Among the factors in question are, for instance, regulatory advancements and market penetration [10]. In Europe, a more comprehensive and encouraging regulatory structure has proven to provide a positive and beneficial impact as it defines a predictable environment for investment, which is critical for the business to operate in the long term [11].

With the changing dynamics in the geoHC market, equipment manufacturers are revising their business approaches. Specifically, manufacturers are integrating more deeply within the geothermal value chain, offering "turnkey" solutions that encompass all stages of

[9] ETIP (), Report on competitiveness of the geothermal industry (D4.6-Report-on-Competitiveness.pdf (etip-geothermal.eu)).

[10] ETIP Geothermal (2023), Strategic Research and Innovation Agenda (SRIA_2023_Final_ForWeb_compressed.pdf (etip-geothermal.eu)).

[11] SAPHEA (2023), Status report on key market drivers related to the implementation of geoHC networks (D2.1_Market-Driver-Report.pdf (egec.org)).

project development, resulting in streamlined processing, lower costs and increased project efficiency. Manufacturers can also achieve cost-cutting and improved viability of geoHC networks by standardising technology and processes. This reduction of cost is necessary to expand the target market and make sure the geothermal alternatives are economically viable.

Finally, knowledge creation and data standardisation are critical enablers for innovation and sustaining business models in the geoHC sector. This entails developing policies providing open access to geothermal data as well as encouraging all stakeholders to make their geothermal data publicly available.

3.2 geoHC innovative technologies for sustainable business models

This paragraph looks at the geoHC technologies that are currently developed and, because of their characteristic, would be suitable for the development of sustainable business models. They may enhance the competitiveness of the Development of business models. Innovative Technologies can improve efficiency and reduce costs.

Underground thermal energy storage (UTES)

UTES refers to the storage of thermal energy underground for later use, leveraging natural or engineered subsurface conditions to store heat or cold. Integrating storage to a geoHC network would improve the conditions to answer the H&C demand profile with a seasonality. These technologies are functional to balance seasonal variations in heating and cooling demands, enhance the efficiency of geothermal systems by providing a buffer for thermal energy, as well as reduce peak load demands on energy systems.

There are several storage technologies:

- Aquifer Thermal Energy Storage (ATES): utilizes natural water-filled aquifers to store heat or cold. Water is pumped from one well, either heated or cooled, and then returned to another well.
- Borehole Thermal Energy Storage (BTES): involves storing heat in boreholes drilled into the ground. It’s commonly used in conjunction with geothermal heat pump systems.

- Cave Thermal Energy Storage (CTES) is often called "mine water" and growing in importance. It uses temperatures between 20-40 degrees for direct use or combined with a large heat pump for higher temperature use. Systems are in operation in Asturias (Spain), Heerlen (the Netherlands), and developed in Country Durham (UK), Midlothian (Scotland), Bochum (Germany), etc. This is a core feature of the EU's Coal Regions in Transition programme, which provides technical assistance and finance for applications in the EU and technical assistance for applications in other parts of Europe.

The trend is to develop underground thermal storage systems at higher temperatures for being applicable in DH, industrial heat processes, etc.

High-temperature UTES involves storing thermal energy at higher temperatures than traditional UTES systems, typically for industrial or large-scale heating applications.

• High-temperature aquifers: Uses deep aquifers that can store heat at temperatures above 60°C.

• Advanced insulation techniques: Ensures minimal heat loss during storage and retrieval.

High temperatures UTES are feasible for industrial processes requiring high-temperature heat, large-scale district heating networks and seasonal storage of excess thermal energy from renewable sources.

These technologies enable efficient storage of large amounts of thermal energy while supporting high-demand heating applications.

Digitalization and Digital Twins

Digitalization involves the integration of digital technologies into geothermal operations to create smart thermal grids. Digital Twins are virtual copies of physical geothermal systems that can simulate and analyse real-world performance. Digital twins allow for the simulation of various scenarios to predict how changes in operations might impact the system. Digitalization implies the use of machine learning to optimize performance and predict maintenance needs, as well as the integration of sensors and the Internet of Things (IoT) facilitating real-time decision-making.

Large heat pumps

Large heat pumps are systems designed to transfer heat from a source to a sink on a larger scale, suitable for industrial and commercial applications.

There are 2 key technologies concerning large heat pumps:

- Absorption heat pumps: Use heat as the energy source, typically for large-scale heating and cooling applications.
- Compression heat pumps: Utilize mechanical energy to transfer heat from a lower temperature source to a higher temperature sink.

These technologies can be employed in district heating and cooling systems, industrial processes requiring substantial heating or cooling, and large commercial buildings.

Large shallow geothermal HP systems & 5th generation geothermal DH

These systems use geothermal energy at shallow depths (typically less than 200 m deep) to provide heating and cooling for large-scale applications, such as industrial complexes or large buildings at low temperatures.

It is possible to identify 2 key methods:

- Ground source heat pumps (GSHP): Extract heat from the ground through buried pipes.
- Water source heat pumps (WSHP): Use water bodies such as lakes or rivers as the heat exchange medium.

These technologies can be installed for the heating and cooling needs of large commercial and residential buildings, industries, and district heating and cooling networks. There is now a major trend in reducing the temperature of district thermal networks. Urban heating is moving from traditional centralized high-temperature to lower-temperature supply. Reducing the temperature of district thermal networks brings efficient, environmental-friendly and cost-effective community thermal supply. A decrease in the supply temperature level allows also more efficient operation (e.g. less heat losses), better integration and a greater variety of renewables/waste heat sources.

5th generation GDH refers to advanced district heating systems that integrate low-temperature geothermal energy with high efficiency and flexibility, often coupled with digitalization for optimized performance.

- Low-temperature networks: Distribute heat at lower temperatures, reducing energy losses and enhancing efficiency.
- Bidirectional heat flows: Allows for both heating and cooling from the same infrastructure.
- Integration with renewable energy: Combines geothermal with other renewable sources like solar or biomass.

5th generation GDH is optimal for urban heating and cooling networks, decentralized energy systems for mixed-use developments, and industrial complexes requiring flexible heating and cooling solutions.

District cooling

District cooling involves the centralized production and distribution of chilled water for cooling buildings and industrial processes within a network.

- Chilled water systems: Uses large chillers to produce cold water that is then distributed through a network of pipes.
- Free cooling: Utilizes naturally cold sources, such as deep lakes or rivers, to provide cooling without mechanical refrigeration.

District cooling can be implemented in urban areas with high cooling demand and industrial parks requiring large-scale cooling.

Single-well geothermal systems

Single-well systems are a type of geothermal energy system that combines both the extraction and reinjection of geothermal fluids in a single well.

- Closed-loop systems: A heat exchanger is placed underground, transferring heat without extracting fluids.
- Open-loop systems: Geothermal fluids are extracted, used for heating or cooling, and then re-injected into the same well.

Among their application, these technologies are suitable for small to medium-scale heating and cooling applications, remote locations where drilling multiple wells is not feasible, and residential or small commercial buildings.

Deep closed-loop systems

Deep closed-loop systems circulate a heat exchange fluid through a closed loop that extends deep into the earth, harnessing geothermal energy without direct fluid extraction.

- Borehole heat exchangers: Long vertical or inclined boreholes with a closed-loop system for fluid circulation.
- Horizontal heat exchangers: Similar systems installed horizontally or at shallower depths but cover larger surface areas.

Deep closed-loop systems are applicable in large-scale heating and cooling projects, industrial applications requiring high-temperature heat, and advanced geothermal systems (AGS) for sustainable energy production.

Multi-geothermal systems

Multi-well systems involve multiple wells for extracting and re-injecting geothermal fluids, enhancing the efficiency and capacity of geothermal energy production.

- Doublet systems: Consist of two wells, one for extraction and one for re-injection, ensuring sustainable use of geothermal resources.
- Cluster well systems: Multiple wells in a single location to maximize geothermal resource utilization.

3.3 Discovering new markets for geoHC

Improving the competitiveness of geothermal technologies in developing new business models for the geoHC industry includes discovering new markets and end users. Being versatile and sizable, geothermal systems offer a large range of opportunities for all H&C demand profiles.

The geoHC networks currently in operation supply heating to buildings and greenhouses at rather high heating temperatures, which means more than 80°C. They operate around 4000 hours of heating per year. In Europe, the average size of systems is ca. 10 MWth to supply heat to around 5.000 inhabitants.

Three characteristics allow geothermal to reach new end users:

1. Geothermal can supply heating but also cooling, this would enlarge the scope of clients.

2. Geothermal is sizable, which means it can supply heat and cold for a couple of buildings operating in a network, but also for an entire city or industry with large capacity.

3. Geothermal can supply heat at low to medium temperatures, and with storage, it can answer any load. It can operate as a base load for the demand profile.

Geothermal heating and cooling networks, especially with the 5th generation of DH at low temperatures, should target less densely populated areas, combined with individual systems. It may notably be the case of buildings in rural areas and peripheric areas.

Regarding buildings, all types of buildings may be looked at to supply geothermal heat and cold. It includes all kinds of living habitats (e.g., houses, apartment buildings, blocks of buildings, public buildings being office buildings, theatres, swimming pools) with different demand profiles. It would also include private office buildings, logistical centres, supermarkets etc.

In addition, geothermal heat production provides a continuous energy supply at many temperature levels, for different loads and capacities, at low cost. This makes it particularly suitable for a vast range of industrial processes. Geothermal can supply heat and cold to different kinds of industries for their industrial heat/cold process. Industry can benefit from geothermal heat and cold at low to medium temperatures, for diverse demand profiles, also in rural areas.

Geothermal energy has also been used extensively in the agricultural industry for the last three decades, notably in greenhouses for vegetables, flowers and fruit production.

