SAPHEA

INTEGRATING GEOTHERMAL HEATING AND COOLING NETWORKS IN EUROPE

Status report on business models relevant for geoHC networks

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Chapter 1. Introduction to geoHC business models

Over the past ten years, the number of geothermal district heating and cooling (geoHC) systems in operation in Europe has doubled from 200 to 400 systems (EGEC Market Report). Traditional and innovative geothermal business models (BM) have led to the operationalisation of these systems. The challenges of getting a secured demand for the heat supply, funding the heat grid infrastructures and de-risking geothermal projects, led geoHC project developers to invent new business models.

This SAPHEA report explores the traditional models used by project developers and operators and these new business models, that have supplanted traditional approaches in use for four decades. Key market drivers and funding policies, essential in shaping these new business paradigms, are also explored.

It is crucial to grasp the nuanced criteria SAPHEA has employed to delineate a geothermal business model. A business model, in its simplest form, serves as a theoretical framework for conducting business. However, there exists no universally accepted definition of a business model or its evolutionary trajectories. Yet, a consensus has emerged that such models are oriented around several core elements. These include the customer-focused components of value proposition, market segmentation, and relationship management, alongside the allocation of resources such as operational activities, assets, and strategic partnerships. Additionally, a model must address the financial dimensions of costs and revenue streams in the context of delivering value to the customer base.

Another layer of complexity lies in the fact that these models are neither static nor universal; they continually evolve and differ considerably across European countries. Typically, a geothermal district heating & cooling business model involves at least two stakeholders, often incorporating a public body, either national or local. Variability in these models arises from several key factors:

1. **Operation of the project**: relates to who controls and manages the geoHC system, reflecting the strengths and weaknesses of each business model;
2. **System of project implementation**: this could correspond to the financing mechanisms. Different business models will have different systems of project implementation, often shaped by their financial structure.
3. **Regulatory framework**: this aspect agrees with the point that the regulatory environment is crucial for the success or failure of a business model. Whether the heat market is liberalised can affect profitability and uptake.
4. **Availability of public funding**: this is directly related to subsidies as financing mechanisms.
5. **De-risking**: Aspects such as Insurances, guarantees or Heat Purchase Agreements (HPAs) and pricing contracts serve to minimise risks, possibly making some models more viable than others.

1) Content

This SAPHEA report first presents in Chapter 2 the traditional business models for geoHC networks to understand their advantages but also their limitations which brings developers and operators to develop new models. This chapter delineates traditional geothermal business models, thereby laying the foundation for a consideration of more advanced and innovative approaches in Chapter 3. During the detailed description of the GeoHC business model, there are described the core aspects of creating value for a GeoHC company, including business strategies, infrastructure, organizational structures, trading options, core processes and influencing regulations. Chapters 2 and 3 highlight key elements and real-world examples of each model, preparing for an analysis of their development and the scrutiny of causative drivers in Chapter 4. Subsequently, Chapter 5 links these business models to pertinent legislation, dissecting the influence at both European and Member State levels. Finally, before concluding, Chapter 6 spotlights innovations and exemplary practices observed in Denmark, France, Italy, and Germany.

2) Business model generation

The business models are generated based on an open creative approach to contribute to the aim of accommodating unique opportunities or advancing from unique resources and competencies, which are also defined as competitive advantages.

To promote the rationality of Geothermal District Heating systems and their economics, the business models define the structure of creating a business to sell the heat and the cold. In other words, the business rationality is described by the business models and therefore SAPHEA project defines a business model as being: “A framework for describing all factors influencing on creating value for a geoHC company, customers and environment”.

The business model development has been carried out based on Osterwalder & Pigneur’s (2010) business model canvas and the new developments on this canvas added environmental and social dimensions. The objective of this business model canvas is to create an overview of influencing factors from both the demand and the supply sides, which are necessary for a geoHC business model to succeed. The clarification is crucial because it creates a common framework for understanding and working with business models.

The business model canvas is illustrated on the next page in Figure 1: Business Model Canvas with economic layer (Osterwalder & Pigneur, 2010), adapted from GEODH project.

The original canvas consists of 9 building blocks that together complete the business model with a first layer focus on economic aspects.

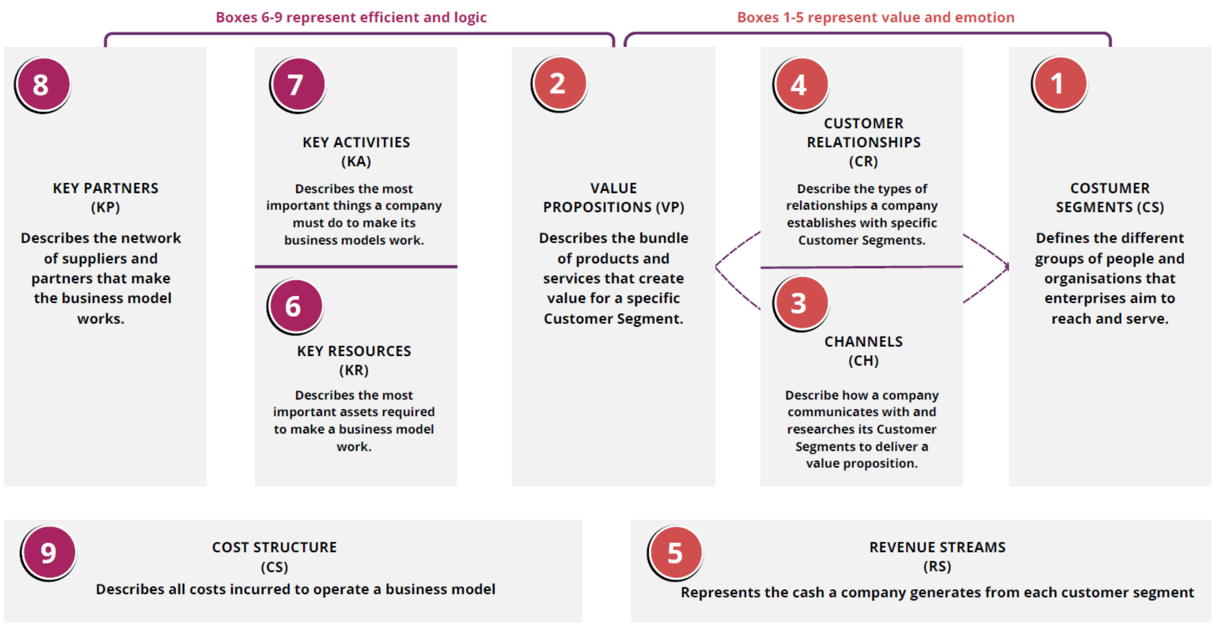

Figure 1: Business Model Canvas with economic layer (Osterwalder & Pigneur, 2010), adapted from GEODH project.

The building block of this Business Model canvas consists of two main categories: on one side, the logic and how the business model seeks efficiency and on the other side, the value and emotions of the business model. The value category represents 1) Customer segments, 2) Value proposition, 3) Channels, 4) Customer relationships and 5) Revenue streams. The efficiency category represents 6) Key resources, 7) Key activities, 8) Key partners and 9) Cost structure.

New research[1] led to the development of a Triple Layered Business Model Canvas – A Tool to Design More Sustainable Business Models. To facilitate the wider uptake of geoHC, the aim is to improve awareness about the environmental, social, and economic aspects of geoHC from a life cycle (LC) perspective, to inform

[1] Reference: Joyce, A.; Paquin, R. & Pigneur, Y. (2015): The triple layered business model canvas: a tool to design more sustainable business models, ARTEM Organizational Creativity International Conference, 26-27 March 2015, Nancy, France.

policymakers, investors and citizens more transparently. Many of the challenges for the uptake of geothermal and renewable energy technologies can be tackled with the concept of the Life Cycle. The scientific method of Life Cycle Sustainability Assessment (LCSA) aims at estimating environmental (environmental life cycle assessment (LCA)), social (social life cycle assessment (S-LCA)) and economic (life cycle costing) (LCC)) impacts of a system.

In sustainable business models, the second layer, to add to economics, is built with a life cycle environmental approach, as developed by the GEOENVI project, and the third layer aims to foster a social approach.

