SAPHEA

INTEGRATING GEOTHERMAL HEATING AND COOLING NETWORKS IN EUROPE

Status report on key market drivers related to the implementation of geoHC network

07 April 2023

Author: Philippe Dumas (EGEC) / Madeline Vander Velde (EGEC)

Deliverable: D2.1 Status report on key market drivers related to the implementation of geoHC network **/ Version:** 4 **/ Status:** V1
Revision Team: G. Goetzl (Geological Survey of Austria) / Kai Zosseder (TUM)
Submission date: 07 April 2023
Verified by: Kai Zosseder (WP2 lead)**/ Approved by:** WP2 partners
Confidentiality level: Public
Contact: G. Goetzl gregor.goetzl@geologie.ac.at

www.saphea.eu

Funded by the European Union

This article/publication is based upon work from the project SAPHEA, funded by the European Union's HORIZON EUROPE research and innovation programme under the Grant Agreement number 101075510

„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

List of abbreviations

Abbreviation	Full name
CHP	Combined heat and power plants
DH	District heating and cooling systems
geoHC	Geothermal Heating and Cooling networks supplied by geothermal energy as a source, sink or storage for heat
GHG	Greenhouse Gas emissions
H&C	Heating and cooling
PPP	Public – private partnerships
RES	Renewable energy sources
UTES	Underground thermal energy storage
kWth and MWth	Kilowatt thermal and Megawatt thermal of the geoHC capacity installed.

Change Log

VERSION	PUBLICATION DATE	CHANGE
1	07.04.2023	

Disclaimer:

This article/publication is based upon work from the project SAPHEA, funded by the European Union work programme HORIZON EUROPE under the Grant Agreement number 101075510. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

Contents

1 INTRODUCTION

The cities do and will play an important role in mitigating climate change and in securing the affordable energy supply for families and the industry. About 75% of Europe's population lives in cities, and urban areas account for 60-80% of carbon emissions (IPCC, 2014: Summary for Policymakers). Globally, 70% of world population will live in the cities by 2050. Urban areas are predicted to be significantly affected by the climate change impacts, such as extreme heat, and therefore must engage in effective mitigation and adaptation strategies. In addition, many cities are not able to supply local needed for their electricity, h&c and energy for transport demand, which makes them more dependent on energy imports.

Geothermal is a part of the solution, as it can supply European cities with competitive and renewable source of energy. Geothermal technologies can be used for heating, cooling, electricity production as well as seasonal heat storage and allowing thermal storage in the underground, while protecting consumers against volatile fossil fuels prices.

Geothermal district heating is the quickest solution to decarbonising the cities, with largest volume of buildings within a decade in an affordable way as it benefits from economy of scale. Geothermal sources also benefit from interconnecting multiple users with different load profiles through a district heating network, as peak loads are better distributed. Vice-versa the network can benefit from the implementation of Geothermal as medium to seasonal storage.

To achieve a successful geothermal district and cooling systems (geoHC) decade, key market drivers must be analysed and ranked to tackle the key barriers.

1.1 Short description of the deliverable

This status report on key market drivers relates to the implementation of geoHC network is to map market drivers and to present the key ones. A geoHC network is understood as a heating (and, or) cooling network using geothermal energy either as a source, sink or heat storage.

A geothermal district heating system comprises three major components, as shown in Figure 1.

The first part is heat production which includes the geothermal production, conventionally fueled peaking station, and wellhead heat exchanger (elements marked 1-2-3-4-5.

The second part is the transmission/distribution system, which delivers the heated or cooled water to the consumers (element 7).

The third part includes central pumping stations and in-building equipment. Geothermal fluids may be pumped to a central pumping station/heat exchanger or heat exchangers in each building. Thermal storage tanks may be used to meet variations in demand.

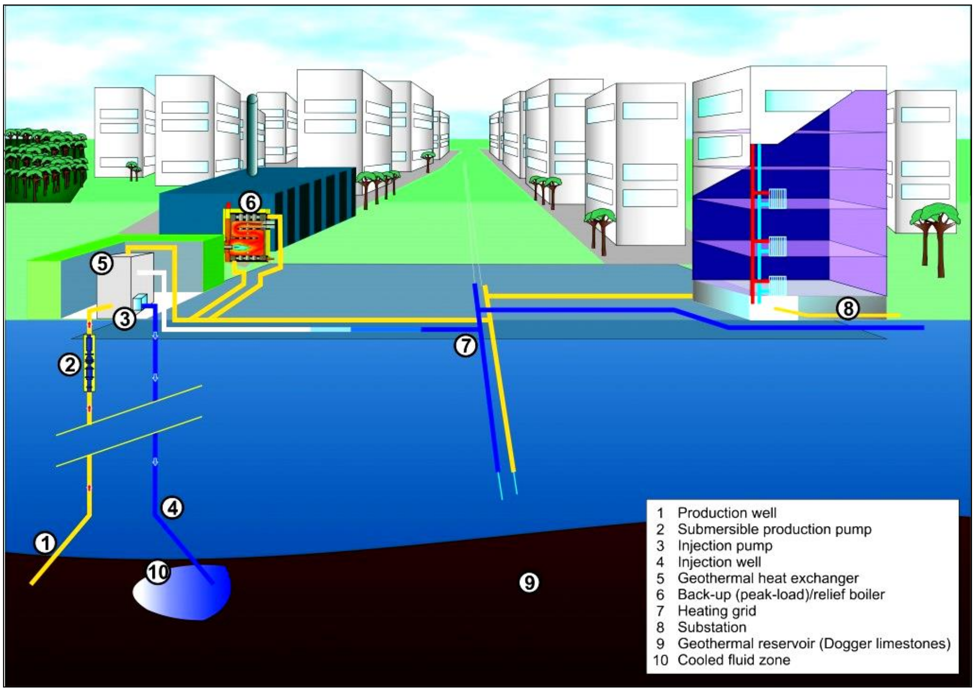

Figure 1 Main components of geothermal district heating system (source: GEODH, 2014)

In SAPHEA, geoHC networks are defined by network temperature levels below 25°C (5th generation DHC network) and approximately 90°C to 120°C (2nd to 3rd generation district heating network). In SAPHEA, geoHC networks are understood as bivalent to multivalent heating and cooling networks, which combine geothermal energy with other energy sources and heat processing technologies, such as heat pumps (Figure 2).

With regard to capacity level, geoHC networks cover local area networks of at least 500 kWth up to city scale district heating and cooling networks of several tens of MWth.

This summary report positions the current situation and expected trends linked to geoHC networks. The report also outlines critical success criteria and key performance indicators for supporting future market uptake.

This publication is part of the task on the characterization of key market drivers (T2.1).

1.2 Executive summary

To reach net zero cities, heating and cooling networks will be the key solutions especially in urban density areas. But the District Heating sector is representing only 10% of the heat supply (IEA (2022), District Heating) and is still largely dominated by fossil fuels (e.g. 76% of the overall supply in Poland is from coal). Geothermal, with 350 heat plants in operation and 200+ under development, is one of the sources contributing to its decarbonisation, and can alleviate the EU's energy dependency with an affordable energy transition. Geothermal has one of the best CO_2-emission reduction potential of heat sources and can provide about 90% reduction compare to heat generated by gas (Stichting Platform Geothermieet al, 2018)),

The first regions to install geothermal Heating systems were those with the best technical potential, however with new technologies and systems, an increasing number of regions are developing geoHC. Systems can be small (from 0.5 to 2 MWth), and larger, with capacities up to 50 MWth. Some new district heating schemes, put not operation during the last 10 years, utilize geothermal resources at lower temperature and are assisted by large heat pumps.