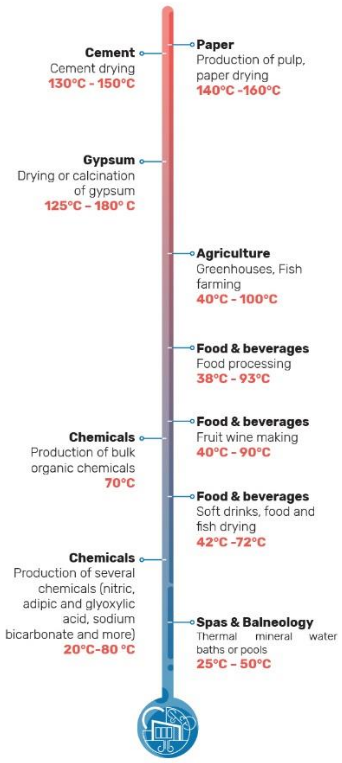


Figure 7: Uses of geothermal energy in industry.

Source: EGEC

3.4 Competitiveness of GeoHC in Europe

GeoHC systems offer a viable long-term energy solution for Europe. As Europe continues to set higher and higher climate objectives and tries to lessen the use of fossil fuel resources, the geoHC becomes a critical economic issue. This chapter examines the financial scope and investment perspective of geothermal energy development concerning traditional fossil fuel-based energy systems to discuss the potential benefits and challenges.

Capital costs and financing

Geothermal heat development costs can vary considerably as they depend on a wide range of conditions: resource temperature and pressure, reservoir depth, geological settings, drilling market conditions etc. The capital costs per geothermal heat technology range from 1-4 €mio/MWth for the resources development and 1 €mio/Km for the surface systems.

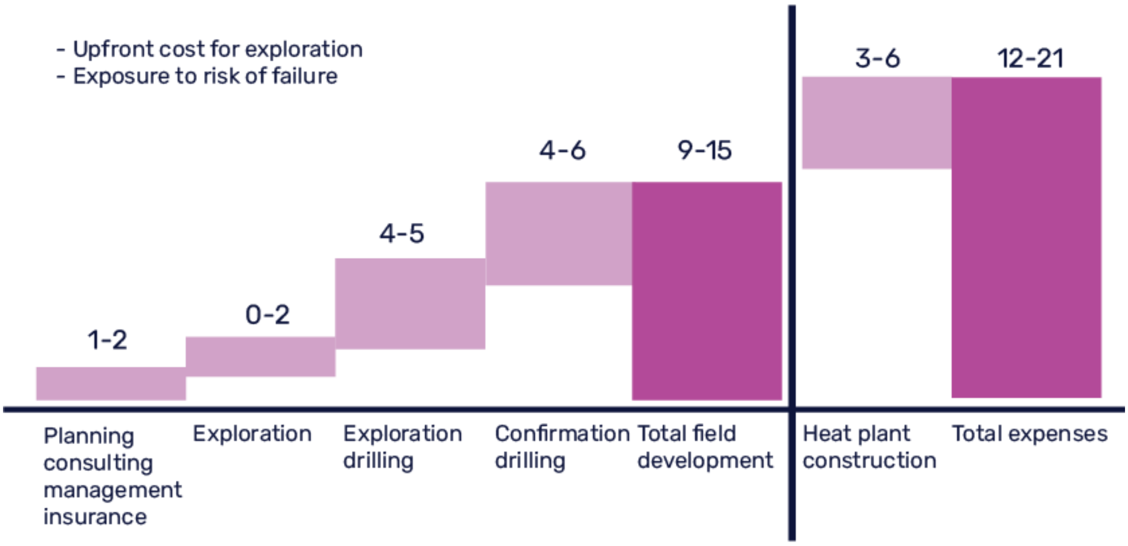


Figure 8: Cost range for the development of a 10 MWth geothermal DH (doublet) system.

Source: ETIP-DG

Plant producing 40.000 MWh/year (investment cost = €1.3-1.8 million/ MWth). Capital costs do not include costs for the installation of the district heating grid (about €1 million/km) [12].

The development of a geothermal heat project until first heat costs between €12 and €21 million for a 10 MWth plant size supplied by a well-doublet, to which, for reasons of maximizing efficiency of energy recovery one may add between €4.3 – 4.9 million for the large heat pump (of 4 MWth capacity). Costs for the development of a 5 MWe and 20 MWth CHP project (including topsides for power generation) range between €20.4 – 28.3 million.

The optimal capital expenditure profile very much depends on trade-offs and probability of success for each of the phases: exploration, development, and power/heat plant construction. One must not add the maximum of each phase to arrive at a cost estimate for a geothermal energy project; each phase influences the cost for the subsequent phase. For example, a more extensive, and hence expensive, exploration phase may pay back through reduced unit drilling cost because the probability of a successful well increases, the planning and design of wells is improved, and the likelihood of costly operational and technical interventions is lowered because of improved knowledge.

The ultimate profitability of geothermal energy projects strongly depends on the weighted average cost of capital. Generally, the cost of capital for investors in risky ventures is higher than for de-risked and predictable ventures. Geothermal energy

[12] EGEC (2024) : Market Report 2024.

projects are not only capital intensive but also require significant up-front investments to de-risk a venture until parameters of the resource, and hence possible revenue streams can be quantified. Regarding the above figures, the high-risk stage corresponds to expenditures for resource identification and exploration and exploratory drilling. In the case of projects lacking permeability with low flow rate, then requiring reservoir engineering, there is uncertainty on the potential capacity of the plant and heat supply of the project until this task has been completed. This means that between 40 and 75% of a typical geothermal project cost must be invested when there is still a high level of uncertainty regarding the success of the project development. This usually translates into higher costs of capital and challenges to finding investors with the appropriate risk appetite. Typical investors in subsurface energy projects (such as oil and gas) are used to high returns on risky investments, others are less familiar and open to this risk.

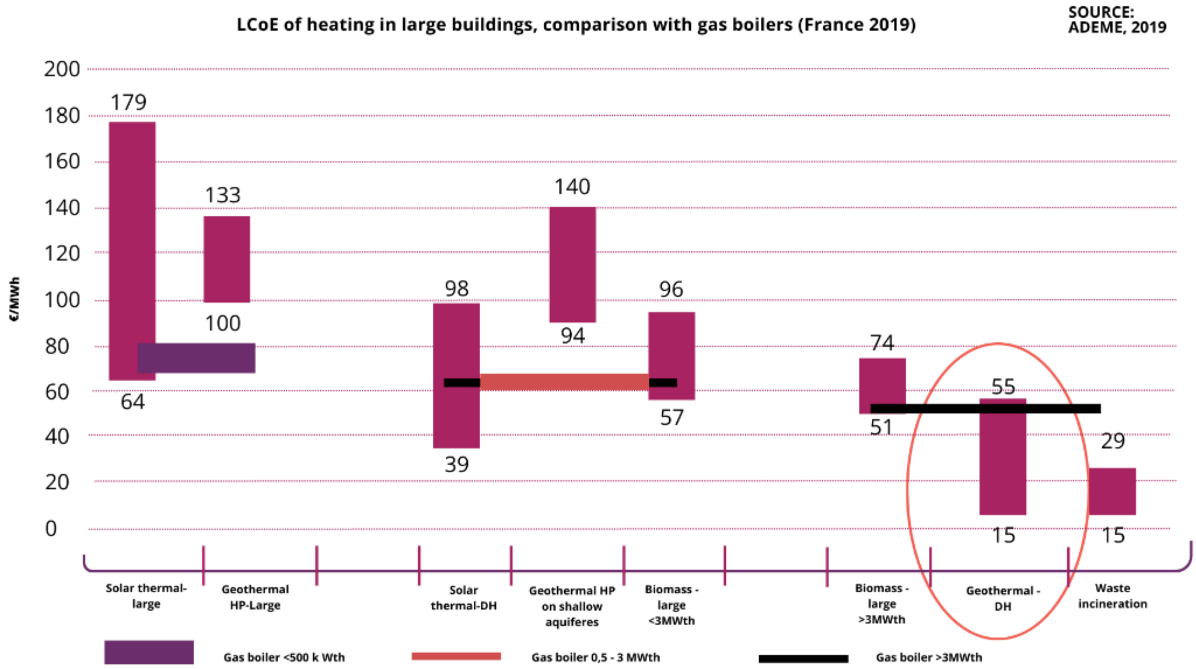
O&M costs in geothermal plants are limited, as geothermal plants require little or no fuel. Commercial costs associated with developments also need to be included when costing a geothermal project. These include financing charges (including establishment costs and interest), interest during construction, corporate overhead, legal costs, and insurance. For geothermal, risk insurance is the main issue. It depends on the origin of the resources invested and the way they are secured, as well as the amount of initial capital investment.

Comparison of the heat generation costs of geothermal/fossil fuels

Deriving an average cost of generating heat from fossil fuels in Europe is not easy because of the high proportion of the operating costs. Approximately 60% of the heat generation costs derive from the operating costs and thus, the price of fossil fuels is the main parameter of heat generation costs. As the prices for fossil fuels are very different from country to country and the prices for fossil fuels are very volatile, a meaningful assessment of heat generation costs is not possible. For example, in Italy, the prices of light fuel are 120% higher than those in Luxembourg, which is due to the high taxes for light fuel in Italy. In the case of gas prices, the gap between the highest-priced country, i.e. Denmark, and the country with the lowest prices, i.e. Romania, is about 215%.

Due to the high differences in the costs for fossil fuels in each EU country, a comparison of the heat generation costs is nearly impossible. In that study, the correlation of heat generation costs with the increase in prices of fossil fuels is monitored and compared to geothermal energy. Operating costs for both geothermal and fossil-fuel heat-generating plants ultimately depend on the price of primary energy. However, the primary energy of geothermal plants is not entirely dependent on fossil fuels, while that of fossil-fuel plants is. Thus, in the case of ever-increasing fossil fuel prices, fossil fuel plants will see their operating costs rise much more rapidly than the costs of geothermal plants.

The heat generation costs of geothermal energy are low in absolute terms due to the assumption of a high rate of utilization of geothermal energy, e.g. up to 8500h per year. This cost advantage, in absolute terms, is not based solely on the technical suitability of geothermal energy, but also on its economic characteristics, that is, on its low variable costs and its high fixed costs. The cost advantage in absolute terms is additional to the



relative cost advantage of geothermal heat in case fossil fuel prices rise rapidly.

Figure 9: Heat generation costs of geothermal/fossil Fuels, highlight geoHC competitiveness.