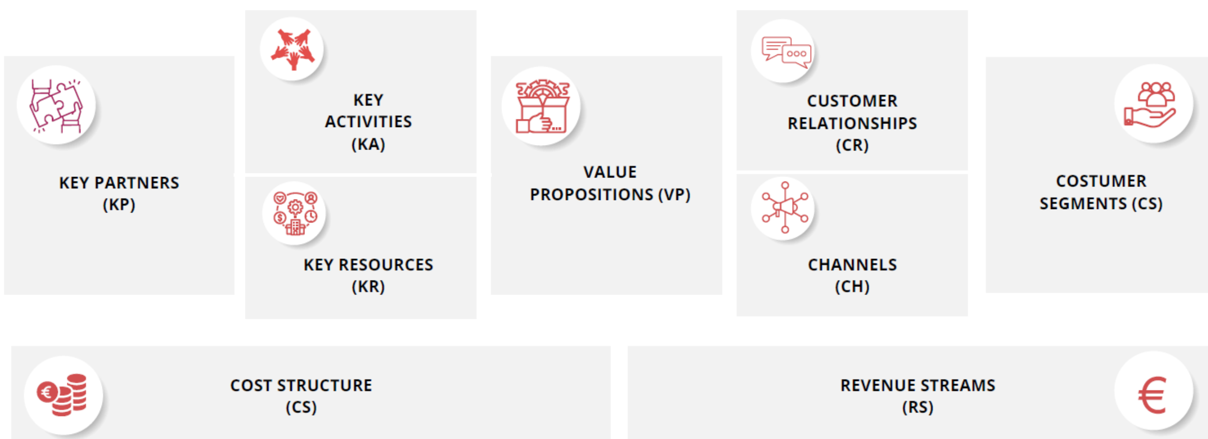

Figure 2: Economic layer of the Business Model Canvas

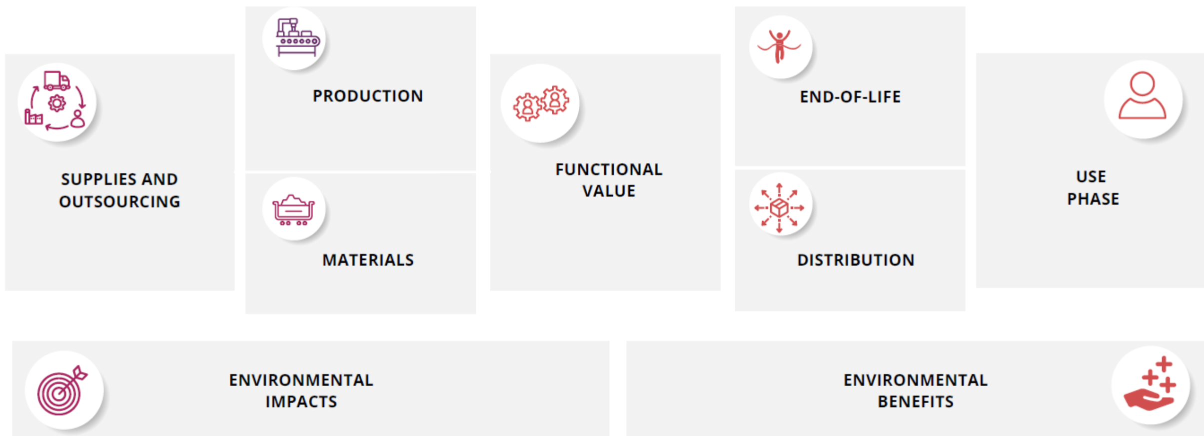

Figure 3: Environmental life cycle layer of Business Model Canvas

Figure 4: Social stakeholder layer of Business Model Canvas

3) GeoDH Channels

For GeoHC project development companies, the existing district heating operator and distributor can be a valuable partner that has the strengths of having well-established channels to the consumers in the forms of DH systems. By using its channel, the company gain complete control over the channel. This, however, involves a large investment and is not currently relevant for all GeoHC projects. The mix of channels should be integrated in the right way to maximise revenue and offer the best customer service. The right mix depends on the country and existing partnerships and energy delivery channels, e.g. if there is already a tradition of heat supply via district heating systems or more individual heat appliances.

For a GeoHC company, channels can be a mix of the following: Technical visits, Invoices, Emails and Brochures, Advertising on the benefits of using geothermal and DH, DH utility (public and private), Website with information especially about prices, Information desk, Personal account for each customer (with information on consumptions, payments, etc.), Customer service toll-free number, Annual meeting with reports from the past year, etc.

The choice of channels is highly dependent on the local context of the specific country and must, therefore, be the optimal mix hereof.

Chapter 2. Traditional business models for geoHC networks

The use of geothermal as a source for district heating (DH) is not new; it dates back to ancient times. An example can be found at Chaudes Aigues, in France; the city pioneered in the year 1330 a DH system, fed by the hot spring at 82°C. it is still in operation today. As reported in the city annals, heated homes were charged a tax by the local landlord in exchange for maintenance duties. Modern technologies allowed geothermal resources with temperatures above 50-60°C to be more widely used for district heating, with peaks following the oil crises in the 1970s. For thirty years, development was slow, but the geothermal district heating market is now enjoying renewed momentum for about 10 years, notably as a consequence of the war in Ukraine and higher oil and gas prices. New technological developments (heat pumps, drilling, etc.), as well as renewed concerns over energy dependency and sustainability, reinforce this development of geoHC.

To define the business model of a geoHC project already in operation, the heat customers are a key element. The presence of one large heat consumer helps the economy of a project greatly in securing revenues. Two other interesting customer segments are DH utilities switching to renewable and flexible heat supply and building property owners with a need for affordable heat supply.

GeoHC offers the heat consumer the following:

- Stable and local secure heat supply
- Fixed and long-term competitive prices (for production and depreciation)
- Lower need for operation and maintenance (compared to other conventional heat sources) so low O&M costs
- Lower risks (when in operation)

- Ease and comfort for the end-user

1) Introduction to traditional Business models

GeoHC technology is quite a mature one, has been in use for more than 50 years, and geoHC installations are competitive in some markets. However geothermal heat plants and district heating infrastructures are capital intensive (1-3 €mio/MWth), especially for the wells drilling phase. Operating and maintenance expenses, nevertheless, are rather low (about 2%) and much lower than in conventional systems. Production costs and selling average prices are usually in Europe around 60€/MWh thermal, and the European average range is between 20 to 80€/MWh thermal (source: EGEC).

The two traditional business models are:

1. The case of a DH company decarbonising its heat supply in close cooperation with Energy Service Companies (ESCOs). Here, the main marketing strategy would be to combine renewable heat supply (possibly with the use of labels or certificates) and energy-saving services to widen the scope of activity and reduce energy consumption.

2. The second case concerns a geoHC project developer (public or private) aiming at proposing a new DH system with geothermal heat & cold supply. The objective would be to convince heat users of the value of renewable energy sources, which are local, stable and competitive.

Finally, specific attention should be paid to cascade uses of the geothermal heat to multiple users. It is sometimes presented as an obvious solution for improving the economy of (notably) Combined Heat and Power plants, but it seems less and less easy to develop them. Today few examples exist all over Europe.

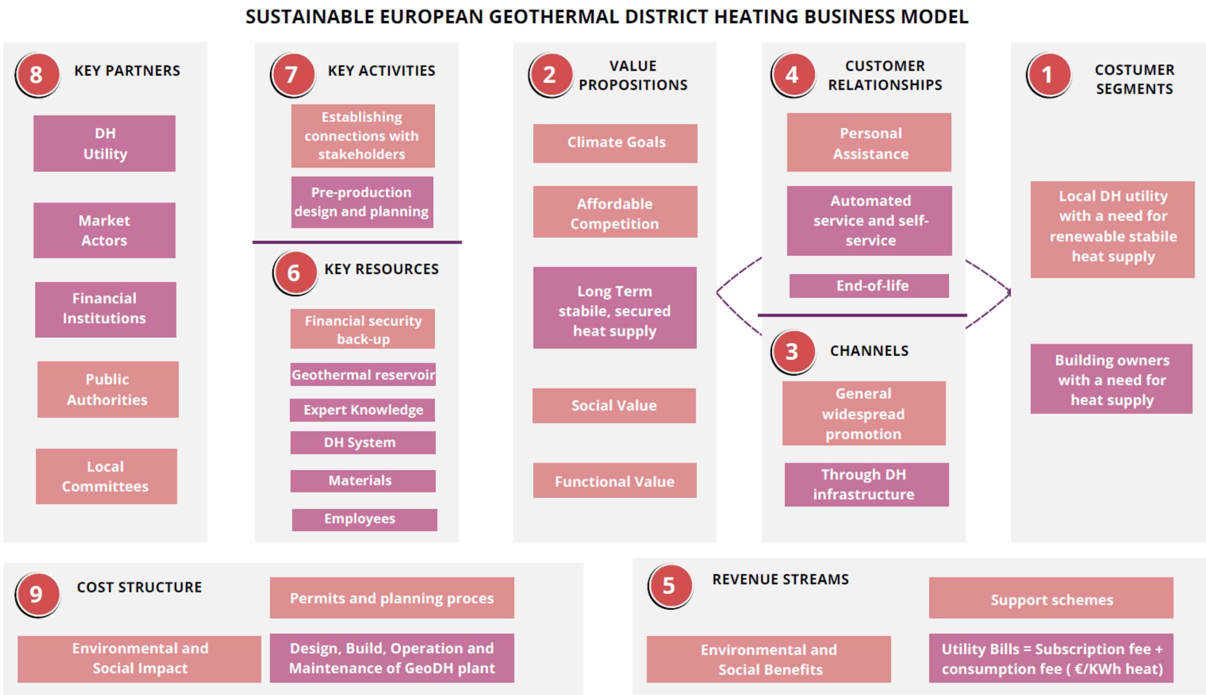

Figure 5: General European Geothermal District Heating Business Model, adapted from GEODH project.