Installing geoHC systems in areas of high urban density, and H&C demand from industry, improves project economics, as both resources and demand need to be geographically matched. One considerable challenge in the current energy crisis concerns the fast development of new heat grid infrastructures. Retrofitting existing district heating systems is a good alternative for developing the geoHC market.

The main benefits of geothermal heating and cooling are provision of local, baseload and flexible renewable energy, diversification of the energy mix, reduction of fossil fuel imports, and protection against volatile and rising fossil fuels prices. Using geothermal resources can provide economic development opportunities for countries in the form of incomes, technology export, and jobs and support the regional value added.

The potential of geothermal H&C is significant. However, geothermal H&C technology is at present poorly developed (1% of the heat market). Key market drivers have been identified as important to improve this situation:

- **Secure the supply chain (casing materials, rigs, pumps, piping…) with an industrial strategy** for geothermal technologies equipments and components manufacturing and to reduce skills shortage in the necessary fields of drilling, planning and in-stallation.

- **Technical improvement in the project development phase:** better resource identification, higher drilling success rate, with efficiency and well integrity, sustainable exploitation for a long term lifetime. New technologies will support the development of geoHC: Large heat pumps and with higher temperature range, Deep closed loop systems, Drilling design, New heating systems

- **Consistent energy policies aiming to decarbonise the heat sector;** a level playing field established by, for instance, liberalising the gas price and taxing GHG emissions in the heat sector appropriately

- **The removal of regulatory and other non-technical barriers, as well as simplified procedures for operators and policy makers:** faster permitting process, Geological data availability, one-stop-shop… The training of technicians, civil servants, and decision-makers from regional and local authorities in order to provide the technical background necessary to approve and support projects.

- **Design heating and cooling planning for municipalities and regions:** Map Availability of local, renewable energy andareas to drill, local authority planning and ambitious regional and cities RES targets (e.g. SEAPs)

- **The development of funding schemes:** risk mitigation schemes, investment fund for construction and infrastructures, operational aid such as guarantee on long term pricing

- **Secure Business models for geoHC project:** legal basis, pricing regulations, taxation, risk sharing mechanism…

- **Ensure stakeholders engagement and acceptance:** support from local communities, mitigate environmental impact.

2 METHODOLOGY

2.1 Objectives

Based on publicly accessible market data, statistics, policy reports and web-based search trends analyses, the key supportive and hindering market drivers for geoHC networks have been assessed and characterized. By performing these activities, the key technological and non-technological market drivers have been identified.

This fact-finding work was then complemented by experts and stakeholder as well as expert online consultation. Results are summarized in this status report (D 2.1). It aims at developing the basis for the thematic work packages of SAPHEA project: Financing, Regulations and Policies, capacity Building and support measures. In addition, the outcomes of this work will feed into the design of the SAPHEA decision support tools, developed in work package 3 and 6 (interactive guideline).

2.2 Description of methodologies applied

The methodology was based on data collection and treatment, analysis of the market drivers: listing and presentation and finally a ranking to select key market barriers.

2.2.1 Literature review

The first step was to decide on the data to be collected. It included both quantitative and qualitative data:

- Quantitative data included:
  - ✓ Market reports on geoHC (from EGEC, EH&P, EHPA, Eurobserv'er) with key performance indicators set about heat pumps, district heating, capacity installed, renewable production etc.
  - ✓ Monitoring media news
  - ✓ Other statistics, policy reports and web-based search trends analyses
- Qualitative treatment with:
  - ✓ Listing drivers (technical (supply chain), technological, policy, regulations/permitting, business models etc.)
  - ✓ Assessing current and future barriers

Once this literature review was achieved, a first draft version listed the market drivers. An internal consultation of the SAPHEA partners led to present the potential key market drivers and a methodology for ranking them.

2.2.2 Consultation

When a final draft was available, a list of key stakeholders was prepared: plant developers/operators and services companies from all over the EU.

An Online consultation was organised in February 2023: 11 geoHC developers and operators were consulted and answered the consultation from France (3), Germany (1), Belgium (2), Italy (2), Denmark (1), UK (1). These developers / operators managed more than 50 geoHC projects or plants.

The survey was on the full final list of market drivers with several categories, two topics: Impact and Relevance, plus the possibility to add any comments and recommendations.

2.2.3 Ranking the market drivers

Each market driver has been ranked with the following principle:

- 1 point if low or hindering
- 2 points if medium or neutral
- 3 points if strong or supportive

Impact	**Relevance**			
		Low	**Medium**	**Strong**
		1	**2**	**3**
hindering	**1**	**2**	**3**	**4**
neutral	**2**	**3**	**4**	**5**
supportive	**3**	**4**	**5**	**6**

And a colour code:

- Orange if hindering or low
- Yellow if neutral or medium
- Green if supportive or strong

List of market drivers		Impact				Relevance			SAPHEA recommendations
Categories		Hindering	Neutral	Supportive		Low	Medium	Strong	

To select the key market drivers, the analysis is based on the following Key Performance Indicators including success criteria and showstoppers:

a) Impact: hindering / neutral / supportive

b) Relevance: low / medium / strong

Each expert (see chapter 2.2.2: consultation) had to qualify the market drivers proposed during the consultation, on both impact and relevance.

The results gave a score for each market drivers and the key market drivers are the ones having both (strong and medium) relevance and (hindering and supportive) impact. It means it includes barriers and opportunities:

- Green: classified at key market drivers
- Yellow: other market drivers

Impact	**Relevance**			
		Low	**Medium**	**Strong**
		1	**2**	**3**
hindering	**1**	**2**	**3**	**4**
neutral	**2**	**3**	**4**	**5**
supportive	**3**	**4**	**5**	**6**

The key market drivers are then classified in two categories: hindering or supportive.

3 GEOTHERMAL ENERGY USE IN HEATING AND COOLING NETWORKS IN EUROPE: STATE AND TRENDS

3.1 The heating and cooling sector as such

Heating and cooling (H&C) represent around 50% of European Union (EU) 's final energy consumption, as stated by the European Commission in its Communication" EU Strategy on Heating and Cooling". Thermal energy is the biggest energy end-use sector. Heat users quite often have specific demand profiles comprising issues of temperature, capacity, and timing. Therefore, a variety of applications and sources are required to cover this demand.

Heat temperatures can be classified as follows:

- Very low temperature below 30°C,
- Low temperature (between 30° C and 90° C);
- Medium temperature (between 90° C and 150° C)
- High temperature (between 150° C and 250° C)
- Very High temperature (above 250° C)

Technologies used should match as closely as possible the temperature levels required by the thermal energy demand, especially in cities for existing buildings requiring a network with medium temperature. Furthermore, it is important to distinguish between primary, final and useful energy when considering energy efficiency in buildings and to bear in mind that additional conversion steps are needed to convert a "final" form of energy into a "useful" form of energy. A distinction should be made between energy sources (e.g., gas, heating oil, biomass, geothermal, solar thermal or aerothermal), enablers or heat processing units (heat pumps, boilers, stoves, district heating) and end-users (households/residential, commercial/services, and industry).

The heating and cooling end-users are:

3.1.1 Residential sector

Energy demand for H&C in the residential sector is strongly dependent upon climatic conditions and follows a clear seasonal pattern. However, domestic hot water is essential in all climates. Capacity demand varies from only a few kW_{th} for small and well-insulated buildings, to some 100 kW_{th} for multi-apartment building blocks. Cooling demand is expected to increase, not only in Southern Europe but also in Central and Eastern Europe. Geothermal heating and cooling technologies can cover this demand, including through district heating and cooling.