Source: ADEME 2019

4. Blueprint business models

The traditional business model for delivering heating and cooling in the EU predominantly involves individual systems for residential buildings. These systems include fossil fuel boilers, bio-energy boilers, solar thermal panels, air heat pumps, electric heaters, and geothermal heat pumps. Currently, there are approximately 120 million of these devices in use across the EU, with 80% relying on fossil fuels.

In addition to individual systems, some buildings and industries are heated and cooled via district heating systems. The EU boasts around 20,000 operational district heating systems. The business models for individual applications and district networks differ significantly. Small-scale individual heating and cooling appliances for residential and some non-residential buildings involve the manufacturing, sale, operation, and eventual removal of equipment. HVAC (heating, ventilation, and air conditioning) companies typically follow this business model, with manufacturers selling heating and cooling equipment directly or through retailers. After installation, customers are responsible for the system's ongoing operation, maintenance, and repair, often handled by service companies.

However, this model does not apply to district heating systems, leading to the question: how can geothermal heating and cooling be effectively sold? Selling heat differs from selling electricity. When selling heat, it is essential to secure clients who will support the investment and operational costs of the grid infrastructure. In contrast, electricity producers sell power to the market and connect it to the grid, with the grid infrastructure costs shared among all consumers and significantly supported by public funds.

Investing in a 10 MWth capacity geoHC system requires an expenditure of 20 to 30 million euros for the plant and an additional 1 million euros per kilometre of surface heat grid infrastructure.

From the status report on business models, nine models have been classified and evaluated through a SWOT analysis:

1. A private-public partnership
2. A joint venture - private-public partnership
3. A local project company established with a partnership between the municipal entity and the geothermal developer
4. Private self-consumption model

5. Secondary private self-consumption model
6. Private collective contract model
7. A special decoupling model
8. A new type of decoupling: subsurface and surface developers
9. Energy Communities

In this report about proposing Blueprints for key business models, five schemes are developed:

1. Local public companies
2. Public-Private project company
3. Model for private self-consumption
4. The decoupled model
5. Energy Communities

4.1 Guide for creating blueprint business models for geoHC projects in Europe

Creating a Blueprint

1. Develop an inventory of the current business process

Identify current processes (client acquisition, project financing, infrastructure management, energy sales, regulatory compliance, customer support) and then evaluate their effectiveness. In this process, it is also important to identify key facilitators such as technology, partnerships, and market demand.

2. Establish the foundation of the business structure

Define the scope, including the process boundaries, roles and responsibilities, resource assessment, costs, context for change, business value, and stakeholder buy-in. Select the legal structure for the business model.

3. **Draw the blueprint**

Develop the future vision.

- Short-term vision: Establish short-term goals such as initial project financing, expected start of operation and budget.
- Long-term vision: Define long-term goals like network coverage of the city, increased market share, and advanced technological integration.

4. **Estimate time and cost**

Draw out the blueprint considering the process ownership, and the detailed cost analysis (initial investments and the operational costs).

5. **Verify the process blueprint**

Assess the technologies, works/furnitures/services needed, and estimate resource allocation and other details with first corrective meaures.

6. **Apply improvement techniques**

Get feedback on the blueprint, while ensuring a continuous feedback loop through stakeholder consultation and meetings. Additionally, simplify complex processes.

7. **Create internal controls and metrics**

Create an implementation plan for all project development and management phases, comprehensive of a progress tracking system, and success metrics.

8. **Start of the project: Do pre-feasibility and feasibility studies**

Prepare a pilot test with a pre-feasibility study and conduct a trial run to test processes with a full feasibility study. Guidelines for implementation. Adjust processes based on new elements.

9. Implement the change and project construction

Communicate new processes to all relevant parties and execute the full implementation of the new processes. Milestones must be specified in the implementation plan, divided into three groups: financial, time and technical milestones.

Set basic tasks and responsibilities of project development management: Planning, Organizing, Staffing, Controlling, Directing with instructing and guiding.

Start construction by drilling wells, wells engineering and surface installation inlcuding the heat grid.

10. Completion of the project and inauguration

Start operation of the heat plant. End exploration licensing period and start exploitation permit. Start selling heat and cold.

11. Drive continuous improvement

Once, the geoHC project is in operation, continuously monitor performance metrics, regularly identify and implement further improvements, and maintain an open feedback loop with all stakeholders.

The phases of a GeoDH project at a glance

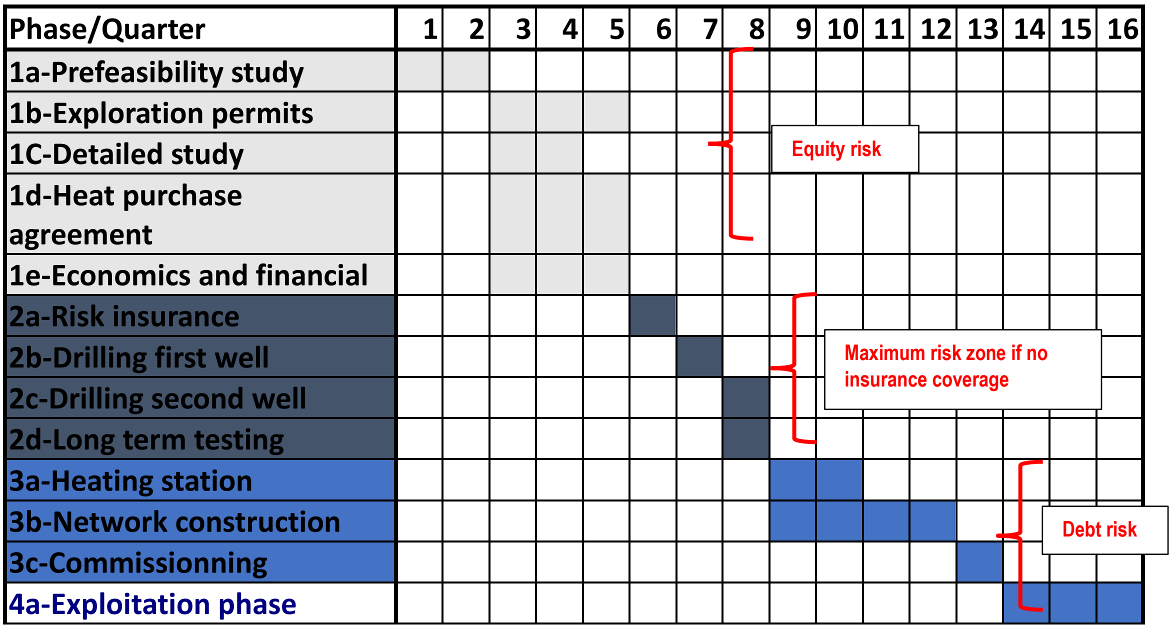


Figure 10: Phases of geothermal HC network project development. Adapted from Geoelec

This planning shows that the normal duration to build a new GeoHC network system is from 2 to 5 years, depending mainly on the permitting process and the drilling phases. The operation period of the plant can last for 45-50 years.

Implementing a geoHC network project:

I. Feasibility study

1 Determination of potential heat customers, and quantify heat consumed

a) Preliminary contracts for connecting to the HC network system

b) Analysis of potential connection to the system.

2 Determination of geothermal energy source

3 Identifying general requirements for project development and definitions of the most important concepts

4 Preparation of technical solutions fort he geoHC network system

5 Estimation of project management, operation and maintenance costs for a life cycle an upon contracting period

6 Proposal of the Business Model to adopt

7 Establishing the project financing and de-risking

II. Pre-construction phase

Key activities before the construction of geoHC network system

1 Tenders for contractor(s)

2 Preliminary design of geoHC system

3 Preparation of relevant acts, required according to the Business model and legal regulations:

   a) Tariff system, price calculation and price list

   b) Conditions for the connection to the system (technical and financial)

   c) System operating instructions

   d) Contracts with customers

   e) License to explore the resource and permit to drill wells

III. Building phase

Key activities of the implementation of geoHC system

1 Planning process

2 Final design for geoHC system

3 Construction phase

4 Inauguration, start operation, commissioning

IV. Operating phase

1 Permits for exploitation

2 Energy supply

3 Management, operation and maintenance in lifecycle or contract period.

Decision-making process with GO / NO-GO decisions for a geoHC network

The following steps of the project development must be engaged:

1) Pre-feasibility study

A. Pre-Sales: geoHC project pre-design, memorandum of understanding for heat purchase agreement with customers and project financing,

B. Preliminary survey about demand and supply,

C. Prefeasibility study (sub-surface and surface)

GO/NOGO

Expected potential of the geothermal resources is confirmed and confirmed customers are ready to buy heat at a fixed price for a long-term duration, exceeding the loan period.

2) Exploration and feasibility study

A. Detailed technical and economic studies, including exploration survey, licensing for the exploration phase and permiting for drilling first wells,

B. De-risking for the first wells drilling and confirmation of the resource,

C. Project economic review and financial strategy

GO/NOGO

Confirmation of geothermal resource potential (wells depth, temperature, flow rate, chemistry), insurance coverage secured, and financial details arranged.

3) Drilling of geothermal wells

A. Drilling of first well (preferably vertical)

GO/NOGO

The geoHC network project is ended if the results from drilling of the first well are below a ratio temperature/flow rate and are under the limits of the success curve built and annexed in the insurance contract.

B. Drilling of the second well and confirmation test

GO/NOGO

The project could be stopped if the capacity of the second well in a doublet system, or of the reinjection wells in case of multi-wells project, is much lower than expected or do not accept to reinject the totality of the flow rate.

4) District heating network construction

A. Geothermal wells construction and subsurface engineering: acquisition of equipments (submersible pump, surface injection pumps, electrical variators, chemical treatment if any), monitoring of the geothermal loop and testing
B. Construction of the surface system: wellheads, heat exchanger installation, and of the heating station (the closest possible from the drilling pad) or adaptation of the existing one
C. Construction of the piping network or adaptation of the existing H&C network
D. Obtention of the permit to exploit the geothermal resources for a long term period

5) Commissioning of the whole installation

A. Inauguration, starting operation and first year of operation with detailed measurements on the geothermal system (levels in the drilled wells, well-head pressure, physico-chemistry of the water, electrical consumption of the pumps etc.
B. First year of operation with detailed measurements on the DH network (temperature, flow rate, return temperature to the exchanger, follow up of backup and peak load systems, and calculations of energy balance with the coverage by geothermal
C. Long-term exploitation of the plant including O&M: well controls, repairs and heavy maintenance and equipment replacement.