Before the drilling of the first well, a contract has to be negotiated to sell the heat and cold to a minimum number of customers to make the project economically viable. This step is of paramount importance; many projects cannot find any financial support if this type of Heat Purchase Agreement (HPA) is not provided to the bank before beginning the negotiation and after covering the geothermal resource risk. There are two different cases:

• If the district heating network already exists and some technical modifications are needed in the network or the heating stations and substations, the client is identified (public or private or a mix), and a pre-contract has to be negotiated. It aims at signing a minimum agreement to purchase a certain amount of heat per year during a sufficiently long period, usually between 15 and 30, to secure the reimbursement of the bank loan, depending on the laws in force in the country.

•If the district heating network is to be built, the same type of agreement has to be signed and negotiated with guarantees of quantity, price and duration of the heat sales contract. Separate contracts will be required if there are several clients.

2) Thirty years of geoHC development

The analysis of the 400 geoHC networks developed and installed since the 90s helps to structure the traditional business models (BM) largely used by developers and operators.

During the years 1990, most national electricity and natural gas markets were still monopolies, so the European Union and the Member States decided to open these two energy markets gradually to competition. The First Energy EU Package was adopted between 1996 and 1998. It consisted of the first liberalisation of the electricity and gas national markets based on the introduction of two new electricity and gas directives about liberalisation. It also changed the statutes of geoHC companies. Firstly, the European Union decided to distinguish clearly between competitive parts of the industry (e.g. supply to customers) and non-competitive parts (e.g. operation of the gas and electricity networks). It aimed also to allow third parties to have access to the energy infrastructure. Thirdly, measures to remove more market barriers were adopted for price regulations and regulated prices. Although significant progress has been made in opening electricity and gas markets, competition between energy market actors is slow to take off, especially in the heat sector. Electricity and gas markets still remain largely national and highly concentrated.

The liberalisation in the energy markets for electricity and heating should open more opportunities for new developments in the geothermal power and heat.

Since then, traditionally, geothermal HC projects have included the following stakeholders:

- A state developer, sometimes an incumbent operator partially or fully publicly owned by the State
- Private project developers and operators, established with the liberalisation of the energy market
- Local authority (such as a municipality - common in France)/ local public utility (common in Germany)

Traditionally, the geothermal projects have seen two major business models:

- Public ownership projects
- Public-private partnership (PPP) to develop and operate the plant and the system

Other ones are detailed in the forthcoming chapter.

3) Presentation of the two traditional models

Two cases can be given as an example:

1. An existing DH system, with a project operator company switching from fossil fuels to decarbonising its heat supply. Here, the main marketing strategy for the business model is to provide both renewable heat supply and energy- performance with saving services.

2. A new construction of a geothermal DH system by a project developer (public or private) aiming at supplying geothermal heat and cold. The goal would be to

convince several types of heat users, with different load profile, about the value of geothermal as a local, stable and affordable energy.

a) Public projects driven by municipal authorities (France) or local utilities (Germany),

The local public entity develops the projects during all phases: resource exploration, drilling, heat plant installation and operation of the geoHC network. It contracts private companies to supply services, supply of equipment and works. It operates the network and fixes the price.

This model is beneficial to local projects supplying heating and cooling to building blocks or residential networks. This BM is very common in Germany and is used sometimes in France.

An example is the Freiham's (Munich, Germany) district heating and cooling plant. Stadtwerke München (SWM), Munich's municipal utility company, has been heating the Freiham district and neighbouring districts in the west of Munich since Autumn 2016 (below figure 6; source: SWM)

Figure 6. Freiham's (Munich, Germany) district heating and cooling plant (source: SWM)

b) A private-public partnership (PPP-1)

This **private-public partnership (PPP)** includes a private utility or private company in addition to the local public authority or utility.

It has been the traditional business model of geothermal district heating systems in France since the 80s. Here, the municipality is the one taking the risk and having the responsibility of the project development. However, it contracts a private entity to develop the project. The French financial risk mitigation scheme allows the municipality to cover this risk. It takes here typically 4 years to develop such a project. This standard PPP model is used in the geothermal project schemas from ENGIE and Dalkia in France.

The municipality associated with the private developer contracts private companies to supply services, equipment, and work during the project development phase. The city delegates then to the private operators the project management and operation for some decades. The heat price is controlled by both parties.

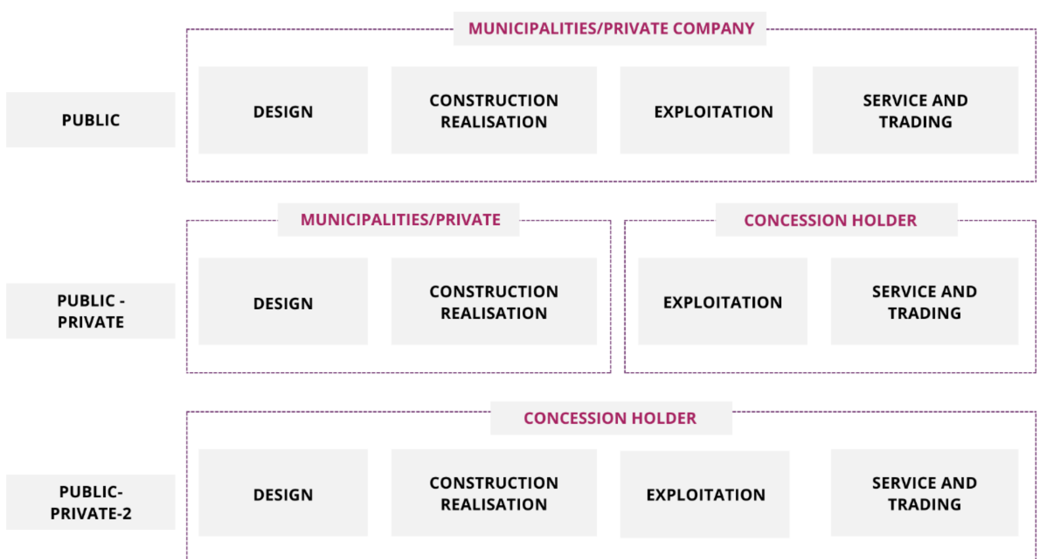

Figure 7: French models of geoHC business models.

The profitability can be increased by formally constructing partnerships between public and private partners to spread out the risk to multiple partners and by involving public partners the demands regarding payback time and return on investment tend to be more accommodative. Regarding the responsibility of the different partners, the model below gives a brief overview.

An example of the increased use of alternative business models is the Hungarian case, where the change in the use of business models in the GeoDH market is a clear example. Today, a third of the systems are operated in a PPPs, the majority being managed by local public authorities, but more than half of GeoDH's ongoing projects are developed by a private operator. One aim is to establish PPP with local municipalities. One key piece of information is to communicate about the project, especially the heat price. As an example, in France, all DH systems are mapped and reported online.

For each one, a factsheet provides technical details, including:

- The DH energy mix
- Heat supply
- Length of the network
- Average heat price of the year