3.1.2 Service sector

In the service sector, H&C demand is strongly influenced by the type of building and its use. Loads are typically higher, starting with some 10 kW_{th} to >1MW_{th} for larger installations. Space cooling and ventilation is almost a standard, while H&C loads can vary widely in a short timeframe. Geothermal heating and cooling technologies can cover this demand but must be rather flexible in capacity provided, adaptive to quick changes, and able to supply substantial amounts of cooling.

3.1.3 Industry

Industrial heat demand varies by temperature levels, sectors, etc. According to the study Ecoheatcool (from Euroheat & Power), around 30% of the industrial heat demand is required at temperatures below 100° C, for instance for washing, rinsing, and food preparation. Some heat is also used for space heating and on-site hot water preparation. Medium temperatures are required to evaporate or to dry. High temperatures are required for the manufacture of metals, ceramics, glass etc. Temperatures above 400°C can be created by using hot flue gases, electric induction and other combustion processes.

In less densely populated rural communities, heating and cooling is consumed by the following end-uses:

- Around 40% is consumed by households,
- A similar share for the industry,
- Services consumed around 15% of the H&C,
- The rest is divided between the agricultural sector and other sectors.

3.2 Heating and cooling networks

According to the EC Communication" EU Strategy on Heating and Cooling", Heating and cooling is largely dominated by fossil fuels (more than 80%). This sector is therefore heavily responsible for EU's Greenhouse Gase (GHG) emissions and its reliance on energy imports from unstable regions, with eight Member States (Finland, Lithuania, Latvia, Estonia, Czech Republic, Slovakia, Hungary, and Bulgaria) having more than 95 % of their total gas supplied by Russia.

The combination of measures such as increasing energy efficiency, fostering renewable heating and cooling technologies (RES) and including geothermal, are the only options to secure H&C supply with affordable renewable energy.

Using on-site harvested RES, heat and cold generation will become sustainable and secure with significant societal benefits by:

- *Improving EU's security of supply*: given the variety of RES for H&C, EU member states will further benefit from an increased security of supply through the local and diversified energy sources used, when compared with today's fossil fuel dominated energy mix.

- *Stabilising energy prices*: RHC technologies are able to provide a competitive alternative to fossil sources, and price volatility is reduced

- *Creating local and sustainable jobs and fostering the European industrial leadership*

- *Fostering sustainability*: As highlighted in the European Commission's plan REPOWEREU, RHC will be vital to decarbonisation of the EU's energy system.

Most of the heat consumed in cities lies in the buildings sector, mainly for space heating and domestic hot water. Addressing the building sector, and particularly the existing building stock, is therefore of crucial importance.

Buildings have enormous energy efficiency increase and decarbonisation potential, because Europe's building stock is old and mostly inefficient, with almost 40 % of houses built before

1950 (source BPIE). Buildings consume more than two thirds of the thermal energy in Europe. The sector is expanding, which is bound to increase its energy consumption. Around 60 % of building's heat is produced from natural gas, and heating oil or kerosene is still widely used in the residential sector. Moreover, the residential and tertiary sectors account for approximately 40 % of gross inland consumption of gas (Eurostat, 2022). This consists mainly of direct use for heating and domestic hot water preparation for households and commercial buildings (using individual or central boilers).

Therefore, reduction of energy consumption and the use of energy from renewable sources in the buildings sector constitute important measures needed to reduce the European Union's energy dependency and greenhouse gas emissions. These ambitions are consistent with the objectives of the Repower EU and EU Green Deal: energy savings, diversification of energy supplies, and accelerated roll-out of renewable energy to replace fossil fuels in homes, industry and power generation. It is necessary to lay down more concrete actions with a view to achieving the great unrealised potential for energy savings in buildings and reducing the large differences between Member States' results in this sector.

Geothermal technologies can be used for H&C in cities (figure 2). It can be installed for single buildings or building complexes: large office buildings, shopping malls, theatres, cinemas, congress, , apartments, hotels, or in networks for heat and/or cold: water-loop at low temperature (10-20 °C) and heat pumps for individual buildings; local heating/cooling network fed by geothermal and underground thermal energy storage in district heating/cooling (ATES/BTES).

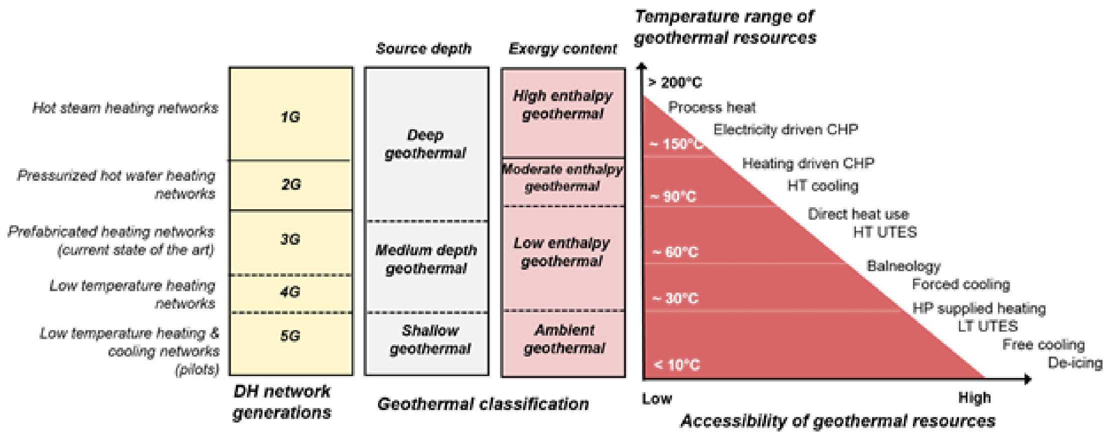

Figure 2: General scheme of the integration of geothermal technologies in district heating and cooling systems (Goetzl et al, 2022).

With around 10.000 European heat networks, district heating and cooling represents 12% of the European heat market, with over a third of DHC energy supplies from renewable and bioenergy sources. The share of district heating varies significantly from one region to another e.g., district heating is by far the most common heating solution in the traditionally cold-winter countries in North/Eastern Europe (Nordic and Baltic regions) whereas it still plays a minor role in Southern and most Western European countries (e.g., The Netherlands, United Kingdom or Ireland).

Overall, the largest district heating market in Europe is in Germany, followed by Poland and Sweden.

District heating sales, the actual amount of heat delivered to final customers is one of the key business indicators to assess the size of the sector. As shown by the graph below from EuroHeat&Power, district heating sales remaint constant during the previous decade.