4.2 Local public companies

The geoHC project, initiated by the municipality, is largely managed by the public entity. It involves some collaboration with private entities but within a structured legal framework to facilitate its development and its financing. Public procurements regulate the acquisition of furniture and services, and the requests of works with calls for tenders. This model follows a traditional business approach, especially in Germany and France, where city council oversees all project development phases, including project funding then exploration of the geothermal resources, drilling wells, subsurface engineering, surface installation of the heat plants and the heat grid, and operation & maintenance of the geoHC network.

Value proposition

- Reliable and sustainable heating and cooling solutions using locally available geothermal resources to heat and cool buildings and industry in the city.
- Control energy costs, fix the price and reduce carbon emissions for the local community.
- Support economic local development through local manufacturing and job creation with public procurement.

Structure and legal framework

- Governance: The municipality is in charge of managing the project development and its operation and maintenance. However, also private firms can be involved for specific services and works.
- Legal framework: Local public services companies structured under national and local regulations (e.g. the Stadtwerke model in Germany) with 100% public shareholding.

Customer segments

- Primary users, local H&C consumers means citizen of the city as residential communities, benefit directly from this model.
- Municipal facilities and public buildings can use geoHC for energy efficiency.
- Industrial entities in the district of the geoHC network, requiring heating and cooling for operations can benefit from geoHC.

Customer relationships

- Long-term service contracts with residential, commercial, and institutional customers.
- Responsive customer support for billing inquiries, service requests, and technical assistance.
- Community engagement and participation in local energy initiatives.

Revenue streams

- Heating and cooling sales: Revenue from selling heating and cooling services to residential, municipal, and industrial customers.
- Service contracts: Fees from operation and maintenance services provided by private firms.
- Public funding and grants: Initial and ongoing public funding support from regional, national or European programs and subsidies.
- Private investment: Equity and debt financing from private firms and investors.

Benefits

- Enhanced local support and investment.
- Control financial responsibility reduces individual burden.
- This model provides security for public services management stability.

Challenges

- Balancing interests of public and private entities.
- High upfront costs requiring effective financial planning.
- Ensuring transparent and accountable management, especially for fast procedures of public procurements.

Case study: Hauts-de-Seine (France)

In Hauts-de-Seine, France, three towns, Fontenay-aux-Roses, Sceaux, and Bourg-la-Reins, have come together to create a new local public company named "GéoSud92" to develop a geoHC network across these municipalities. GéoSud92 will start its drilling operations in 2025 and progress to network development by 2026. The initial delivery of heat is anticipated by 2027, with an estimated project cost of approximately EUR 63 million to serve 15,000 households. The geoHC network will interconnect social housing, residential buildings, and public and commercial structures. Consumers are expected to benefit from competitively priced heating, projected at around EUR 100 per MWh. This rate represents a significant cost savings of 10 to 15% compared to current prices for individual gas heating as of 2024. Each consumer will pay a subscription fee linked to the initial investment costs, ensuring stability over time. This fee is projected to constitute between 60% to 75% of the total utility bill, with additional expenses covering ongoing operational costs associated with the geoHC network[13].

4.2 Public-Private partnership

This business model involves the development of geoHC projects through a collaborative framework between private companies and public entities, such as municipalities. In this partnership, several models exist for the collaboration between private companies and public entities to lead the project development, governance and project financing.

Value proposition

- Sustainable and efficient heating and cooling solutions using local geothermal energy resources for buildings or industries in the city.
- Enhanced energy security and resilience for public and private buildings, agriculture and industry.
- Economic development opportunities and job creation in the local community.

Structure and legal framework

- Governance: The governance structure typically includes joint ownership between local governments and private energy companies (project developers, utilities, ESCOs, etc.).
- Ownership: Ownership shares can vary (minority participation by the public, 50%/50% or a majority of shares by the public entities) and supply contracts usually span over 20 years, after which ownership might transfer to the municipality or another entity.

Business model variants

- Public initiative for a Public-Private Partnership (PPP) with Majority Public Ownership (>51%): The public entity holds a majority share, maintaining significant control.

[13] Le Moniteur (2024) *Hauts-de-Seine : création de GéoSud 92*, Hauts-de-Seine : création de GéoSud 92 (lemoniteur.fr).

- Public initiative for a PPP with Minority Public Ownership (Public Minority Shareholders can vary): Private partners hold the majority shares, with the municipality retaining some influence.
- Private initiative for a PPP where a new private company is created, with a shareholding from the public entity (e.g. in France, this type of company is called "SAS EnR": Simplified Joint Stock Company for Renewable Energy). Public entities are involved in the governance and the project financing.
- Private initiative for a specific PPP where a public-private company with a majority shareholder is the public entity, acquires shareholding in a private company developing a geoHC network. The public-private company can act directly or through a subsidiary. It's mainly developed at a province or a regional level.

Customer segments

- Municipalities and local governments are key stakeholders in the governance and financing of the project. Municipalities benefit from sustainable energy solutions that reduce carbon emissions and provide stable heating and cooling for public infrastructure,
- Industries that require heating and cooling for their processes, such as manufacturing plants, can benefit from a stable and potentially lower-cost energy source,
- Private developers and operators manage the development and the operational aspects of the geoHC network, ensuring efficiency and reliability, and may also be end-users of the energy services.

Customer relationships

- Long-term contractual agreements with public and private sector clients.
- Stakeholder engagement and community involvement throughout the project lifecycle.

Revenues streams

- Revenue from energy sales and service contracts with public and private sector clients.
- Government subsidies, grants, and incentives for renewable energy projects.
- Potential revenue from surplus energy sold to the grid or neighbouring communities.

- Financing arrangements and investment opportunities for private sector partners.
- Energy performance contracts: Savings from improved energy efficiency shared between the project and end-users,
- Carbon credits and RECs: Revenue from selling carbon credits and renewable energy certificates.

Benefits

- This model simplifies public tendering for works, furniture and services, reducing development time to approximately 2 to 3 years
- Municipalities benefit from the specialised expertise of private companies and ESCOs, and by the investment brought by the project operator.
- This model provides a secure foundation for public-private cooperation, enhancing project stability and transparency.
- Leveraging economies of scale and specialized expertise from private firms.

Challenges

- Balancing profitability for private entities with public service requirements and community interests can be complex and sometimes lead to conflicts or delays.
- Ensuring these aspects throughout the project lifecycle is critical due to the involvement of public funds and infrastructure.
- Ensuring transparent and accountable management, especially with minority public ownership.
- For the public entity in a minority position, one drawback is its lack of influence in choosing the operator and a second one is the need to be involved in the project management which can require technical competencies.
- Public actors must have the financial capacity to invest in the project

Case study: Vélizy-Villacoublay

In 2019, the municipality of Vélizy-Villacoublay partnered with ENGIE Solutions to create Véligéo, a S.A.S ENR (Simplified Joint Stock Company for Renewable Energy). This company solidifies the local partnership between ENGIE Réseaux (holding an 80% share) and the Vélizy-Villacoublay Council (holding a 20% share).

For the next 28 years, this local company will provide heat to the Vélizy district network and local industrial firms, with over 50% of the energy generated from renewable sources.

The total investment in the project amounts to 22 million euros, including over EUR 8 million in subsidies from ADEME and the Ile-de-France Region[14].

Case study: Orléans

The municipality of Orleans implemented the first Energy Performance Contract with Deferred Payment (MGPE-PD) for a geoHC project for the energy renovation of two schools. During this six-month project, a dry geothermal system will be installed that will use heat pumps for its functioning. The contractor will also handle the system's maintenance and management for the remaining 9.5 years of the contract. This project aims for a 75% reduction in energy consumption and a 93% decrease in CO_2 emissions over 10 years. [15].

Figure 11: Public service delegation contract. Adapted from AFPG

[14] Engie (2019) *Geothermal energy: Vélizy-Villacoublay and ENGIE Solutions* commit to transitioning the town's heating network to zero-carbon energy*, PR-Geothermal energy-Vélizy-Villacoublay .pdf (engie-solutions.com).

[15] dayFREUR (2024) We are testing the deferred payment energy performance market", Serge Grouard, Mayor of Orléans, "We are testing the deferred payment energy performance market", Serge Grouard, Mayor of Orléans (dayfr.com).

4.3 Model for private self-consumption

This business model focuses on joint ventures for geoHC projects, where industrial partners independently develop and manage the projects to meet their own heating needs. The model showcases a collaborative approach, with potential public funding.

Value proposition

- Energy independence with reliable and sustainable heating and cooling solutions.
- Long-term cost savings on energy bills compared to traditional heating and cooling methods.
- Full project management, internalising all activities for the project development and operation.

Structure and legal framework

- Private self-consumption model with an industrial company developing its geoHC project for its industrial heat process with self-consumption. It becomes a geothermal developer undertaking the entire project in-house. It contracts with private purchase works, furnitures and services.
- Collective private self-consumption model for a multi-end-users contracting a geothermal developer to supply geoHC to their multiple industrial heat process. A private contract is established between the heat supplier and the end users.
- Collective private contract model. It is similar to the above but usually comprises a model where the geothermal heat is supplied for a handful of corporate buildings or even blocks of buildings. It includes two parties contracting privately: a private project developer to supply geoHC and a collective party to buy and consume the HC.
- ESCO or energy service provider as a natural or legal person providing energy services with geoHC aimed at improving energy efficiency in installations or premises of end customers. In this case, the EPC or energy performance contract is then a contractual agreement between the beneficiary and the supplier of the geothermal h&c supply.
- A joint venture with eventually a private-public partnership: supply of heat to an industrial partner within a joint venture. Public entities can contribute to project funding.