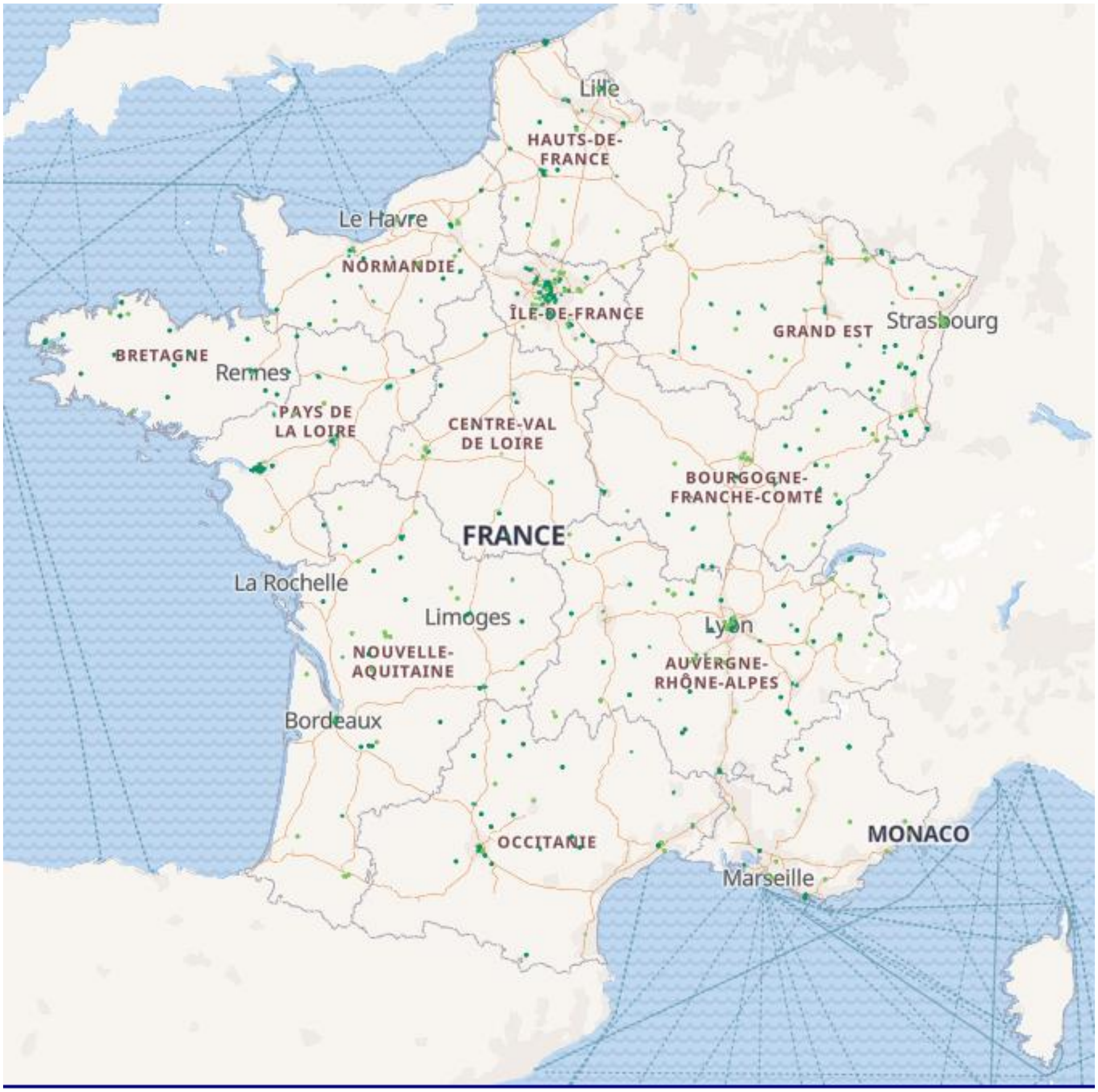

Figure 8: Online mapping of the district HC systems in France

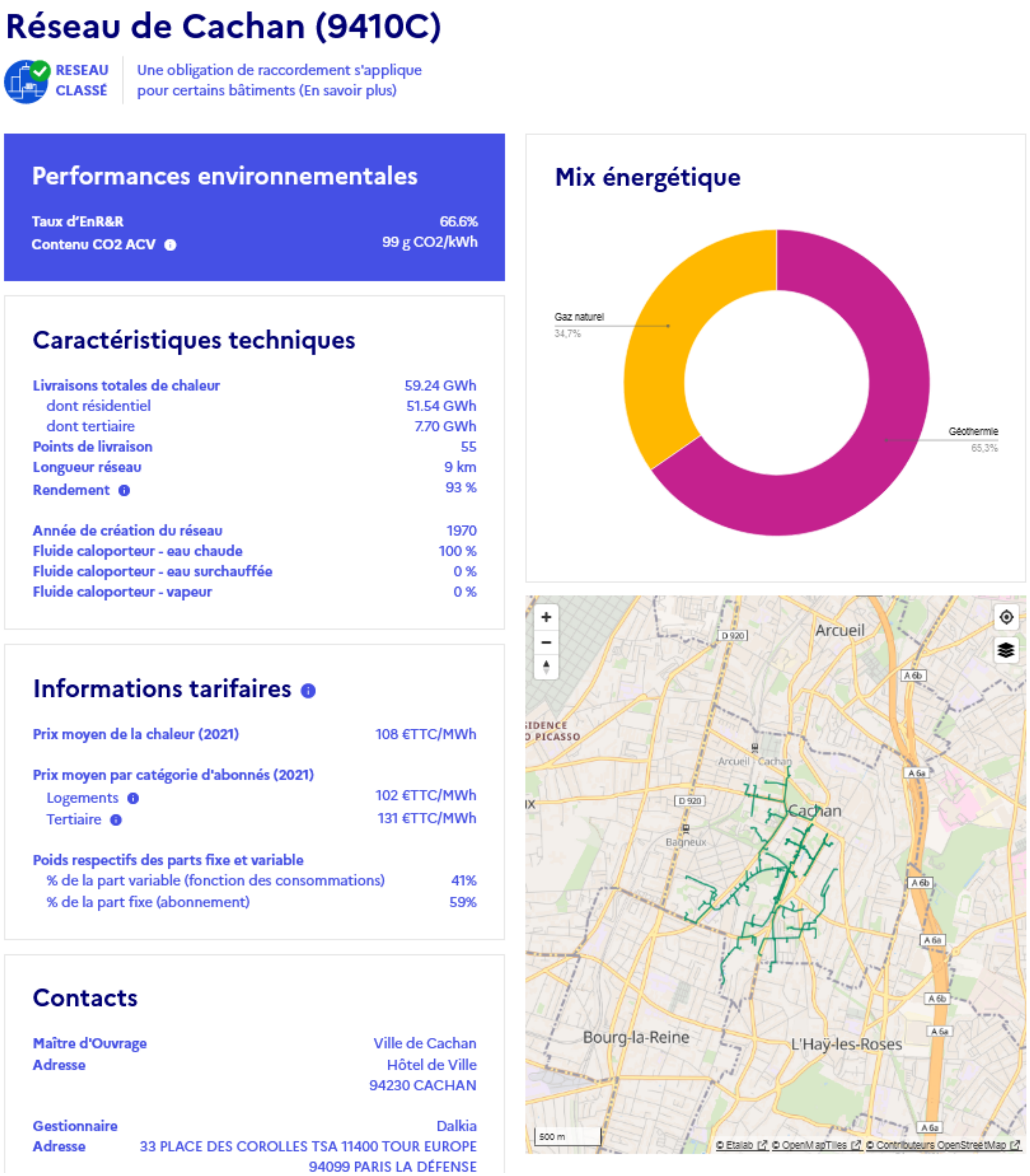

Figure 9: Case of geoHC in Cachan

4) Towards a new geoDH market

After 50 years of development, the geothermal district heating market is seeing a new development for which innovative business models are required.

Projects firstly tapped areas with the best geothermal resources: locations with already known resources, data availability from previous underground exploration…but also where DH infrastructures were available, or DH was already known by consumers to convince them to connect.

These fields became brownfields with the development of several geoDH systems in the same area. In many countries, the development over the decades remains in these regional areas: France (east of Ile de France and Aquitaine), Italy (Tuscany), Germany (Bavaria), and The Netherlands (South Holland).

The new demand for geoDH comes from other regions in these countries, but also from new countries so for a development mainly in green fields for the geothermal resource. But these regions can be familiar with DH and with heat infrastructure available. A new demand will also come from heat supply to industry at different temperatures and loads and to agriculture and its heat processes.

One can assume that these projects will be riskier or with a different risk profile at minimum. The phase of exploration will become even more crucial.

In greenfields, the investment in the exploration phase will be higher to have the same level of de-risking. PPP could be a solution for large-scale 2D/3D Seismic exploration Campaigns.

In terms of investment, a second consideration is the investment in heat grid infrastructures. It’s considering three cases:

- An Existing DH to decarbonise with geothermal

- A need for new heat infrastructures to supply geothermal heat to buildings in dense urban areas via DH
- A special need for heat infrastructures in less densely populated areas such as rural areas, to supply heat to industry and agriculture

This last option will require guarantees and a heat purchase agreement to cover investment in the geothermal and surface parts. Contracting large heat demanders will allow to start the project and look for new clients.

Finally, specific attention should be paid to new opportunities such as multi-purpose uses. It is sometimes presented as an obvious solution for improving the economy of (notably) CHP, but it seems less and less easy to develop them. Today, few examples exist all over Europe.

Chapter 3. Innovative business models for geoHC networks

Recently, a number of new business models have been created for optimising the implementation of the geothermal projects around which they are structured.

The main change for the business models in the geothermal sector has been the European legislation developed since the nineties to liberalise the electricity and gas markets. A second key change has been the climate and energy package 2020 and 2030 allowing an important development of renewable energy with support policies. Finally, inflation is again a major characteristic of the European economy, driven by the explosion of the cost of hydrocarbons on energy prices.

After having developed geoHC projects in brownfield areas, new developments take place in green fields, a challenge with a lack of information for the developers and the customers.

Here are some considerations that must be taken into account:

- A demand-side project approach: developers have to define the heat demand first and then see the resources available to supply heat at the requested temperature and load, especially supply heat and cold to industry
- Multi-purpose uses of geothermal heat: the geothermal brines can be utilised several times to increase revenues. It includes Cogeneration (heat and power) and Trigeneration (minerals extraction) whenever feasible. The Combined heat & power can also be combined in cascade uses where the heat is supplied to several consumers with different temperature levels in cascade mode. Trigeneration is when minerals such as lithium are also extracted from the brine and valorised. One can add to this the underground thermal storage, for example, industrial or municipal waste heat, and its remuneration by the market in system integration.

Consequently, many new types of PPPs have come about, as well as various privately structured models and different kinds of decoupled models. There are new models for organising PPPs where the ownership and the financing of the project are shared between the public and private sectors and involve the sharing of risks and profits. Through SAPHEA project analysis, we have pinpointed the following new business models for geothermal District Heating and Cooling systems:

1) Summary

The table below presents you the nine innovative models identified and described in this report:

	Business models	Comments
1	A private-public partnership	(hereafter referred to as PPP-1)
2	A joint venture - private-public partnership	(PPP-2)
3	A local project company established with a partnership between the municipal entity and the geothermal developer	(PPP-3)
4	Private self-consumption model	(Private 1)
5	Secondary private self-consumption model	(Private 2)
6	Private collective contract model	(Private 3).
7	A special decoupling model	(DEC-1)
8	A new type of decoupling: subsurface and surface developers	(DEC-2)
9	Energy communities	(COM-1)

2) A local project company with a public-private partnership

a) A joint venture- private-public partnership (PPP-2)

The case of a geothermal heat plant in Rittershoffen (France) shows the supply of heat to an industrial partner within a joint venture.