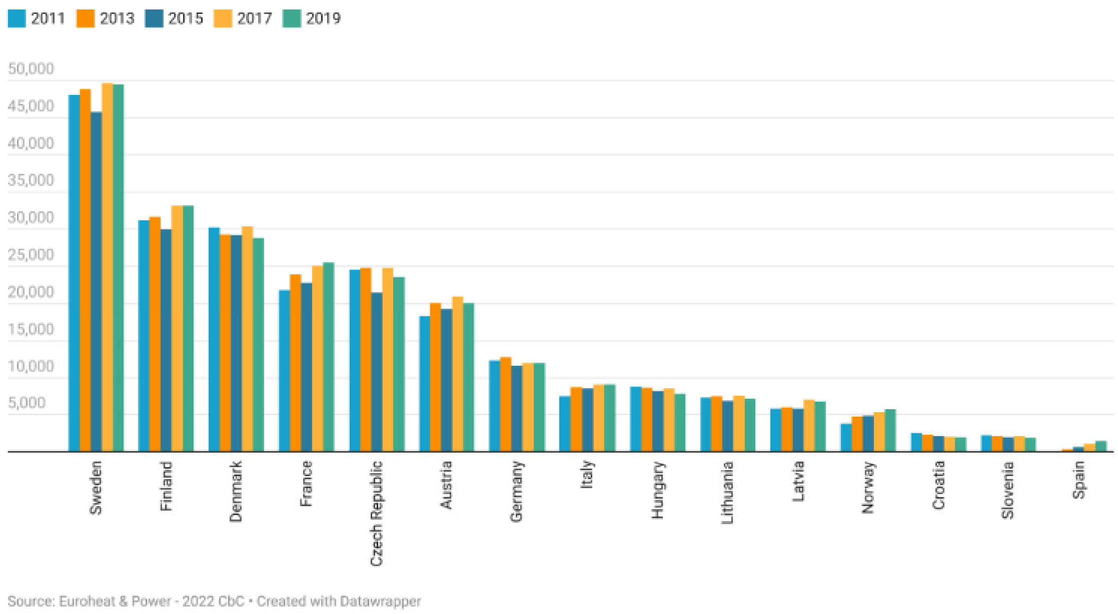

Figure 3: District heating sales to customers (in GWh) in some European countries, from 2011 to 2019

3.3 Geothermal energy supplied heating and cooling networks

3.3.1 Brief technological overview

Per definition, Geothermal Energy is the energy stored in the form of heat beneath the earth's surface (RES Directive, 2018). This energy can be found at different temperatures in the ground and the ground water, depending on local geology and depth.

With geothermal energy for heating and cooling, two main resource types are distinguished:

- The first one (very low temperature in the range of the annual mean air temperature on site, up to about 30 °C) is based on the relatively stable groundwater and ground temperatures at shallow depth (the limit is typically set at 400 m). Typically, heat pumps are used to extract energy from the ground and process the temperature to the level required by the heating systems.

- The second one (low and medium temperature, ranging from 30 °C to 150 °C) extracts the heat from ground and groundwater at higher temperature, and typically at greater depth, for supplying H&C directly.

- A third category, high temperature (high enthalpy) resources of well above 150 °C, is primarily used for electric power generation. However, residual heat from such applications can still provide energy for heating, and some high-temperature industrial processes could be supplied directly with heat from this type of resource.

Concerning the application side, a distinction can be made between systems using additional energy and devices to match the temperature requirements, and those using the geothermal heat directly:

- If the geothermal heat is at a level of temperature lower than the temperature required by the heating system, further system components are installed:
    - Heat pumps can be used to raise the temperature to the required level (ground source heat pumps, GSHP). In this case ground and ground water might also be used for cooling; by free-cooling in cases the right boundary conditions, or by using a heat pump as chiller if lower temperatures are required. Actual high-temperature heat pumps can offer up to 130 °C on the supply side whereby the efficiency decreases with increasing temperature spread.
    - The subsurface may also be used for heat or cold storage, UTES (Underground Thermal Energy Storage), e.g., for combined heating and cooling in commercial and institutional buildings
- If the geothermal heat is at a level of temperature compatible with the temperature required by the heating system, the energy from the ground or the ground water can be used directly (without any thermodynamic processing unit). Direct applications are found in:
    - district heating or combined heat and power facilities (CHP)
    - agriculture (horticulture, aquaculture, drying)
    - industrial processes
    - balneology (tourism)
    - absorption heat pumps for cooling purposes

Also, in the low to medium temperature range ‘Underground Thermal Energy Storage’ (UTES) is an option, making use of available surplus heat from building cooling or from heat and power cogeneration, or of renewable heat as from geothermal or solar thermal sources.

Currently, geothermal energy sources provide more than the equivalent of 7 million tonnes oil (Eurostat: Energy data 2020 edition) per year for heating and cooling in the European Union, equivalent to more than 15 GWth installed capacity, where geothermal Heat Pump systems contribute the largest part. But still the potential is huge.

Following current trends, in the European Union (EU-28), the contribution in 2021 amounted to around 40 GWth installed, corresponding to about 10 Mtoe. Combined Heat and Power (CHP) plants are marginal, with less than 1 GWth capacity for heating, but the development of new plants will provide further opportunities for CHP systems.

During the next 10 years, new geothermal combined heat and power plants with low temperature installations will be developed. CHP installations could provide heating at high temperature, suitable for energy intensive industry.

The technological challenges for an accelerated deployment of geothermal heating & cooling across Europe are to develop innovative solutions especially for refurbishing existing buildings, but also for zero and plus energy buildings, as the systems are easier to install and more efficient at low temperature for both heating & cooling.

Secondly, to develop geothermal district heating (and cooling, geoHC) systems in dense urban areas at low temperature, a planning at city levels is required.

Finally, the third goal is to contribute to the decarbonisation of industry by providing competitive solutions for heating & cooling.

Promising areas are the development of smart thermal grids with the building of new district heating & cooling networks (Geothermal District Heating & Cooling, with ca. 15-55 €-MWh, is one of the most competitive energy technologies; Ademe 2019), optimisation of existing networks, and the increase of new and innovative geothermal applications in transport, industry and agriculture. The first regions to develop will be those possessing the most accessible resources from an economic point of view, as well as higher grade resources where combined heat and power projects will be developed.

The graph 6 below shows how a geoHC ("Geothermie profonde") can be competitive: with a costs range between 15 and 55 €/MWh it appears to be cheaper than a gas boiler with a capacity higher than 3 MWth at a cost higher than 50 €/MWh.

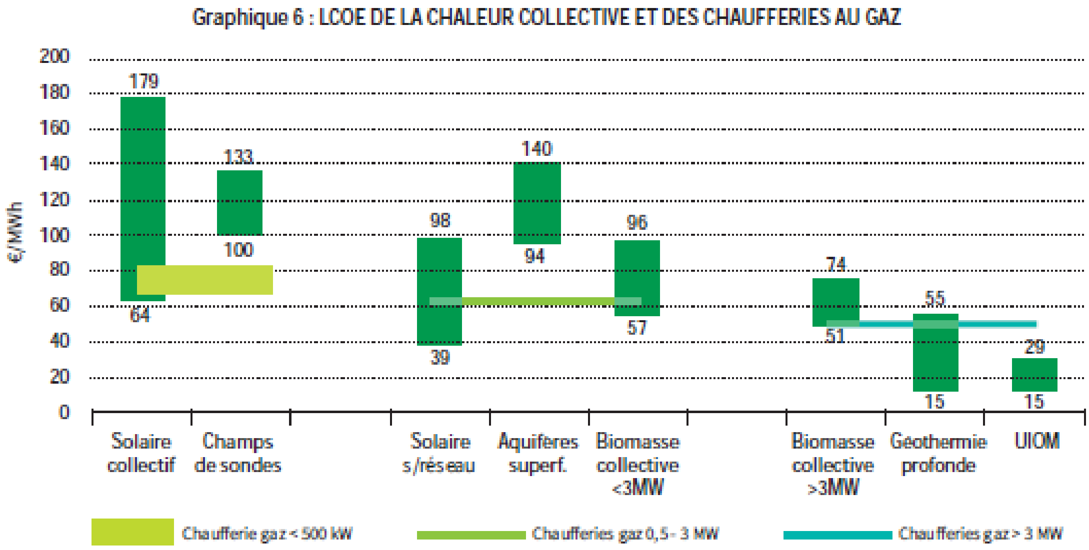

Figure 4: Lifecycle costing of heat for collective buildings, comparison with gas, in France (Ademe 2019)

To sum up, the main opportunities for deploying geothermal in cities are the following:

- Heating and cooling demand is close to the source of heat
- Potential for substantial reduction of energy demand and emissions is part of regional to national policies
- Geothermal energy integration onto multivalent H&C solutions
- Elevated temperatures in the underground under cities– favourable for heating, shallow geothermal can help reducing the excess heat in the subsurface, especially in shallow urban groundwater bodies, to improve the ecological conditions.