Business model variants

- Self-consumption when a direct link is established between the supplier and the end user. The end user is involved in project management.
- Collective with multi end-users of the geothermal h&c supply.

Customer Segments

- Companies and industrial factories that seek sustainable and cost-effective heating solutions can directly benefit from geoHC supply.
- ESCOs to propose energy and carbon performance contract.
- National and local public agencies interested in promoting renewable energy projects within a joint venture.
- Greenhouse owners and agricultural businesses that require reliable heating and cooling solutions.

Revenue streams

- Costs savings from self-consumption, reducing purchases
- Revenue from sale of geothermal heat.
- Service fees for system maintenance and ongoing support.
- Optional financing services for customers investing in geothermal systems.
- Potential revenue from energy surplus sold back to the grid.
- Service fees or subscription-based revenue from property owners or ESCOs.

Customer relationships

- Customized system design and installation tailored to specific property requirements.
- After-sales support for maintenance, troubleshooting, and system upgrades.
- Long-term service agreements with property owners or ESCOs.

Benefits

- Reduced dependency on external energy sources,
- Enhanced control over energy costs and supply stability,
- Potential for significant long-term cost savings,
- Customizable energy solutions tailored to specific industrial processes.
- In a Joint venture, the risk is shared between public and private entities, the user is associated with the producer, and the public body plays the role of supporting the learning curve.

Challenges

- The financial burden may be substantial for individual industrial partners or small to medium-sized enterprises (SMEs), posing a barrier to entry.
- The model heavily relies on the continuous operation and financial stability of industrial partners.
- Managing the entire geoHC system internally, including contracting out services and maintaining operational control, adds layers of complexity that require specialized knowledge and resources.

Case study: Janssen Pharmaceutical in Belgium

An exemplary case of a self-consumption business model can be observed with Janssen Pharmaceutical in Belgium. At their site in Beerse, Janssen Pharmaceutical pumps geothermal brine at 85°C from a groundwater layer 2.4 km deep. The heat is extracted via a heat exchanger and distributed across the Janssen site through a 3.5 km long heat grid. This allows Janssen to provide sufficient and appropriate heating to its buildings and production processes. After the heat is utilized, the cooled water is returned to the same groundwater layer, where it is naturally reheated [16].

4.4 The decoupled model

The decoupled business model for geoHC network system implies to divide the project in two phases. The project development is divided between assessing and accessing the geothermal resource and generating heat and cold on one side, and developing the grid infrastructure and selling the heating and cooling to end users on the other side. The first phase deals with the underground and the second phase with the surface systems, each one requiring a specific expertise.
Private companies and individual investors spearhead the project for the subsurface, with minimal public sector financial involvement. The grid infrastructure is managed by a public or private body, in charge also of selling the heat and cold to clients.

Value proposition

- Access to sustainable and efficient heating and cooling solutions with division of upfront investment in subsurface development and network infrastructure.
- Higher expertise with reduced operational risks.

[16] Janssen Geothermie: ecologische innovatie, Diepe geothermie bij Janssen: we gebruiken aardwarmte als primaire warmtebron | Janssen België.

- Long term benefits through contracting at more than 20 years.

Structure and legal framework

- Contract with the geothermal plant owner sells the geothermal brine to heat networks of several cities.
- Heat purchase agreement between the geothermal heat supplier and the grid operator also in charge of selling the heat and cold.

Business model variants

- The subsurface developer will always be a private entity, but the surface developer can be a private or a public operator.
- The end users can be diverse: buildings or industry.
- To decrease the risk on the underground, the developer can opt for multi wells instead of a doublet for the geoHC system but it can also adopt a projects portfolio approach developing a series of projects.

Customer segments

- Companies and investors looking for profitable, sustainable energy projects,
- Large industrial clients seeking reliable and cost-effective heating solutions,
- Associations of landowners interested in geothermal heating for residential areas,
- Public entities involved in the regulatory and permitting processes.

Customer relationships

- Long-term heat purchase agreements,
- Regular communication on energy savings, system performance, and maintenance.
- Customer support for technical issues and service requests.
- Continuous engagement to promote energy efficiency and sustainability practices.

Revenue streams

- Service fees or subscription-based revenue from end users.
- Revenue from energy sales based on consumption or heat/cooling units provided.
- Fees for system installation, connection, and maintenance.

- Government subsidies and incentives for renewable energy projects.

Benefits

- Reduced dependency on public funds, leading to faster project timelines.
- Enhanced control over project management and decision-making.
- Innovative approaches and technologies driven by private investment.
- Collaborative governance that addresses local interests and fosters community support.

Challenges

- high initial capital investment required from private actors can be a significant barrier, particularly for SMEs.
- Dependency on the continued operation and financial stability of the private stakeholders.

Case study: Cornia power plant in Tuscany

A notable example of a decoupled business model in the geothermal sector can be found in Italy, where ENEL Green Power operates its geothermal plants primarily to generate electricity (geothermal brine is here used at temperatures exceeding 200°C). The brine is then employed in a cascade mode to local municipalities generating and distributing heat to their local heat networks [17].

Case study: Aarhus geoHC network project in Denmark

Another example of a decoupled model is given by the project under development by Innargi. Through 19 wells, the project will supply heat to the district heating managed by the utility of Aarhus, which has entered a 30-year agreement. Innargi is financing the upfront investment associated with the sub-surface: exploration and construction phase, and therefore excluding the Aarhus DH company to not being exposed to any risk of the underground [18].

[17] Think Geoenergy (2016) Enel inaugurates combined biomass and geothermal plant in Italy, Enel inaugurates combined biomass and geothermal plant in Italy | ThinkGeoEnergy - Geothermal Energy News.
[18] Innargi, Project in Aarhus, Project Aarhus, Denmark - Innargi.

4.5 Energy Communities

Energy communities enable local communities from surrounding cities, consisting of building owners and individual consumers, to collaborate and invest in shared energy projects. The initiatives can be driven by private contracts, SMEs, public entities, or a combination, promoting community engagement and investment.

Value proposition

- Sustainable and reliable heating and cooling solutions powered by geothermal energy.
- Lower energy costs and reduced carbon footprint for community members.
- Community resilience and independence from fossil fuels.

Structure and legal framework

- They can take different form of legal entity, including an association, a cooperative, a partnership, a non-profit organisation or a limited liability company.
- It can involve private companies, public entities or a public private partnership

Business model variants

- Self-consumption may happen in the case of 5th generation geoHC networks, with reduced investment costs especially in drilling wells at shallow depth.
- It can consist of a heat purchase contract by the Energy communities to the geoHC network.
- Association of landowners, promoting collaborative governance and efficient operation.

Customer segments

- Residential building owners interested in sustainable and cost-efficient heating and cooling solutions,
- Real estate businesses seeking to reduce energy costs and carbon footprint,
- Local citizen groups and cooperatives focused on renewable energy projects,
- Municipalities and local governments aiming to support community-driven energy initiatives.

Customer relationships

- Long-term contracts for energy supply and maintenance.

- Community engagement and education on geothermal energy benefits.
- Responsive customer support and service for network maintenance and troubleshooting.
- Regular communication on energy savings and environmental impact.

Revenue streams

- Subscription-based revenue from community members for heating and cooling services.
- Installation fees and connection charges for new customers.
- Government subsidies and incentives for renewable energy projects.
- Potential revenue from surplus energy sales back to the grid (if applicable).

Benefits

- Enhanced community involvement and ownership.
- Shared responsibility.
- Leveraging economies of scale to achieve cost savings and efficiencies.

Challenges

- The complexity of coordinating multiple stakeholders with diverse interests and priorities.
- Ensuring equitable decision-making and benefit distribution among community members.
- Sustained community engagement and participation.

Case study: geothermal 5th generation of district heating and cooling in Denmark

The lighthouse project Vridsløsemagle (Denmark): local district heating company (Høje Taastrup Fjernvarme) converted a small village with individual oil boilers to district heating with geothermal heat pumps connected to a thermostat with a centralised borefield with 23 shallow geothermal probes and a pumping station.

Case study: Bavaria

Four municipalities in Bavaria, Germany are collaborating to establish a new geothermal heating company Geo Energie München Ost (GEMO), to develop an inter-communal geothermal heating project. GEMO will construct and operate a geothermal district heating system spanning the four communities. The company's startup capital is EUR 500,000, with contributions of 45% from Vaterstetten, 25% from Grasbrunn, 20% from

Haar, and 10% from Zorneding. The total financial requirement for the project is EUR 50 million, divided in the same proportions [19].

5. Recommendations for policymakers, investors, and project developers

5.1 Recommendations for Policymakers

With the increasing global need for sustainable energy solutions, the geoHC networks are a resource that can be used to significantly cut the emissions of greenhouse gases and improve energy efficiency. However, to realise the full potential of geoHC networks, policymakers must implement strategic measures that support the development and sustainability of these systems. The following policy recommendations are intended to create a solid basis for developing and sustaining business models which are suitable for geoHC networks.

Risk mitigation schemes

One of the primary challenges facing geothermal projects is the high financial risk associated with their development. To address this, policymakers should establish financial derisking schemes designed to mitigate these risks. Such schemes could include:

- Loan guarantees: providing guarantees to reduce the risk for financial institutions lending to geothermal projects.
- Insurance mechanisms: developing insurance products that cover various project phases, from exploration to operation, to protect against financial loss.
- Risk-sharing facilities: creating public-private partnerships where the financial risk is shared between the government and private investors.

[19] Think Geoenergy (2023) *Four communities in Bavaria, Germany establish new geothermal heating company*, https://www.thinkgeoenergy.com/four-communities-in-bavaria-germany-establish-new-geothermal-heating-company/.

Support schemes

The implementation of tailored support schemes is crucial for promoting the adoption and integration of geothermal technologies. These schemes should consider the market maturity and technology readiness of geothermal projects and include the following measures:

- Subsidies and grants: offering financial incentives to reduce the initial capital expenditure required for geothermal installations.
- Tax incentives: Providing tax credits or deductions for investments in geothermal technologies.
- Feed-in tariffs and premiums: establishing guaranteed pricing structures for geothermal energy to ensure a stable revenue stream for project developers.