Electricité de Strasbourg (geothermal developer), CDC (Caisse des dépôts – national public funding agency) and ADEME (public energy funding agency), and Roquette Frères (industrial partner) held a stake in the project undertaking to supply geothermal heat for the industrial process (fertiliser).

This model remains unique as it has not yet been replicated. But for demonstrating innovative geothermal technologies, a first of a kind, in a country with juvenile geothermal market development, this solution of joint venture seems a good solution. 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.

b) A local project company established with a partnership between the municipal entity and the geothermal developer (PPP-3)

A local project company is where there is a partnership to create a project company between the municipal entity and the geothermal developer (PPP3) from the start of the project until the operation phase.

National legislation can favour the development of geothermal DHC networks with the creation of a legal framework to support public-private partnerships. This is the case of France, which in 2015 approved the Energy Transition for Green Growth Law, which supports municipalities to access capital from joint stock company, the SAS LTE (Energy Transition Law) to produce renewable energy. This allows public-private companies to be jointly established between the energy supplier and the local authority with a joint stock company. It is jointly owned by the city and ENGIE solutions, with different sharing models: 50%/50% or 20%/80% stake to develop the geothermal resource, which then feeds directly into the district heating network. The supply contract is for long term, typically 20+ years, after which ownership transfers to the city or can be issued to another company if the city desires.

In France, this standard PPP model has now been used since 2015 for geothermal DH projects of private utilities. Such a model allows to simplify the procedures for public tendering by the municipalities and it seems to be able to reduce the time necessary for the project development to around 2 to 3 years. It simplifies the process, especially for contracting private companies to supply services, equipment and work during the project development phase. It is illustrated, for example, in the geothermal district heating in Vélizy-Villacoublay, France. In 2019, the Vélizy-Villacoublay municipality and ENGIE Solutions signed the creation of a simplified joint stock company for renewable energy, the first in the Ile-de-France region. Winner of the Ruggero Bertani European Geothermal Innovation Award 2021, Véligéo is 20% owned by the city and 80% by Engie Solutions. Its mission is to develop geothermal energy in the municipality and supply an existing network with low temperature conversion (initially pressurize hot water)..

Figure 10 Photo of the Veligeo geoHC project (source: Mairie Vélizy-Villacoublay)

Véligéo plant supplies Vélizy-Villacoublay with 110 GWh of heat and 16 MW of geothermal energy + heat pumps (parallel and series configuration), while saving the production of 22,800 tons of CO_2 per year. Velidis Network combined now combined now geothermal, gas boiler and cogeneration, geothermal allows for the city to use local renewable energy sources for where fossil energy used to be the main supplier—providing more than 60% of the heat demand for the city. The project uses multidrains technology wells, allowing the doublet to cross the Dogger reservoir multiple times with a depth of 1600 meters.

GéoRueil stands as an another noteworthy exemplar of a simplified joint-stock company dedicated to advancing renewable energy initiatives in Ile-de-France area. In 2021, Rueil-Malmaison decided to build and develop a geothermal solution. Collaborating with ENGIE Solution, the municipality has embarked on infusing a contemporary and pioneering essence into the project by establishing the GéoRueil joint stock company this time for a greenfield heating network.

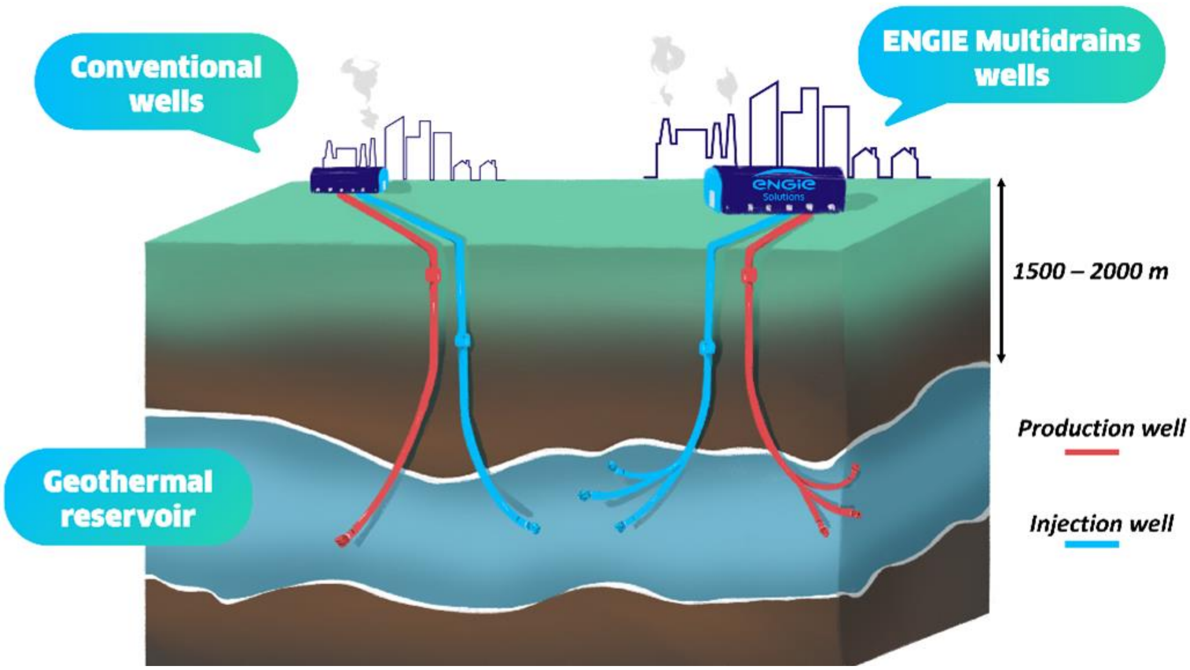

Figure 11: Graph presenting the Veligeo geoHC project (source: ENGIE)

c) Acquisition of a geothermal CHP plant

The combined heat and power geothermal plant of Traunreut in Bavaria is a quite rare business model schema – perhaps the first of its kind, where the geothermal project was developed and put into operation by Grünwald Equity Geothermie GmbH (GET) and then acquired by a private investment fund.

It can be considered as another type of business model with two elements: a combined heat and power production and a plant acquisition. The private company Grünwald Equity developed a geothermal combined heat and power plant to generate electricity, motivated by the interesting feed-in tariff in Germany and heating for a DH system. The Construction began in July 2011 under the direction of the Geothermal Power Plant Company Traunreut mbH and the geothermal plant has been in operation since 2014.

The heat is transferred to the district heating network of Stadtwerke Traunreut, the local public operator.

Figure 12: Photo of the combined heat and power geothermal plant of Traunreut.(source: Equitix)

In 2022, the plant was acquired or inherited by a private investment company (Equitix). The new company operating the plant is called Geothermische Kraftwerksgesellschaft Traunreut mbH and continues to supply the heat to the network of Stadtwerke Traunreut.

3) The decoupling model of the subsurface and the surface

a) A special decoupling model (DEC-1)

This type of business model is not very common. The geothermal electricity plant owner sells the geothermal brine to heat networks of several cities. Then, a local public entity develops the geoHC network, using the brine supplied, and distributes heat into the city. The decoupling is between the geothermal developer and the HC developer.

This case can be found in Italy, where ENEL Green Power operates geothermal plants only to generate electricity. After having used the geothermal brine at high temperatures (> 200°C) to generate electricity, ENEL GP supplied the heat to local communities in a cascade mode. The municipalities surrounding the powerplants use the brine to generate heat and distribute it to a local heat network.

An example is the Cornia power plant in Tuscany, Italy. Enel Green Power was inaugurated in 2016.

Figure 13: Photo of the Cornia power plant (source: Enel Green Power)

b) A new type of decoupling: subsurface and surface developers (DEC-2)

Currently, there are European geoHC projects under development in which a company develops the subsurface to produce geothermal heat. Then, a separate company develops the heat network to distribute the heat to buildings or industry. Here the risk is also decoupled as the resource risk is taken by the developer of the underground. In this model, the expertise of both companies is capitalized on in their respective domains. This decoupled risk business model is employed by Innargi in the geothermal DH project in Aarhus, Denmark. Innargi fully takes the exploration risk and sells heat directly to the local, publically owned DH company. The DH company does not own any part of the geothermal infrastructure nor does it partake in any maintenance of the system, they simply procure heat from Innargi.

Baker Hughes InteQ GmbH, based in Celle in Germany, has been requested and then assigned the Ahnsbeck permit field for the exploration of geothermal energy for commercial purposes. The permit, granted by the State Office for Mining, Energy and Geology (LBEG), is first limited to five years, so until 30 September 2028. The permit field has an area of 144 square kilometres. The Ahnsbeck permit field is also located almost immediately to the east of the Altencelle permit field, which had also been assigned to Baker Hughes earlier last year.