The main constraints would be the limited area available (for drilling works and placing geothermal heat exchangers), the mutual impact of shallow geothermal installation which must be strictly observed, regulated and controlled and environmental risks related to drilling following a massive increase of geothermal installations. As a consequence, urban areas will need to consider subsurface spatial plans in the future in order to avoid conflicts of interest and allow for sustainable and efficient use of the underground.

3.3.2 Smart cities and smart thermal grids

The coverage of the heating and cooling consumption in the smart cities must pass through smart thermal grids for answering the challenge of heterogeneity in urban infrastructure and energy demand, respectively to enable the energy transition into a low carbon economy. The approach we suggest is to have to step in this transition:

- A first generation would aim at retrofitting and decarbonising existing district heating and cooling systems and at developing off-grid RES systems

- A second generation would consist in deploying intelligent and interconnected thermal grids in areas where no DH systems have been installed so far, the main innovation would concern the use of low temperature systems, with a RES integration, a connection to electricity and the use of storage as a balancing facility. In this new generation the role of ICT will be primordial.

Smart Thermal grids will use renewable energy like geothermal to ensure a reliable and affordable heating and cooling supply to various customers. This is possible because they are:

- Flexible, adapting: In the short-term to the energy supply and demand situation. In the medium-term by adapting to the temperature level in existing networks and the installation of new distributed micro-networks. In the long-term by aligning the network development with urban planning.

- Intelligent: they are intelligently planned and operated and enable the end-user to interact with the heating and cooling system. They can, for instance, supply heating or cooling back to the network and to off-grid applications.

- Integrated: they are integrated in the whole urban energy system from a spatial point of view (related to urban planning parameters and processes), and from an energy system point of view (e.g. optimising the interfaces to other urban networks – electricity, sewage, waste, ICT, etc).

- Efficient: they are designed to achieve the highest overall efficiency of the energy system, by choosing the optimal combination of technologies and enable a maximum exploitation of available local energy resources by cascade usage.

- Competitive: They are cost effective in a way that makes operation affordable, both for consumers and businesses. They increase the cost efficiency of heating and cooling supply, and create opportunities for customers to participate.

- Sizable: These systems can be both applied for neighbourhood level or city-wide, according to the demand of heat and cold.

Smart grids also require a rethinking of network topographies leaving the concept of structured, hierarchical networks behind. As indicated in the figure below, connected smart networks harvest multiple sources and sinks of heat and allow for 'meshing' by applying heat exchangers. Meshed networks might follow a temperature cascade (see figure below, "cascade scheme" or exchange heat in an unstructured way at similar temperature levels (see figure below "mesh pattern").

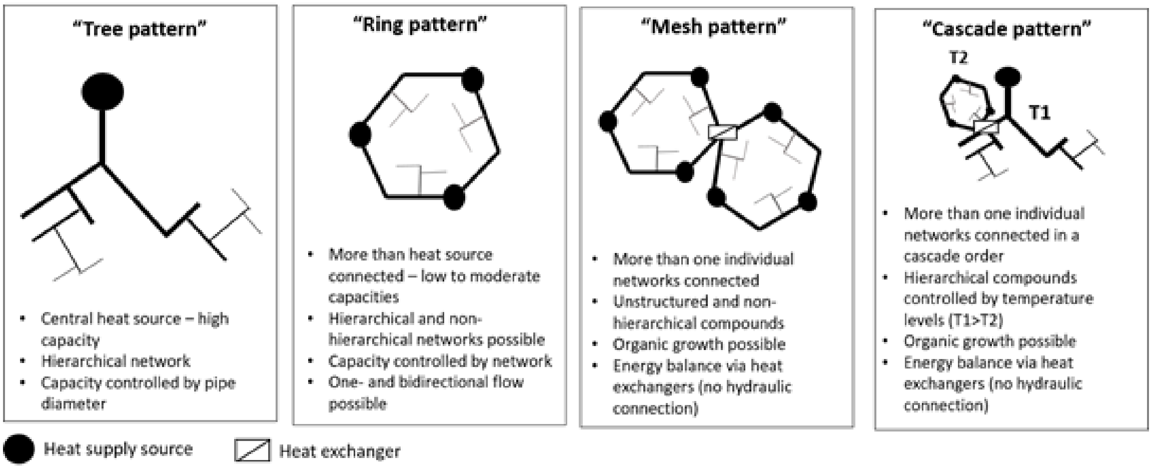

Figure 5: The evolution of the heating and cooling network topographies offering vital chances for a better integration of geothermal energy (Goetzl et al, 2023 – in press).

3.3.3 Market development: trends and prospects

The year 2021 marks the end of a transition period for the European geothermal district heating and cooling sector. The COVID-19 pandemic had a negative impact in 2020, leading to the delay of several projects and the slowdown of project commissioning, from a year 2019 which was already relatively slow. 13 new geothermal district heating and cooling were commissioned in 2021, for a total of more than 154 MW_{th} of new capacity (EGEC market report, 2021). The new systems were mainly commissioned in the Netherlands and France (3 projects respectively), with France representing more than a third the new added capacity (51.5 MW_{th}). A major milestone in the Netherlands however is the commissioning of a new geothermal district heating system focused on heating buildings instead of greenhouses. Other countries commissioning new systems include Iceland which continues to expand its use of geothermal energy for heating, Germany, Poland or Switzerland. Moreover, several emerging geothermal markets have seen the commissioning of new geothermal district heating and cooling systems, notably Finland which is commissioning a geothermal cooling project in 2021.

The total installed geothermal district heating and cooling capacity reached 5.6 GW_{th} in Europe in 2021, 2.2 GW_{th} in the EU, spread out over 364 and 262 geothermal district heating and cooling systems, respectively. After several years of declining numbers of new geothermal district heating and cooling system, 2021 marks a return to a growth. Compared to 9 geothermal heating and cooling networks commissioned in 2020, 2021 represents nearly a 50% increase and a returned to deployment levels last observed during the middle of the past decade.

3.3.3.1 Ongoing trends and prospects in coming years

The European geothermal district heating and cooling is evolving towards a greater diversification. Forces in the market and high-level policy pressures are pushing more and more local authorities and businesses to plan for geothermal district heating and cooling projects or for use in the industry. Moreover, the adoption of innovative technologies in geothermal project development – but also for the use of the geothermal energy in buildings for instance – is contributing to improving the economics of various types of projects in various areas. This is also true in areas where geothermal uses for district heating and cooling is not necessarily targeting medium to high temperature levels, but where the focus is on scaling up geothermal heat pumps at low- to ultra-low source temperature levels. Geothermal projects are quickly diversifying in their nature (more diverse range of target temperatures, cooling become a greater component of the project development), their uses (with a greater focus on 5th generation district heating, uses of industry), and in their business models.