Such support mechanisms can lower costs, facilitate technology adoption, and promote the consolidation and growth of the renewable energy industry, particularly in the geothermal sector.

Local authority urban planning

Local authorities play a crucial role in the deployment of renewable energy solutions. Policymakers should encourage these authorities to integrate geothermal energy into their urban planning and sustainable energy action plans by:

- Designating specific zones for geothermal development to streamline the permitting process and reduce bureaucratic hurdles.
- Ensuring that new urban developments include infrastructure that supports geoHC networks, such as district heating and cooling systems.
- Educating the community about the benefits of geothermal energy to increase public support and facilitate smoother project implementation.

Translation of EU targets into national and local measures

To ensure cohesive and effective implementation of renewable energy policies, it is essential to align national and local measures with EU targets for renewable energy and energy efficiency. Policymakers should focus on the following actions:

- Integrating detailed measures for geothermal energy development within National Energy and Climate Plans (NECPs) to provide a clear and actionable roadmap.

- Ensuring that national regulations support the EU's renewable energy goals by facilitating investment and removing barriers to geothermal project development.
- Establishing a strong mechanism for tracking progress towards EU targets and adjusting policies as needed to stay on course.

The revised EU legislation, driven by the Green Deal Initiative, sets a strategy for a substantial increase in efficiency and renewable energy, which presents opportunities for geoHC networks, even though geothermal energy is not always explicitly mentioned.

EU legal framework	Description of the impact on renewable energy sources
Environmental Impact Assessment (EIA) Directive (2011/92/EU)	This directive requires an assessment of certain public and private projects' effects on the environment. Geothermal projects must ensure they comply with environmental standards.
Water Framework Directive (2000/60/EC)	This directive aims to protect and improve the quality of water resources across Europe. It is important for geoHC networks as it regulates the use of water in geothermal processes.
F-Gas Regulation (EU) No 517/2014	This regulation addresses greenhouse gases, which are sometimes used in heat pumps for geothermal heating systems. It is currently under revision.
Energy Taxation Directive (2003/96/EC)	This directive provides a framework for the taxation of energy products and electricity. It has been revised to reflect the EU's climate and energy goals.
Connecting Europe Facility (CEF) Regulation (EU) 2021/1153	This regulation supports the development of trans-European energy infrastructure, which could include geoHC networks.
Guidelines for Trans-European Energy Infrastructure Regulation (EU) 2022/869	This regulation sets guidelines for trans-European energy infrastructure, which could impact the development of geoHC networks.
Renewable Energy Directive (RED) and Energy Efficiency Directive (EED)	These directives set targets for renewable energy and energy efficiency.

Table 2: EU Directives and Regulations with an impact on renewable energy sources

As the EU moves forward with legislation aimed at enhancing renewable energy deployment, project developers in geoHC networks have a unique opportunity to capitalize on these regulatory advancements. To navigate this evolving landscape and ensure the successful implementation of geoHC projects, developers should consider the following strategic recommendations.

5.2 Recommendations for Investors

Investors looking to engage with geoHC networks must navigate a complex landscape that encompasses regulatory, financial, and technical considerations.

Energy communities have demonstrated a certain potential in fostering the uptake of geoDHC networks with shallow geothermal. Drawing from the Danish experience, where DHC networks are owned by consumers, investors should consider encouraging the development of geoDHC projects that are owned and managed by local communities. This can push for local engagement and acceptance, and ensure that benefits are directly felt by consumers.

Investors should explore various financial incentives that can enhance the viability of geoHC projects, such as green loans and environmental benefits available. Green loan schemes with subsidised interest rates that support low-carbon heating and cooling projects can reduce the cost of capital and improve project feasibility.

The Recovery and Resilience Plans (RRPs) offer substantial funding for renewable energy projects, including geoDHC networks. Investors should then assess whether initiatives financed by RRPs have led to lasting changes in market structure and readiness, or if they have only triggered short-term increases in renewable energy projects. Also, it is important to align investments with long-term goals supported by RRPs, ensuring that projects contribute to enduring market transformation rather than temporary boosts. Aligning with RRPs can indeed provide a strategic advantage and access to substantial funding, fostering sustainable growth in the geoHC sector.

Finally, the investors ought to leverage both technical assistance and capacity-building interventions and should make use of standardised templates and expert opinions on project funding applications in addition to enhancing cooperation between national energy agencies, geological surveys and financial agencies to increase the chances of success of the projects while minimizing the risks involved.

5.3 Recommendations for Project Developers

Capitalizing on accelerated permitting rules

The recent push at the EU level for streamlining the permitting process should be leveraged by project developers to shorten project development cycles and reduce associated costs.

Engaging with policymakers and local authorities

Effective collaboration with policymakers and local authorities can help address regulatory barriers and simplify administrative procedures. It is then necessary to advocate with the relevant authorities to minimise the cost and time implications of regulatory burdens and also to encourage the establishment of a clear and equitable regime that is conducive to geothermal undertakings. Enhanced understanding between the government and the developers of the energy resource can lead to the easing of the policies that otherwise are burdensome to the developers leading to a more favorable climate for geoHC endeavors. Project developers should also align their projects with urban planning by ensuring that their projects are integrated into local urban planning and sustainable energy action plans.

Navigating risk mitigation schemes and exploring public-private partnerships (PPPs)

Navigating financial and legislative frameworks is vital for project viability. Developers should understand and utilise available risk mitigation schemes to protect against financial uncertainties, as well as navigate taxation frameworks.

PPPs offer a sustainable model for financing and developing geoHC projects. Working with government entities to create mutually beneficial partnerships that support project goals can be indeed extremely beneficial as PPP can provide the necessary financial backing and resources to ensure the successful deployment of geoHC networks within district heating systems.

Embracing digitalisation

Digital transformation is crucial for streamlining operations and improving stakeholder engagement. Relevant data, such as renewable energy zones, should be available in electronic formats to facilitate the licensing and permitting processes, while project development should be pursued through digital platforms enhancing the coordination and efficiency of the whole process. In this way, developers would have the possibility to significantly reduce bureaucratic delays and enhance transparency, hence accelerating project timelines and fostering better stakeholder relationships.

Investing in communication and educational initiatives

Public perception and awareness are also critical to the success of geothermal projects. Project developers should not underestimate this aspect, and therefore should be prepared to launch communication and educational campaigns to inform policymakers, citizens, and stakeholders about the benefits and workings of geothermal energy. It is also important to proactively counter misinformation to build public trust and support.

6. Country/region-specific recommendations

The "Political Readiness Level Evaluation Scheme" is designed to evaluate the readiness of national legislation for the implementation of geoHC networks. It involves assessing various national legal frameworks against eleven key requirements, evaluating each country and then leading to a classification into three categories: red, yellow, and green labels, indicating different levels of readiness.

Country	Policy Readiness Level	Recommendations for policy	Recommendations for regulations	Recommendations for finance
Austria	Yellow	Develop heat plans and a supportive framework. Improve connection support	Simplify administrative procedures and set reduced tax rates for renewable energy	Enhance financial support schemes and create subsidies for clean heating technologies
Denmark	Green	Further, improve administrative procedures and set specific geoDH targets	Ease administrative procedures and implement legislation on energy price regulation	Increase financial support schemes and subsidies for geoHC projects
France	Green	Enhance financial support schemes and reduce tax rates for renewable heating.	Reduce the duration of licensing and commissioning procedures, and set up de-risking instruments.	Provide additional subsidies and financial support for geoDH projects.
Germany	Yellow	Streamline licensing and commissioning procedures. Support connection to HC networks	Enhance licensing procedures and implement specific targets for geoDH	Develop comprehensive financial support schemes and subsidies for geoHC networks
Italy	Red	Create de-risking instruments for geothermal projects and set clear geoDH targets.	Establish clear frameworks for licensing and commissioning. Reduce administrative burdens	Create substantial financial support schemes and risk insurance for geothermal projects.
Poland	Yellow	Establish specific geoDH targets and improve administrative procedures	Implement supportive frameworks for HC networks and reduce tax rates for clean heating	Implement financial support schemes for geothermal projects
UK	Red	Develop PPP frameworks and establish supportive financial schemes	Create comprehensive regulations for geothermal projects and ensure energy price regulation	Establish strong financial support mechanisms and provide risk insurance for geoHC projects

Table 3: Recommendations for countries based on Policy Readiness level

7. Recommendations for EU-27 country

Strengths	Weaknesses
Policy support	High initial costs
Technology expertise	Geological constraints
Environmental benefits	Permitting and regulation
Market demand	Competition with other renewables
Opportunities	**Threats**
EU funding	Economic viability
Technological advancements	Public perception
Urban renewal projects	Policy changes
Energy security	Technological risks

Table 4: SWOT analysis

Alignment with national or regional energy policies

The development and implementation of geoHC networks present unique opportunities and challenges across different countries and regions in Europe. To foster sustainable business models, it is essential to consider the specific contexts, resources, and regulatory frameworks of each area.

Robust policy and financial frameworks

Regions should implement robust policy and financial frameworks by enforcing laws that mandate the integration of geothermal energy into DHC networks, and by providing financial incentives for renovating existing buildings to integrate geoHC systems.

The German Renewable Energy Sources Act (EEG) provides a stable legal framework and financial incentives for geothermal projects, encouraging significant investment in the sector. [20].

Technical assistance and capacity building

Regions should focus on offering technical guidance and support to project developers, as well as developing training programs to equip the workforce with the necessary skills for geoHC projects.

[20] BMWK (2022), Eckpunkte für eine Erdwärmekampagne. Geothermie für die Wärmewende (eckpunkte-geothermie.pdf (bmwk.de)).

The French Environment and Energy Management Agency (ADEME) provides extensive support and training for geothermal energy development, contributing to a skilled workforce in the sector. [21].

Information Accessibility

It is highly recommended to centralise the information on funding programs, by creating national portals that provide comprehensive overviews of all active incentives and funding programs.

Austria's Klima- und Energiefonds provides a centralised platform that lists various incentives and funding opportunities for renewable energy projects, including geothermal energy. This transparency helps project developers and investors navigate available support mechanisms effectively. [22].