Figure 14: boundary map of the Ahnsbeck permit field in Celle, Lower Saxony, Germany (source: LBEG)

One can assume that once the geothermal energy is produced, another company may be in charge of selling this heat to individual clients or we will see services companies becoming operators.

4) Self-consumption: esp. for industrial and agricultural heat & cold process

A private self-consumption model (Private 1) is where an industrial Partner develops a geoHC project for its industrial heat process for self-consumption. It becomes a geothermal developer undertaking the entire project in-house.

This model is used in the Netherlands to supply geoHC for greenhouses and agricultural use. The owner of the greenhouse develops the project during all phases: exploration, drilling, and plant installation. It contracts companies to supply services, equipment and works.

This industrial partner operates the geoHC network for self-consumption.

Another example is given by Janssen Pharmaceutical in Belgium. Geothermal brine of 85°C is pumped up from a groundwater layer at 2.4 km depth, the heat is

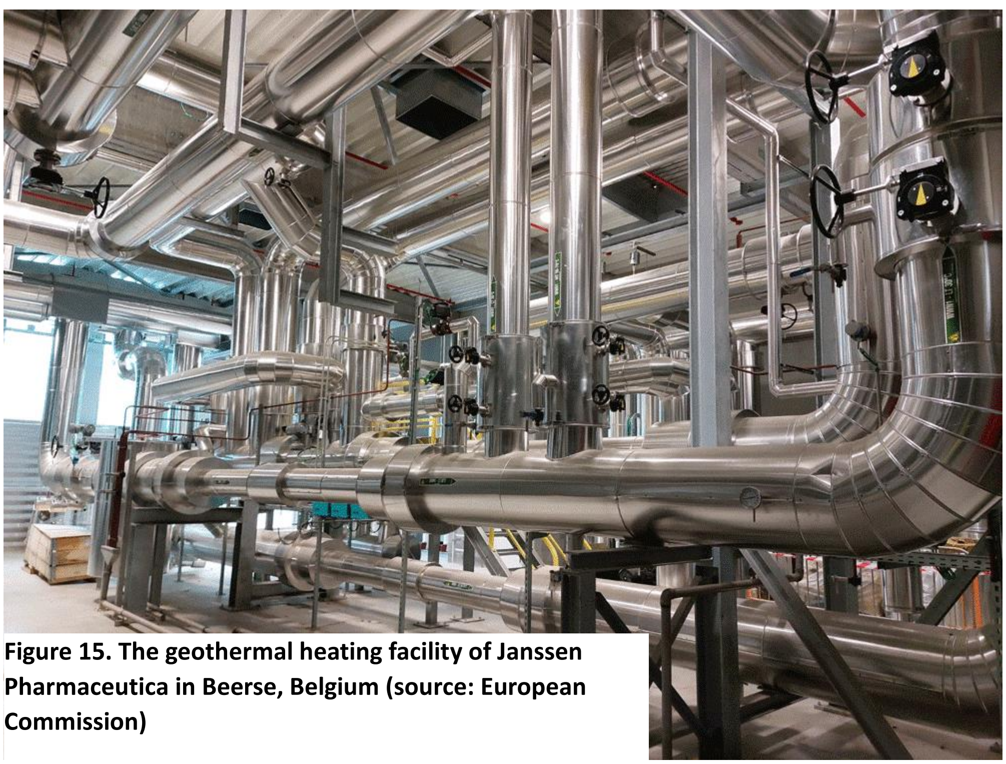

Figure 15. The geothermal heating facility of Janssen Pharmaceutica in Beerse, Belgium (source: European Commission)

extracted via a heat exchanger and then distributed across the Janssen site in Beerse via a heat grid (a pipe system of 3.5 km long). This allows Janssen to supply its buildings and production processes with the necessary heat: temperature and load. The cooled water then goes back into the same groundwater layer where it is reheated (by the heat naturally present in the earth).

A secondary private self-consumption model (Private 2) is close to the above but based on the idea of self-consumption for a collective that contracts a geothermal developer to supply geoHC to their multiple industrial heat process. It is done for their self-consumption of the geothermal heat and cold supply.

This model was also developed in the Netherlands; it is again related but not limited to the agricultural sector with greenhouses.

An example of the Private 2 model is the geothermal district heating in Westland (South Holland), the Netherlands. In Westland, a unique geothermal project serving both greenhouse horticulture entrepreneurs and residential buildings has been operating since 2018, thanks to Trias Westland.

Trias Westland is a geothermal project by and for greenhouse horticultural entrepreneurs. Through their cooperation, these companies worked together with each other and with large regional parties to switch to a sustainable energy supply.

Source: Westland municipality

Figure16: Greenhouses heated by geothermal in Westland (source: Westland municipality)

A third model is t**he private collective contract model (Private 3)**. It is similar but usually comprises a model where the geothermal project will provide for a handful of corporate buildings or even blocks of buildings.

It includes two parties: a private project developer to supply geoHC and a collective party to buy and consume the HC.

The case of energy and carbon performance Contract

According to Directive 2012/27/EU, an ESCo or energy service provider is a natural or legal person who provides energy services or other measures aimed at improving energy efficiency in installations or premises of end customers.

The EPC or energy performance contract is then a contractual agreement between the beneficiary and the supplier of an energy measure aimed at improving energy efficiency. It is verified and monitored throughout the duration of the contract. The assessment aims at checking the terms of investments (being works, supplies or services) on how they are remunerated based on energy efficiency improvement. This is contractually defined with agreed energy performance criteria, such as financial savings.

EPC Services typically includes a focus on energy efficiency work solutions, but new contracts add a carbon component. ECPC also deals with the carbon content of the energy consumed to decarbonise buildings and industry. Recent high electricity and gas prices have obliged consumers from industry, agriculture and tertiary sectors, to look for alternative energy supplies. Here, renewable energy solutions for self-consumption is the alternative and geothermal energy offers a unique solution with electricity, heating, cooling, sanitary hot water, thermal underground storage and potential some minerals such as lithium.

ECPCs in the public sector offer a practical solution to make public buildings more efficient, since the initial investment can be assumed by a private partner and then reimbursed by guaranteed financial savings on the energy bill.

These contracts appear now to be more popular also in the industry and services for their tertiary buildings and factories.

e.g. P3, one of the Europe’s leading long-term logistics real estate investor and developer, installed a geoHC system in Rouen (France) for the post company (La Poste). The heat is carried by water in the pipes, at temperatures of between -3 and 40°C, with a maximum geothermal output of approx. 365kW for both heating and cooling supply.

https://www.p3parks.com/whats-new/sustainability/p3-hits-sustainability-milestone-with-first-warehouse-powered-by-geothermal-energy

5) Projects portfolio approach: a basket of projects

Integrating geothermal resource assessment into the evaluation of the distribution and configuration of the energy demand is crucial to accelerating the implementation of geothermal energy into the European energy system, in particular for Heating & Cooling applications.

H&C resources need to be located close to demand, such as populated areas where H&C demand is concentrated or close to a large demand from tertiary buildings, industry and large agriculture facilities. They need to be derisked and tested before district heat networks can be constructed or adapted to the geothermal resource.

Today, a challenge is that most geothermal resources are still largely unexplored because of a lack of data (due to the absence of past hydrocarbon exploration and production) as a starting point for derisking potential resources.

Consequently, in such underexplored areas exploration expenditures will be relatively high and a priori chance of success is low. Therefore, a single asset-focused development often leads to market failure as the potential financial benefits of a successful development of a single prospect will not trade off against the risks of high exploration expenditures (which cannot be recovered when the project is not successful).

Play-based portfolio approaches, as developed in the hydrocarbon industry overcome, this development barrier. The play-based portfolio concept builds from the notion that the chance of success of a geothermal prospect is linked to several prospective geological factors that are spatially correlated in the so-called play (play refers to interlinked geological factors contributing to the chance of success, i.e. a high permeability due to certain depositional environment). Consequently, if the geological factor is proven in one prospect, it will also de-risk the nearby prospects, adding to the value of information (VOI) of drilling the first prospect. Using the portfolio approach, the high exploration expenditure of the first prospect can be justified from the perspective of successful development of the whole portfolio instead of the single prospect.

One example is given in Denmark. Innargi has entered a 30-year agreement to develop and operate the EU's largest geothermal heating plant in Aarhus, Denmark. Innargi is developing 19 wells to supply heat to the district heating managed by the utility of Aarhus, with a long-term purchase agreement.

Innargi plans to de-risk the required infrastructure for geothermal DH by financing the upfront investment associated with the exploration and construction phase. The DH company is not exposed to any risk at any stage as it procures heat directly from Innargi without owning any of the geothermal plant installations. Legal regulations, stipulated by the Danish Heat Supply Act of 1979, require that geothermal projects demonstrate a superior socio-economic business case relative to alternatives (e.g. biomass or large air source heat pumps). Once the business case is approved, public funding from the municipality finances the project. Moreover, the act further requires DH companies to be non-profit, providing a high level of consumer protection. The model is easily extended to include the 5th generation of Geothermal DH projects.

6) Energy communities: of cities of consumers

Energy communities (COM-1) enable collective and citizen-driven energy actions to support energy project development and operation.