The energy price crisis is a major driver of policy making and investment decisions in renewable heating and cooling projects throughout Europe. This crisis highlights the vulnerability of the EU to gas supply disruption, and the disruption that high heating bills creates in many European economies. The importance of the heating and cooling sector in the economy has become starker than before from the beginning of the fall 2021 and the first months of 2022. Households have been confronted with dramatically increased heating bills, leading to dramatic social consequences, and putting tremendous strain on public budgets. Also industry faces the challenge of tremendous increasing cost for their productions and therefore looking for alternative energy sources with lower and secure price levels.

Geothermal and renewable energy have therefore been the focus of more and more attention from local authorities, energy suppliers, industries and national governments. In Europe, we have seen a renewal in the planning of new projects and various high-level commitments to geothermal district heating and cooling. After several lacklustre years for the geothermal district heating and cooling sector, 2021 has seen the announcement of a new geothermal risk mitigation scheme in Hungary, while several other countries are exploring the best means to implement such a scheme for their national markets. The European Commission also announced risk mitigation schemes, notably for geothermal energy, as a core measure to accelerate the deployment of renewable heating and cooling in its proposal to revise the Renewable Energy Directive. In the aftermath of the COVID 19 pandemic, several European countries have been looking at geothermal district heating and cooling as one of their priorities in their recovery investments.

On top of national policy support towards geothermal district heating and cooling, we witness a shift from public to private market actors. During the year, several major energy companies have entered the European geothermal energy sector, either via project acquisition, investing equity in existing developers and projects or seeding their own geothermal “start-up” companies. For instance, Shell, E.ON, Equinor, Baker Hugues, Schlumberger or OMV are among the oil and gas companies and utilities intensifying their presence in the European geothermal district heating and cooling market. Meanwhile, other companies already heavily invested in the sector such as Engie and its subsidiaries continue their development. A general trend during the years 2020 and 2021 was an important attractivity of the geothermal sector for companies traditionally focused on the oil and gas sector, especially for subsurface service and manufacturing. This trend is the result of low hydrocarbon prices during most of 2020 and 2021, but also hinges on the increasing regulatory risk for oil and gas activities in Europe, as well as the reduction in uncertainty for the prospects of geothermal energy as the market and policy signals towards the fuel switch in the heating and cooling sector are increasingly robust. In the first half of 2022, despite increased hydrocarbon prices, diversification towards geothermal energy continues to be an attractive prospect for many actors of these industries – at least in a medium to long term perspective.

Over the coming years, demand for geothermal district heating and cooling is likely to increase significantly if there is the proper policy and awareness raising framework. The combined pressure of the political imperative to decarbonise, and the renewed understanding of the economic and social impact of dependency on natural gas imports for heating and cooling is leading European countries to intensify the development of technologies such as geothermal district heating and cooling. However, if traditional barriers to development remain – including lack of regulatory framework, suitable risk mitigation, local planning and knowledge of the resource – the market for geothermal district heating and cooling may be challenged to accelerate rapidly.

3.3.3.2 District cooling: an emerging market for geothermal energy projects

Europe is not cooled very much. Compared to economies such as the USA, China or Japan, European buildings are largely not equipped with cooling systems. Even in the tertiary sector, cooling systems are not ubiquitous – although widespread. This is changing rapidly however, and cooling is fast become a core priority of energy policy for European countries (RES Directive 2018).

The 2021 energy price crisis first manifested during the summer in Spain, where spikes in electricity needs to face a heat wave drove electricity prices to extremely high level because of a low availability of gas (and gas power plants due to maintenance) to provide the needed flexibility. This case highlights the growing importance of cooling in European economies, and the rapid progression of this energy need in the face of evolving building codes, technologies, uses and expectations, but also as an aging population is preparing itself to cope with more intense and frequent heat waves. Moreover, cooling for various processes is also an important market for geothermal developers, especially for the provision of cooling to the IT sector, notably data centres.

The commissioning of the Pori geothermal district cooling system in Finland in 2021 (EGEC market report) is an important milestone highlighting the rise of large-scale geothermal cooling as a major policy, technology and economic challenge. The development of this project is a direct consequence of the maturity of the shallow geothermal industry in Finland, but also the availability of integrated infrastructure planning to mobile investments towards the direct adoption of renewable cooling. In Spain meanwhile, the developer Hunosa (Ruggero Bertani European Geothermal Innovation Award 2021) is planning integrated geothermal district heating and cooling projects. Beyond the ability to cover more energy needs (and increase the capacity factor of the project) the provision of both heating and cooling can be a mean to ensure the stability of the geothermal resource, especially for projects relying on heat pumps. Geothermal cooling can also be produced from higher temperature geothermal brines, although fewer projects are structured around this focus. In Munich, Germany however, SWM has invested towards extension of its district cooling network The district cooling network is based on shallow geothermal source like groundwater and now further extended by geothermal cooling via absorption cooling.

The important market potential for geothermal district cooling is not only a function of the changing climate and the requirements Europeans have of their building services. The recent adoption of a methodology to define renewable cooling as part of the implementation of the Renewable Energy Directive (adopted in 2018) is one of the many regulatory drivers appearing throughout Europe, and likely the most susceptible to drive investors, local authorities and planners to consider the role of technologies such as geothermal district cooling. This methodology, because it focuses on maximising the amount of renewable cooling (i.e., the amount of heat that can be extracted with the least possible amount of auxiliary energy) is notably strongly incentivising European countries to promote geocooling, free cooling, and more generally geothermal cooling.

4 KEY MARKET DRIVERS

4.1 Overview of market drivers

List of all Market drivers identified for the consultation:

I. Technical

Delay in the supply materials (equipments or components) for developing a geoHC	
	Casing materials
	Rigs availability
	Pumps
	Heat pumps
	Piping

Technical and environmental risks	
	Identification / Exploration
	Drilling / Testing
	Exploitation / Development
	Post-closure

New technological developments	
	Heat Pumps for geoHC
	Deep Closed loop systems
	Drilling design
	New heating/cooling distribution systems
	Industrial process heat at low-medium temperature

II. Policy and Regulation

Legislations and policies	
	EU and national Plans & Roadmaps, regional and cities RES targets (e.g., SEAPs)
	Policy Signals: References to geothermal or DH in speeches and communiques

	Energy and climate policies

Market conditions	
	Gas market
	Electricity market
	Availability of local, renewable energy and decarbonisation plans
	Local authority planning
	DSO management of grids and heating systems

Regulations/permitting	
	Provisions on liberalisation of the DH market
	Definition of efficient DH
	Permitting for geothermal: level of complexity and duration (e.g., one stop shop)
	Geological data availability

Support schemes	
	Risk mitigation scheme
	Investment fund
	Operational aid
	Awareness campaigns

III. Socio-economic conditions

Business Models	
	Legal statutes of the project developer/operator
	Heat sales
	PPP and heat purchase agreement
	Taxation and carbon pricing
	Investment Risk associated

	Regional / national income levels, GDP levels – availability of public/private investment capital
	Regional energy supply profile – cost profile of competitive heating / cooling supply technologies

Engagement and Acceptance	
	Stakeholder support: local communities (Citizens, residents, future clients), policy makers
	Stakeholder acceptance: resilience towards risks and impact, which appeared at other locations
	Environmental impact, Noise, Disturbances

To select the key market drivers, the analysis is based on the Key Performance Indicators as presented in chapter 2.2.3.

The results gave a score for each market drivers and the key market drivers are the ones having both (strong and medium) relevance and (hindering and supportive) impact. It means it includes barriers and opportunities.

The key market drivers are then classified in two categories: hindering or supportive.