Energy communities

Regions should encourage the development of energy communities by providing support for energy communities, specifically through the establishment of an efficient regulatory and financial support mechanism.

Denmark's model of consumer-owned energy communities has significantly contributed to the adoption of DHC networks. These communities are empowered through supportive policies that facilitate local ownership and management of energy resources, leading to high acceptance and integration of renewable energy systems.

Market maturity

Different best practices across Europe have demonstrated the importance of leveraging established markets to attract investments. As a result, regions with mature geoHC markets should focus on attracting private investors by utilising their established market position to draw in private investments and foster further growth.

Italy's well-established geothermal sector, particularly in Tuscany, has leveraged its market maturity to attract private investors. The region's long history of geothermal energy use should provide a stable investment environment, encouraging further

[21] Ministère de la transition énergétique (2023), Géothermie : un plan d'action pour accélérer son développement (Annonce officielle du gouvernement : le plan d'action finalisé en faveur de la géothermie est lancé ! - AFPG).

[22] Bundesministerium für Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie (BMK) (2022), FTI-Roadmap Geothermie (BMK_Geothermie_Roadmap.pdf (nachhaltigwirtschaften.at)).

development and innovation. However, excessive bureaucracy and the complexity of the regulatory environment have seriously hampered the potential of attracting investments in the country.[23].

Financial incentives

Promoting financial incentives has been a key element to drive geothermal project development in some European countries. Raising awareness and explaining the benefits of geoHC represent an additional but very relevant complementary initiative to undertake. Regions should not forget to enhance the visibility of financing schemes, which need to be transparent and easily accessible to project developers and investors.

In the Netherlands, various financial incentives are implemented, including grants and subsidies, to promote geothermal energy projects. The SDE++ (Stimulation of Sustainable Energy Production and Climate Transition) scheme is a key program that supports geothermal energy projects, providing substantial financial backing and attracting private investments [24].

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[23] EGEC (2023), Market Report 2022.

[24] Dutch Ministry of Economic Affairs and Climate Policy (2023) SDE ++ 2023 Stimulation of Sustainable Energy Production and Climate Transition (BrochureSDE2023English.pdf (rvo.nl)).

8 Conclusions

The investigation into the various business models for geoHC networks offers significant insights into their potential for implementation and success across Europe. This analysis shows that there are many ways one can apply and exploit geothermal energy and each has its advantages and disadvantages. Different geoHC network business models have been explored in this report, stemming from the more traditional ones as local public companies and public-private partnerships to the innovative ones that have emerged recently as the private self-consumption model, the decoupled business model, and the energy community model. Traditionally, local public companies play a critical role in developing and managing geoHC networks, due to their ability to tap into public funds and use local skills in the implementation of geothermal projects as well as taking into account community needs. Public-private project companies represent a collaborative approach where public entities partner with private companies to develop geothermal projects. In this model, the public oversight together with the implementation in the hands of the private company facilitates the deployment of large-scale geoHC networks.

The business model based on private self-consumption involves industrial partners developing geoHC projects solely for their own energy needs. This model, as demonstrated by the Janssen Pharmaceutical case, underscores the potential for businesses to achieve energy independence and sustainability through in-house geothermal solutions. If its primary advantage of providing a stable and predictable energy supply to the needs of the company makes this model a really attractive solution, the high initial investment and technical expertise required to develop and maintain such systems may discourage its adoption. Therefore, comprehensive feasibility studies and strategic planning are crucial for industries considering this approach.

The decoupled business model, illustrated by ENEL Green Power in Italy, is an example of efficient resource utilisation and collaborative community engagement. The approach behind this model allows indeed specialised entities to focus on their strengths, leading to optimised performance and efficiency. However, successful implementation requires robust coordination between different stakeholders and a supportive regulatory environment to manage the complexities of such interdependent systems.

Finally, energy communities represent a forward-thinking approach to local energy management. These communities enable collective and citizen-driven actions, significantly contributing to the public acceptance of renewable energy projects and facilitating private investments in local energy assets. By empowering citizens to drive their energy supply locally, energy communities enhance energy efficiency, reduce costs, and ensure a secure energy supply. The model's flexibility allows it to take various legal forms, such as cooperatives, partnerships, or non-profit organisations, making it adaptable to different local contexts. Energy communities also benefit from EU energy legislation, which provides a regulatory framework supporting their development.

Despite the promising potential of geoHC networks, several challenges need to be addressed: the technical feasibility of geothermal projects, particularly in regions with less favourable geological conditions; the economic viability of projects; and the existing regulatory barriers. The business models for geoHC presented in this report offer promising opportunities for the development of renewable energy in Europe. By addressing the technical, economic, and regulatory issues, and adopting encouraging policies and financial initiatives, geothermal energy can play an important role in successfully addressing the sustainability challenges in Europe.

ANNEXES

Annex I SWOT analysis

1. Local public companies business model in geoHC networks	
Strengths	**Weaknesses**
Public accountability Local public companies are accountable to the community, ensuring transparency and trust. **Stable funding** Access to municipal funding and public grants can provide financial stability and lower borrowing costs. **Community focus** Local governments tend to be trusted messengers and therefore better placed to gain public acceptance. Projects can be tailored to meet the specific needs of the local population, businesses, industry and farmers ensuring relevance and acceptance. **Integrated resource management** Public entities can manage local resources, aligning geothermal projects with other public services and infrastructure.	**Bureaucracy** Decision-making processes in public companies can be slow depending on the voting structure. **Limited risk appetite** Public entities may be more risk-averse, potentially limiting innovative approaches and rapid deployment. **Funding constraints** Dependence on public budgets can lead to funding limitations, especially in times of economic austerity. Some local governments are legally bound not to go into arrears which limits their ability to absorb geological risk for deep geothermal projects. **Operational inefficiencies** Public companies may face operational inefficiencies compared to private sector counterparts due to less competitive pressure.
Opportunities	**Threats**
Government support Increasing government focus on renewable energy could lead to more grants, subsidies or resource de-risking guarantees for geothermal projects. **Community engagement** High potential for community support and engagement, leading to successful project implementation and utilisation. **Regulatory advantages** Favourable regulations for public projects can provide an advantage in project approval and operational phases. **Sustainability goals** Alignment with local and national sustainability goals can enhance project funding and support.	**Political changes** Changes in political leadership or policies can impact funding and support for public projects. **Economic downturns** Economic challenges can lead to budget cuts, affecting the financial viability of projects. **Market competition** Competition from private sector companies with more agile and innovative approaches can pose a threat to public projects. **Price controls** In some countries, heating prices are controlled. This changes the profitability of projects.

2. Public-private partnership (PPP) business model in geoHC networks	
Strengths	**Weaknesses**
De-risking The PPP model spreads the financial and operational risks between the public and private sectors (e.g., municipalities in France cover initial project risks, reducing the burden on private developers). **Shared expertise and resources** Combining public sector oversight and private sector efficiency and innovation can lead to better project outcomes. The involvement of experienced private entities like ENGIE and Dalkia has been instrumental in the successful deployment of geothermal projects in France. **Increased investment potential** The joint investment from both the public and private sectors can lead to more substantial capital for large-scale projects. Public funding agencies like CDC and ADEME play a critical role in financing. **Operational efficiency** Private operators manage daily operations, leveraging their expertise to enhance efficiency, while public authorities can focus on regulatory and community aspects.	**Complex contractual agreements** Establishing PPPs requires detailed and often complex contractual agreements that can be time-consuming and costly to negotiate. **Dependency on public policies** The success of PPPs heavily depends on supportive public policies and legislative frameworks. Changes in policy or government priorities can indeed impact project continuity and stability. **Potential for conflict** Divergent objectives between public and private partners, such as profit motives versus public service obligations, can lead to conflicts and inefficiencies.
Opportunities	**Threats**
Expansion into new markets The liberalisation of energy markets and supportive EU policies create opportunities for expanding PPP-based geoHC projects into new regions and countries. **Multi-purpose utilisation** Opportunities for cogeneration (heat and power), trigeneration (minerals extraction), and underground thermal storage can enhance revenue streams and project viability.	**Regulatory and political risks** Changes in regulations, political instability, or shifts in government policies can pose significant risks to PPP projects. These changes can impact funding, project approvals, and operational guidelines. **Market and economic fluctuations** Economic downturns or fluctuations in energy prices can affect the financial viability of geoHC projects, impacting both public and private investment returns.

3. Decoupling business model in geoHC networks	
Strengths	**Weaknesses**
Risk mitigation The decoupling model separates the subsurface (geothermal resource development) from the surface (heat distribution), which allows for a clearer allocation of risks. Subsurface developers handle the exploration and production risks, while surface developers focus on distribution and customer management. **Expertise utilisation** By decoupling the subsurface and surface activities, companies can specialise in their areas of expertise. This specialisation can lead to more efficient and effective project execution. **Scalability** This model is adaptable to various project scales, from small local networks to large regional systems. It allows for incremental growth and scaling up as the market demand increases.	**Coordination challenges** The separation of responsibilities requires effective coordination between subsurface and surface developers. Misalignment of goals or communication breakdowns can lead to project delays or inefficiencies. **Regulatory complexity** Navigating different regulatory frameworks for subsurface and surface operations can be complex and may require significant legal and administrative efforts. **High initial costs** While risk is mitigated, the initial costs for exploration and infrastructure development remain high, necessitating substantial upfront investment and financial planning.
Opportunities	**Threats**
Market expansion As demand for sustainable heating solutions grows, the decoupling model can be replicated in new regions, offering opportunities for market expansion and new project developments. **Partnerships** This model opens up opportunities for various types of partnerships, including public-private collaborations, which can provide financial support and share the risk burden. **Technological advancements** Advancements in geothermal exploration and heat distribution technologies can further reduce costs and improve the efficiency of decoupled projects.	**Market competition** The growing interest in renewable energy solutions might increase competition from other renewable technologies, potentially affecting market share and profitability. **Policy and regulation changes** Changes in government policies, subsidies, or regulations related to geothermal energy could impact the feasibility and attractiveness of the decoupling model. **Economic factors** Economic downturns or fluctuations in energy prices can affect the financial stability and investment attractiveness of geothermal projects.