These energy communities contribute to increasing public acceptance of renewable energy projects and making it easier to attract private investments in local energy assets. By empowering citizens to drive their energy supply locally, they also benefit from better energy efficiency, lower bills, and security of energy supply. Energy communities also allow local communities from surrounding cities to join forces and invest in common energy projects. Energy communities act as a single entity, they can then access to electricity and heat markets on a level playing field with other energy market actors. Under EU energy legislation, energy communities are defined and regulated. They can take different form of legal entity, including an association, a cooperative, a partnership, a non-profit organisation or a limited liability company.

In geoHC projects, there are two main barriers for renewable energy communities of individual consumers: 1) the capital investment is intensive for large-scale projects typically €1Mio/MWth 2) the risk component during the exploration and drilling phases typically adverts such communities.

It is the reason why the geothermal sector has not seen the development of such renewable energy communities for project development.

But two examples can be given of such schemes with alternative models.

Firstly, in Germany, four communities decided to establish a new geothermal heating company in Bavaria. The communities of Vaterstetten, Grasbrunn, Haar, and Zorneding created a company called Geo Energie München Ost (GEMO) to work on an inter-communal geothermal heating project. The capital of the company is around EUR 500,000, with 45% of the funds coming from Vaterstetten, 25% from

Grasbrunn, 20% from Haar, and 10% from Zorneding. The capital investment for the geothermal project is estimated at EUR 50 million, which will be split in the same manner. The communities have different stakes in the company because their heat demand profile is not the same in terms or load, temperature, quantity,etc.

Secondly, the case is about the geothermal 5th generation of district heating and cooling (Geo5GDHC). Geo5GDHC connects distributed individual prosumers with heat pumps to a heat / cold network that distributes energy supplied by small-scale geothermal installations. The grid allows for combined heating and passive cooling, capable of shifting thermal loads by seasonal energy underground storage. Currently, there are twelve commercial Geo5GDHC grids in Denmark using different energy sources and models for ownership and operation. Some more exist in Europe.

Chapter 4: Model development and causal drivers

We are currently seeing many developments in business models for geoHC. Several changes happened in the business models of the companies due to their strategies to be integrated vertically or horizontally: or for example due to the regulations like the liberalisation of the heat markets.

In this chapter, key drivers of new business model developments are listed and presented. Market conditions for geoHC are described as they influence their BMs. Innovative tools and heat purchase agreements are further explained as new tools to consolidate business models. Finally, a review of national geoHC markets is depicted to illustrate how BMs are used in these countries.

1) Key drivers of new business model developments

We have observed that the financing and risk appetite of geothermal projects, as well as the related regulations, greatly shape how the business models are structured. Where there used to be two traditional business models (see Chapter 2, municipality or local utility, or private-public partnership) there are now many different variations with private models, public-private partnerships, de-coupling models, self-consumption, and energy communities. Aside from the three key shaping drivers, the presence of an existing heat grid system, the project management organisation from the underground and the surface development, and the type of entities (public, private, individuals) involved in the operation are equally important; the following are the six new key drivers in innovative business model developments:

1. The plant **operation** itself can be the source of problems that inhibit, greatly delay, or impede the efficiency of a geothermal project. There is a need to collect

revenues in the short period, complemented by guarantees, during the first period to cover project investment. A heat purchase agreement can be a solution.

2. **Heat purchase agreements** (HPAs) are essentially pricing contracts, which in the end, facilitate the business model in question.
3. The **resource identification** to develop the geothermal project is crucial. We will see more projects develop in greenfield areas; more exploration will be required by the project developer.
4. **De-risking** schemes of geothermal projects aim to facilitate project financing during the first phase of project development. It is crucial for geoHC projects with heat demand for ca 10,000 inhabitants and industrial process heat for less than 10 MWth capacity, where only a doublet of wells is required. The risk mitigation scheme typically covers partial failure regarding the resource's temperature and flow rate.
5. With the liberalisation of energy regulation, the project risk comes also from the demand side, where clients can disconnect from the grid. **Public funding for heat infrastructures** becomes necessary to de-risk surface development, together with long-term heat purchase agreement contracts.
6. In other cases, the **regulatory** framework for district heating and/or the heat market has been liberalised. Consequently, geothermal projects have also adapted to a decrease in the security of revenues, so multiple revenues: heat, electricity, storage and minerals extraction such as lithium, offer new financial opportunities but a regulatory frame is required to further explore these opportunities. About regulations, **permitting** is a key aspect of project development time which needs to be reduced to about 2 years.

Not only has it been our observation that new business models themselves have developed and are being used, but also that business models of a project can and do change over the lifetime of the project. The shifting from one model to another can be due to:

- Strategic planning
- Financial modelling
- Pilot testing
- Stakeholder communication
- Operational changes
- Monitoring and adjustment

2) Market conditions

The current market dynamics within the European Union's electricity and heat sectors pose challenges for geothermal energy to effectively compete with traditional technologies that have historically thrived in sheltered, monopolistic market environments. These traditional technologies benefited from a setup where cost reduction and risk were shifted onto consumers rather than shared with plant suppliers and operators. Unfortunately, the internal market is still a long way from achieving perfection and transparency.

To begin with, numerous countries continue to regulate electricity and gas prices, which means these prices do not accurately represent the full costs associated with generating electricity and heat. Additionally, fossil fuel and nuclear industries continue to receive substantial subsidies, further distorting the market landscape. Lastly, there remains a glaring lack of transparency in the market, including inadequate information dissemination to customers and taxpayers, as well as opaque billing practices.

As technology evolves, increasing the likelihood of successful geothermal reserve discovery and development, and as developers gain experience, leading to cost reductions, they will gradually become more adept at handling and, when suitable, transferring various project risks (technical, economic, commercial, organizational, and political). This evolution in risk management will open the doors to private funding for geothermal endeavours. Until such a transformation occurs, the establishment of a pan-European Geothermal Risk Insurance Fund emerges as an attractive means of public support for the geothermal industry. For now, the European Investment Bank (EIB), along with national equity and debt financing providers, are key.

2.1 Policies: market liberalisation, state aid

The market conditions in the EU electricity and heat sectors prevent geothermal to develop with a fair competition with conventional fossil technologies. Fossil fuel assets were developed historically under protection, with operators in monopolistic market structures where cost reduction and risks were borne by the State rather than by plant developers and operators. The EU internal energy market is still, in 2024, far from being achieved, fair and transparent. In many countries, electricity and gas prices are regulated by National authorities. They do not reflect the full costs associated with electricity and/or heat generation. Secondly, fossil fuel and nuclear sectors still receive many subsidies more than the renewable energy sector. Thirdly, there is a lack of transparency in the energy market, including a lack of information for customers and taxpayers and clear billing.

2.2 Heat and electricity demand

The demand for heat and cold in Europe depends on climate conditions and energy efficiency measures in buildings, and on the demand profile for industry, services, and agriculture. It is also linked to economic conditions: during an economic crisis with high energy prices, vulnerable consumers may demand less heat, and the industry can also suffer so also with less heat demand.

The future of the heat demand in the short, medium, and long term is uncertain. Energy efficiency measures can reduce the demand for heating in buildings but with a higher demand for low temperature provided by geoHC.

The demand for cooling is still a niche market but with a fast-growing demand. Several criteria influence this growth: comfort, urban heat island effect, new demand from data centres for example, etc.

The demand for geoHC is increasing in all sectors, as it can answer many heat demand profiles.

3) Geothermal economic parameters

3.1 Geothermal Risk mitigation schemes

Only in a few European countries, developers operate in brown field areas, well-developed geothermal regions. In the rest of Europe, project developers do not have the full capability to manage the financial risk owing to green field areas, with poor knowledge of the deep subsurface. With technology development for increasing the probability of success in finding and developing geothermal, coupled with lessons learnt and thus cost reductions, project developers would be able to accept their share and, where appropriate, transfer project risks (technical, economical, commercial, organisational and political) in such manner that private funding will become available. Until then, a public Geothermal Risk Mitigation Insurance Fund has been seen as an appealing public support measure for deploying geothermal.

3.2 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.

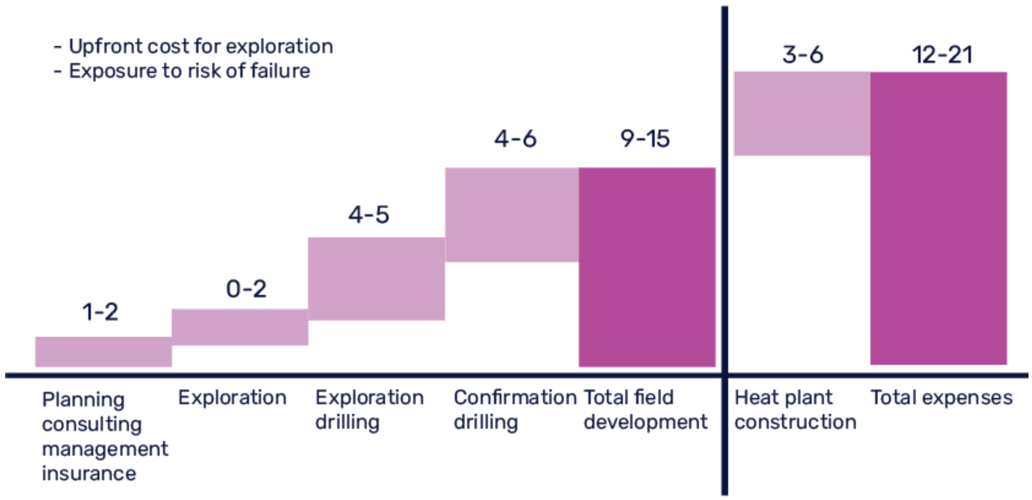

Figure 17*: Cost range for the development of a 10 MW_{th} geothermal DH (doublet) system.*

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). (source: EGEC)

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 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 find 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.