4.2 Detailed presentation of key market drivers

I. Technical aspects:

a) Hindering factors:

The key technical market drivers hindering the development of a geothermal district heating projects are:

- **Casing materials: strong impact**

For the geoDH in the Paris Basin, the supply chain was partially interrupted since 2020; for the casing materials. The supply chain of geothermal equipment and components is a high concern for future geoDH projects, an industrial strategy should be developed to remove this temporary barrier and sure equipments and components are provided.

- **Resource Identification / Exploration: strong impact**

Identifying the resource and the well to drill is crucial. In the geoHC sector, success rates are of 50% in green fields and about 90% in already operated areas (EGC2016 paper: Deep drilling costs reduction). A dry well is a stopper, but unsuccessful project refer more to a partial failure inn terms of temperature reached, flow rate or permeability obtained.

- **Drilling / Testing: strong impact**

50% of the full projects costs comes from this phase (EGC2016 paper: Deep drilling costs reduction). A drilling cost includes the following elements:

▪ Drilling rig with all equipment incl. BOP

▪ Drilling tools incl. bits, fishing tools etc.

▪ Materials incl. cement, mud etc.

▪ Drillers : drilling crew, drilling supervisor etc.

They operate the following works:

▪ Rig mobilisation

▪ Drilling incl. directional drilling services

▪ Mud engineering

▪ Casing run

▪ Casing cementing

- **Rigs availability: medium to strong impact according to the respective country**

For deep drillings, it includes the lack of predictability regarding the start of deep well drilling. It is often due to the delay in licensing procedures. It seems there are not enough drilling rigs in Europe to tackle future issues when geothermal interest increases). The lack of competition between drilling companies comes from the lack fluidity in the market (national regulations, etc.). The drilling price is also too much driven by the oil and gas industry due to higher revenues.

Regarding shallow drillings, the lack of drillers and machinery is already hindering market development in Europe. There is a need to train qualified drilling staff. Regulations and bureaucratic hurdles for drilling in some EU countries represent further barriers.

- **Pumps: medium impact, depend on countries**

In Regions such as Bavaria, the lifetime of the pumps (ESP: electrical-submersible pumps) has been an issue for many years. They were lasing just some months. A new pump developed by Baker Hugues helps now t have a lifetime higher than 2 years.

- **Piping: medium impact, depend on countries**

The source of geothermal fluid for a H&C use application is often located some distance away from the user. This requires a transmission pipeline to transport the geothermal fluid. Piping materials must provide corrosion resistance, chemical resistance, temperature resistance, flexibility, impact resistance, resistance to slow crack growth, and long-term hydrostatic strength (pressure capability).

Both metallic and nonmetallic piping can be considered for geothermal applications. Availability and prices of these raw materials have impacted geothermal.

- **Exploitation / Development: medium impact**

The costs of Operation & Maintenance (O&M) for geoHC represent about 2% of capital costs. It includes:

• Personnel costs for the following actions: remote control, regular routine inspections, start up / shutdown of the plant and during maintenance

• Routine maintenance costs: replace or clean equipments such as valves, pumps, the generator, switchgear etc

• Consumables for the operation: filters, oil and chemicals.

About 1 to 2 weeks scheduled shutdowns are foreseen each year for general maintenance and 5-8 weeks every 3-6 years for major maintenance. This influence the maintenance cost but also the expected utilization hours.

The survey revealed that post closure phase is not seen as a strong factor.

Availability of large heat pumps is not seen has a problem today. Many manufacturers are already in the market or are stepping into it as such systems are required by other industries too.

b) Supportive factors

None of the new technology developments are planned to have a strong impact, but some of these innovations could impact relatively the market:

- **Large heat pumps and with higher temperature range**
- **Deep closed loop systems**
- **Drilling design**
- **New heating/cooling distribution systems**

More details can be found in the publications of the ETIP geothermal.

II. Policy and Regulations:

a) Hindering factors:

The strongest hindering factors are:

- **the Gas market**

European and National regulations relating to the Internal Market for Gas give it a dominant market position at the expense of competition from renewable heating and cooling services, particularly from geothermal energy. Long-term gas supply and consumption contracts prevent measures to implement EU legislation on energy renovations in buildings. Energy refurbishments are put at a disadvantage as other fossil fuel consumers are threatened by price increases to compensate for the loss of income from lower consumption. The EU, through the Connecting Europe Facility and the Trans-European Networks for Energy (TEN-E), supports investment in transboundary fossil heating infrastructure at the expense of European heating reservoirs and basins which provide domestic heating and cooling to numerous Member States across the EU. There is no uniform EU carbon price on gas and other fossil fuel heating and cooling supplies for buildings. It is essential that the leakage of methane into the atmosphere from fossil fuel imports as well as CO_2 emissions fossil heat usage are subjected to a uniform EU carbon price, which is sufficiently robust to drive investment in renewable heating solutions as well as enabling Member States to set more stringent national carbon prices.

- **Permitting for geothermal: level of complexity and duration (e.g., one stop shop**

The lack of harmonised guidance on licensing and permitting is a significant barrier to the deployment of geothermal and could jeopardise achievement of geoHC project.

The following factors contribute to delays:

• Complexity: Geothermal energy is regulated by many entities and regulations, dealing with mining in the underground and the surface as an industrial application, but also for the environmental, water and energy regulations. As illustrated in the delegated acts on EU taxonomy, geothermal resource is combined with several engines: turbine for Combined heat and power plants, District heating and Cooling systems, Heat pumps, Underground Thermal Energy Storage. Each engine has additional regulations and technical standards.

• Capacity: Skillsets required for geothermal assessment is often underutilised or there is a lack of qualified professionals at national, regional and local levels to undertake the necessary checks and approvals. This is compounded by a lack of harmonised terminology sometimes within a Member State and across the internal market. These factors create avoidable administrative delays and bottlenecks.

• Engagement: There is a lack of consistency and clarity in the formation required from project developers which cases delay. Furthermore, transparent and time sensitive processes are required to manage potential legal challenges and subsequent mediation in an application.

The permit-granting process for geothermal technologies is different to all other Renewable Energy Sources (RES). This is because geothermal provides both small and large-scale applications to three final energy consuming sectors – heating, cooling and power generation. Large-scale geothermal energy requires two permits – the first for exploration and the second for exploitation of the renewable resource. Small-scale geothermal energy requires a tri-zonal approach to permitting, sometimes referred to as a 'traffic light system' indicating zones where a simple notification is required, zones where a permit is required and where drilling is prohibited.

- **Geological data availability**

The acquisition of geological data can also be a barrier when the data purchase is too expensive and when the confidentiality block the communication of the data. In the case of publicly funded projects, data protection is rather short but for private developers the confidentiality can remain for several years, with copy to the geological surveys. A Best practice comes from The Netherlands where geological data become publicly available after a short period. Access to geological information from previous exploration activities (e.g. oil and gas) is crucial.

b) Supportive factors:

The stronger supportive factors include:

- **Local sustainable energy action plans (e.g. SEAPs)**

Municipalities showing ambition in terms of renewable energy deployment in their cities, are a favourable condition for a geoHC. Heating and cooling for buildings and industry being the highest share of their energy consumption, cities must tackle this issue in priority. It is also the sector emitting high share of GHG and on which concerns about security of energy supply are high.

Sustainable energy action plans should plan at city level the decarbonisation of the h&c consumption, for which h&c networks are a solution to decarbonise at large scale.

- **Local authority urban planning**

The deployment of a h&c network in a city or a district of a city requires urban planning. The design of the h&c system is managed by the local authority. The availability of an existing infrastructure to deploy geothermal HC networks is an enabler to develop geoHC.