<table>
<tr><th colspan="2">4. Self-Consumption business model in geoHC networks</th></tr>
<tr><th>Strengths</th><th>Weaknesses</th></tr>
<tr><td>Autonomy and control

Industrial partners can develop and manage geoHC projects in-house, offering them full control over the energy source and usage.

Cost efficiency

This model reduces operational and maintenance costs compared to conventional heating sources.

Reliable energy supply

Provides a stable and secure local heat supply, crucial for industrial processes that require consistent energy.</td><td>High initial investment

Requires significant upfront capital for exploration, drilling, and installation, which can be a barrier for many organisations.

Technical complexity

Managing the entire project lifecycle from exploration to operation requires specialised expertise, which might not be readily available within the organisation.</td></tr>
<tr><th>Opportunities</th><th>Threats</th></tr>
<tr><td>Energy independence

Industrial and agricultural sectors have the potential to become self-sufficient in their energy needs, reducing reliance on external energy suppliers.

Government support

Potential for subsidies, grants, and incentives aimed at promoting renewable energy projects, which can help offset the initial investment costs.

Scalability

The model can be scaled to meet the needs of various industrial and agricultural applications, offering flexibility and adaptability.</td><td>Market competition

Competition from other renewable energy sources like solar and wind might affect the adoption rate of geothermal energy.</td></tr>
</table>

5. Energy communities business model in geoHC networks	
Strengths	**Weaknesses**
Increased public acceptance Energy communities contribute to higher public acceptance of renewable energy projects by involving citizens directly in energy production and management. **Attraction of private investments** The collective approach makes it easier to attract private investments in local energy assets. **Local empowerment** Citizens are empowered to control their energy supply locally, leading to better energy efficiency, lower bills, and enhanced energy security. **Variety of legal forms** Energy communities can take various forms (associations, cooperatives, partnerships, non-profits, LLCs), providing flexibility in organisation and operation.	**High capital investment** Large-scale geothermal projects require significant capital investments, typically around €1 million per MWth, which can be a barrier for community-based projects. **Risk during exploration and drilling** The exploration and drilling phases pose high risks, often deterring community involvement in geothermal projects.
Opportunities	**Threats**
Collective investment potential Communities can join forces to invest in common energy projects, thereby sharing the financial burden and risks associated with geothermal projects. **Market access** As a single entity, energy communities can access electricity and heat markets on a level playing field with larger energy market actors.	**Intensive capital requirements** The intensive capital investment required for large-scale geothermal projects may limit the participation of smaller communities or deter potential investors. **Regulatory and market changes** Changes in regulations or market conditions could impact the feasibility and profitability of energy communities, especially if they rely heavily on specific incentives or subsidies.

Annex II Risk Mitigation Schemes

Risk mitigation schemes are required to support the development of geothermal heating and cooling networks in Europe. De-risking projects lowers the cost of capital for project developers and provides more cost-effective renewable energy for consumers.

Risks to cover in geoHC projects

- **Exploration risk**: The uncertainty associated with locating sufficient geothermal resources. Geothermal energy projects face a resource risk during the project development phase: the possibility of not finding the economically viable resource expected (e.g., the reservoir temperature is too low or flow rates are unsuitable for commercial exploitation).
- **Technical risk**: Challenges related to drilling, well completion, and resource management. The impact of partial success may require additional investment such as exploration or development, and equipment like heat pumps.
- **Financial risk**: High upfront capital costs and uncertain returns. For geothermal, CAPEX is about 80-90% of total project cost. Up to half of a project's CAPEX needs to be invested before the level of risk of the project decreases significantly.
- **Operational risk**: Long-term performance and maintenance of geothermal systems.

Project developers, especially municipalities in case of a geothermal district heating system, need to cover these risks. Experiences in risk insurance schemes for de-risking geothermal have been successful, with huge leverage effects like in France: for every €1 paid by the State, €42 of investments were guaranteed. In a well-functioning market, these risks can be easily addressed through private insurance products. In less mature markets public and public/private risk instruments are required.

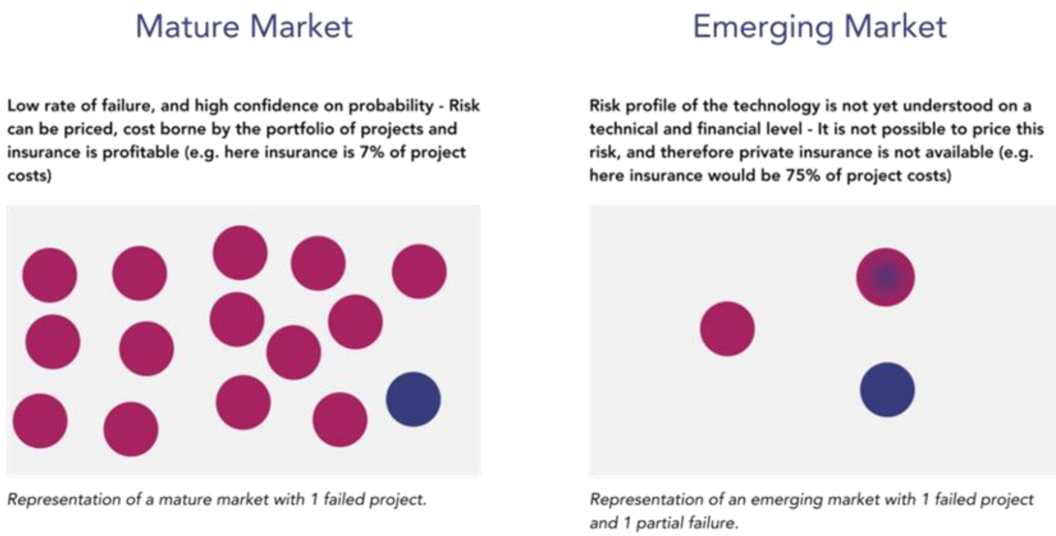

Figure 12: Representation of mature and emerging markets.

Source: EGEC

De-risking instruments can take many forms. This is dependent on the overall maturity of the market. They provide geothermal energy developers with a means to reduce and manage their exposure to project risk. It is very relevant for small developers and vital for cities developing heat & power projects.

Financial incentives and subsidies (e.g. government grants, loans, and tax incentives) are effective tools to reduce financial burden. Grant schemes are especially suitable for markets where there is little information about the geothermal resource and few projects for reference. In such instances, grant schemes are needed for the initial development of the market. Convertible loans or grants are also relevant at early market development, allowing investors to be shielded from the excessive amount of risk linked to the development of innovative technology while the resource is not yet well understood.

Public-private partnerships (PPPs) are a suitable solution to share risks and benefits. PPPs are collaborative agreements between public sector entities (such as government agencies or municipalities) and private sector companies. These partnerships leverage the strengths of both sectors to finance, build, and operate projects, sharing the risks and rewards.

Where there is a liquid geothermal market with many projects plentiful information about resources and understanding of the risk, public-private partnerships can establish insurance schemes. These schemes can be publicly funded initially with an important leverage effect on private financing. Private actors, providing traditional insurance projects, are likely to enter the market when it is mature.

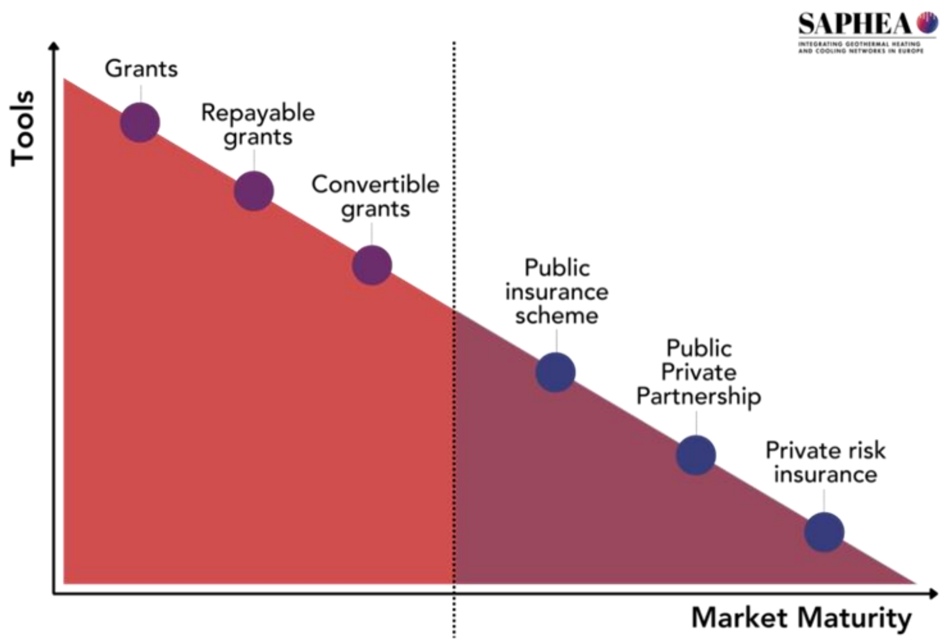

Figure 13: Matching risk mitigation schemes to market maturity.

Source: EGEC

Risk mitigation schemes can be set up at a **regional scale**, but it is more efficient to pool the risk of more projects on a **wide scale**. Establishing a financing of geothermal de-risking at the European Union level would allow to reduce the costs for policymakers and developers.

Key elements for an effective mitigation scheme

- Coverage of electricity, heat, and cogeneration plants;
- Coverage of both green and brown fields;
- Coverage ranging from 60% (up to 80-90% if possible)

- low premiums in the range of 3 to 7% are needed to encourage a great number of subscribers to mutualise the risk.

Market	Products	Reduces CAPEX costs	Business model compatibility	Examples from European countries
Early	Grants	Yes	High	Hungary and Wallonia grant schemes
	Repayable grants	Yes		
Transitional	Convertible grants	Yes		
Mature	Public-private partnerships (PPPs)	Yes	High	France's PPP projects in geothermal exploration
	Commercial products	No		

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„SAPHEA will tackle this challenge to promote more geothermal energy supply heating and cooling networks to become a key element of the green and sustainable transformation of the European energy sector.“

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