3.3 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 18 Heat generation costs of geothermal/fossil Fuels, highlight geoHC competitiveness.

3.4 Innovative tools and practices

Innovation, both technical, financial, and organisational impacts, the business models of geothermal projects. Tools such as smart meters, which are widely being deployed throughout the European Union and digital technologies are crucial to enable the operation of equipment such as geothermal heat pumps as participants in the European electricity markets instead of being merely price takers. Such tools are also necessary – along with the deployment of some innovative technologies within the geothermal industry – to enable the development of business models around geothermal thermal energy storage. For such projects, knowing when to store energy and when to release it is crucial, but even more crucial is knowing which moments will allow the operator to extract the highest margin since the economic case of energy storage is the current European energy system entirely structured around the hourly price volatility in the electricity market. Overall, innovative tools to provide access to a higher quality and higher granularity of information have a major impact on the business models of geothermal energy systems since it enables, in theory, to better maximise the value of energy services provided. It is also enabling the emergence of new markets for energy services, typically such as demand response.

Beyond technical systems, financial innovation is a very important feature of the organisation of geothermal project business models. The industry overall is steadily preparing for a future with a much higher degree of financialisation, notably as public financial support has been gradually reduced or abruptly suppressed in several European countries over recent years. The recently adopted European Sustainable Finance framework highlights the growing involvement of the financial sector in the deployment of renewable energy technologies that European institutions are wishing for. The Sustainable Finance Framework, while poorly integrated thus far by both the financial sector and the geothermal industry, has the potential to greatly impact not only the capacity of geothermal projects to raise capital but also the nature of these projects.

Another of these innovative financial instruments is crowdfunding, which is used notably for larger geothermal energy projects. Crowdfunding has been identified as a valuable tool to foster community engagement towards a project. However, it is not limited to that and has proven efficient to raise significant sums of money at crucial points of project development, for instance, in the case of the United Downs projects in the UK.

4 Innovative pricing with Heat Purchase Agreement (HPA)

Project developers face significant challenges in managing financial risk. This challenge arises from limited knowledge about the deep subsurface, insufficient technological advancements, and high costs associated with geothermal projects. Consequently, the weighted net present values of project cash flows tend to skew heavily towards negative outcomes, effectively deterring private capital from investing in geothermal energy. In addressing these challenges, innovative contractual agreements like Heat Purchase Agreements (HPAs), Power Purchase Agreements (PPAs), and pricing contracts play a pivotal role. These agreements can help stabilize project finances, mitigate risks, and attract private investment, thereby fostering the growth of geothermal energy.

Heat purchase agreements (HPAs) are contractual agreements where a buyer, often a heat consumer or utility, agrees to purchase geothermal heat from a project developer at an agreed-upon price. HPAs help geothermal projects by providing a steady revenue stream, reducing financial risks, and attracting investors, which ultimately promotes project development.

Power purchasing agreements (PPAs) are contracts where a buyer agrees to purchase electricity generated by a geothermal project at a predetermined price over a specified period. PPAs help geothermal project development by providing a reliable income source, reducing financial uncertainty, and making projects more attractive to investors and lenders.

Pricing contracts involve negotiated agreements for the sale of heat or electricity at specific pricing terms, often with flexibility in pricing structures. These contracts can benefit geothermal project development by providing cost predictability, attracting potential off-takers, and enhancing financial feasibility, thereby supporting project financing and sustainability.

HPAs, or contractual arrangements between project developers and buyers, often heat consumers or utilities, play a crucial role in promoting geothermal energy growth. These agreements have evolved to address key challenges specific to geothermal ventures. HPAs are innovative for many reasons, of which the following four aspects stand out.

Diversification of Off-Takers: Rather than being reliant on a single buyer, with HPAs geothermal project developers now have the flexibility to engage with multiple potential consumers. This diversification not only provides a stable, diverse revenue stream but also plays a crucial role in reducing financial risks. Moreover, it enhances the project's attractiveness to investors, promoting its financial viability and long-term sustainability.

Flexible Pricing Mechanisms: HPAs have revolutionised pricing structures by departing from traditional fixed-rate agreements. In the evolving landscape, some HPAs incorporate dynamic pricing mechanisms that may be linked to market rates or adjusted for inflation. This newfound adaptability empowers project stakeholders to navigate market fluctuations and economic uncertainties with greater resilience, ensuring that the agreement remains responsive to changing conditions.

Incentive-Driven Agreements: HPAs have introduced an innovative feature that allows for incentive-driven arrangements. Within these agreements, off-takers commit to purchasing geothermal heat at a base price, but they can earn discounts or incentives by meeting predefined environmental or sustainability targets. This innovation aligns the interests of all parties involved, fostering responsible resource utilisation and bolstering the project's overall viability.

Multi-Year Commitments: Longer-term multi-year commitments embedded in HPAs have gained considerable traction. These commitments extend beyond the conventional project horizon, attracting investors and facilitating financing for larger-scale geothermal endeavours. Such commitments not only enhance investor confidence but also play a pivotal role in driving sustainable growth within the geothermal energy sector.

Chapter 5: Conclusion

In conclusion, this report has outlined the roadmap for our exploration of geothermal business models. It is more than an evolution; it appears to be a revolution in the number of models.

We began by establishing the groundwork in Chapter 1 about business model generation. Chapter 2 delved into traditional geothermal business models, providing a solid foundation for our subsequent discussion on more intricate and innovative models in Chapter 3. These chapters showcased key elements and real-world examples of these business models, paving the way for our subsequent analysis of model development and the examination of causal drivers in Chapter 4. This Chapter also forged a connection between these business models and the pertinent legislation, both at the European and Member State levels, shedding light on how regulatory frameworks shape the geothermal industry.

Besides the barriers to geothermal heat production, such as geological data availability, energy/environment/mining regulations, permitting processes, and supply chain availability, the high upfront costs and risks associated with the geothermal resource are key factors. For geothermal projects, upfront capital expenditure (CAPEX) is typically high, about 80-90% of total project cost. This is combined with the risk profile of geothermal for the resource identification, which may require additional investment in exploration or development. There is the risk of not finding the expected resource and an economically sustainable geothermal resource after the first drilling, and there is the risk of the geothermal resource naturally depleting in the long run, rendering its exploitation economically unprofitable. For the profitability of a project, mitigating these risks is crucial. On the one hand, risks can be minimised with improved exploration techniques and better data availability. A widely proven solution to facilitate the market uptake of geothermal energy is the establishment of financial de-risking schemes such as insurance, grant schemes or public-private partnerships. In mature markets, they 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 especially suitable for markets where there is little information about the geothermal resource and few projects for reference. Best practices for upfront cost support schemes and risk mitigation exist in France with the SAF Environment Fund and in the Netherlands with the Geothermal Heat Guarantee Scheme.

The report investigates the solutions to overcome these hurdles with new business Models.

The decoupling of the subsurface and the surface to mitigate the risk and develop the project seems to be the new appealing approach.

It also proposes a new model for pricing and tariff-setting with the heat purchase agreement. A Heat purchase agreement is defined as a legal document between a buyer and a seller of heat or cold. The agreement describes the terms and conditions of the sale and ensures that both parties will follow through on their promises for some time (typically over 20 years). HPA is a key instrument in less populated and industrialised areas to combine heat demands. Geothermal and other renewable heating solutions can supply nearly half of the industrial heat demand, provided they have market access. There are three different types of industrial heat demand: (1) low temperature (< 100 degrees), (2) medium temperature (100-500 degrees), and (3) high temperature (> 500 degrees).

A good purchase agreement will identify the following basic elements: (1) the party who owns the heat plant and wants to sell it, (2) the party who wants to buy the heat supply and become the new owner, (3) a detailed description of the heat being sold, (4) the amount the buyer will pay, and (5) how and when the seller will be paid.

The market for Heat Purchase Agreements (HPAs) is relatively young yet growing. This accounts for the limited case studies on the topic. HPAs, unlike Power Purchase

Agreements (PPAs), face an infrastructure gap which holds the market back at present. There is a lack of dedicated renewable heating and cooling infrastructure. The variability of the heat demand: climate conditions, and seasonality are also issues for long-term contracting. Demand uncertainty and the potential loss of clients reinforce this issue.

There is a growing trend for companies to invest in their geothermal energy capacity to provide on-demand renewable heating and cooling. Large industrial and retail users are turning to this solution. Long-term heat purchase agreements are a crucial means to secure investments in geothermal district heating and cooling projects and are often a prerequisite. This serves as a de-risking mechanism and allows for private entities to join the heating & cooling system to purchase the remaining heat from the project.

> *„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.“*
>
> Gregor Götzl – main proposer

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