- **EU and national Plans & Roadmaps, regional and local RES targets**

RES targets decided at EU or National levels provides a positive signal to regional and cities to show also ambition in developing renewable energy. The 2030 H&C targets (art.23 of RES Directive) decided by the EU, is feeding into the National Energy and Climate Plans.EU Members states are currently preparing updates of NECPs for mid-2023. They must also detail the measures to reach these targets. Provisions to deploy geoHC must be presented. Regions and municipalities might have stronger goals and might be more specific for deploying locally RES.

- **Public awareness campaign:**

Well-designed campaigns can motivate people to reduce their energy use. According to the IEA, many lessons have been learned on how to design awareness and behaviour change campaigns to achieve maximum effect. It is clear that good design matters – simply transmitting information will not change behaviour and poorly designed campaigns often do not deliver their expected impact. The choice of message, the tone, how the campaign is designed and the transmission channels, can all fundamentally affect the resulting impact on behaviour. Four key concepts are crucial:

Getting the message right

Getting the message across

Combining information with behavioural insights

Campaigns for a crisis context

On geoHC, there is clearly a lack of visibility, more attention on this technology is needed.

Regarding the other market drivers on Policy and Regulations have less impact.

For example, the electricity market is seen neutral or supportive. Current high electricity prices make geoHC assisted by heat pumps less competitive, but less efficient electrical heat devices also lose competitiveness.

Policy Signals such as References to geothermal or DH in speeches of politicians and Energy and climate policies are seen as rather supportive such as the "Statement of tripling geothermal heat until 2030" (mentioned in solar strategy).

It is to notice that Provisions on liberalisation of the DH market are viewed both as hindering and supportive.

c) The case of support schemes

All support schemes presented as market drivers have been evaluated with a strong supportive impact. “The right scheme for the right market maturity.” This could be the maxim for financing geothermal energy projects as the geothermal sector is far from being uniform in terms of maturity and technology readiness across geographical, technology lines and uses. Suitable support schemes and financial instruments allow for the cost reductions necessary for a technology to reach the market and for the consolidation of an emerging renewable industry in a market that remains very favourable to incumbent fossil technologies.

- **Risk mitigation scheme:**

Exploration is necessary to identify potential geothermal resources. However, beyond exploration, the bankability of a geothermal project is threatened by a resource risk:

- The short-term risk of not finding an economically sustainable geothermal resource after drilling;

- The long-term risk of the geothermal resource naturally depleting rendering its exploitation economically unprofitable.

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

- **Investment aid:**

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

- Direct grant financing happens when a grant is provided to a project in order to finance it. The money awarded is given to the project operator without financial conditionality (such as equity or reimbursement), but some conditions may be set to ensure the money is properly used. The Heat Fund in France is a major and successful example of a large scale facility providing grants to geothermal energy projects (usually at a larger scale) in order to correct the market imbalances due to the dominant position of gas or nuclear energy in the heat market.

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

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

In general, in the European Union, grants do not cover the entirety of the funding needs of a projects and other sources of capital would often be needed for 50% of the total investment costs. However, grants are usually designed to decrease the cost of capital – which increases with the risk. This is intrinsically the case when part of the project is funded for “free”. The fact that grants can come in at the early stages of the project to provide funding for project development (ELENA, EHIA…) or for high risk stages of the project (such as drilling an exploratory well for a geothermal project) can provide benefits in terms of cost of capital that far outweigh the actual size of the grant. The European Union, in the name of a more efficient use of public funding, is increasingly developing financial instruments that use grants as a risk mitigation tool, developing repayable or convertible grants, or funding crucial parts of projects.

- **Operational aid:**

In some European markets, the implementation of a feed-in-tariff for renewable heating and cooling has been a successful strategy to support the deployment of geothermal energy projects. The feed-in-tariff or premium (FiT/FiP) for heating and cooling has been a crucial factor in enabling the rapid deployment of privately led geothermal heating and cooling projects in the Netherlands over the past decade. When adequately targeted, feed-in-tariffs can be a winning solution in the heating and cooling sector as well as in the electricity sector. The Dutch case shows that tailoring the schemes to SMEs with high energy costs can be beneficial: such actors have the incentive to benefit from the tariffs and the capacity to invest in order to recoup their costs in the short to medium term. Such private investor-led investments (even when a FiT/FiP is available) however requires the availability of some form of geothermal derisking scheme to incentivize SME developers to deploy geothermal systems.

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

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

III. Socio-economic conditions

The majority of the socio-economic factors influencing the business models are seen strong but neutral (nor supportive neither hindering the project development, but requiring an adaptation). It includes:

- **The legal statutes of the project developer/operator:** being a local public energy company, a public private partnership, a private Utility…

- **Heat sales and pricing:** The type of client determines the h&c demand profile in terms of temperature and load. The metering of the heat consumed at the supplier and customer interface for billing purposes of DH is quite highly regulated in most EU countries, as a result of the European Energy Efficiency Directive (2018/2002, EED). Some countries in the EU defined some form of price rules and price control with price caps, price adjustment clause etc.

- **Heat purchase agreement:** A HPA is an heating and or cooling purchase agreement, concluded directly between an energy producer and a consumer company. In recent years, this form of purchase agreement, historically reserved for very large consumers of grey electricity, has been developed more widely around the world for all types of consumers, especially those wishing to be supplied directly with renewable electricity. The company makes a commitment to a renewable energy developer or energy supplier to purchase a given volume of electricity at a predefined price (fixed, indexed, bounded, etc.) over a period of 3 to 20 years. In return, it receives the energy produced as well as the associated guarantees of origin, directly participating in the creation of new renewable energy assets or in the continuity of operation of assets that are no longer under the purchase obligation. In the case of green heat, the production assets (biomass boiler, biomass cogeneration, waste treatment plant, geothermal system, solar thermal...) are necessarily located near the site or on the site. They are connected via a dedicated hot water or steam network.

- **Taxation and carbon pricing:** A different taxation of electricity and gas is seen has a driver, especially when gas is less taxed. Lower VAT rate for geoHC is seen as a supportive element. Lack of carbon pricing in the heat sector hampered the development of geoHC. EU legislators recently agreed to introduce a carbon price on buildings and road transport fuels. The new carbon price will apply to petrol, diesel and heating fuels such as natural gas.

Two macro-economic factors influencing the business models with a medium impact are:

- **Regional / national income levels, GDPs – availability of public/private investment capital:** In general, the presence of a geoHC industry and financial community in the country is enabling the development of further projects. Lessons learnt on financing can be shared. Being capital intensive, geoHC required large amount of funding. Some rich municipalities support the project development.

- **Regional energy supply profile – cost profile of competitive heating / cooling supply technologies:** the energy mix of a region and/or a city, but also the presence or not of a

DH infrastructure, influence the decision to develop a geoHC. Of course if a geoHC it already in operation in the region, experiences and geological data can be shared.

Regarding stakeholders engagement and acceptance, one factor is seen strongly hindering project development:

- **Environmental impact, Noise, Disturbances:** The main obstacles in terms of public acceptance is about environmental risks and impacts. Two of them have been highlighted: noise during drilling operations and disturbances during construction of geoHC plants. It is important that both issues are manageable.

Stakeholder support is important, especially coming from local communities (Citizens, residents, future clients) and local policy makers. Stakeholder acceptance, i.e. resilience towards risks associated with geoHC, is seen as a strong market driver:

- **Stakeholder support from local communities (Citizens, residents, future clients), policy makers:** It helps the project to start its development. The communication is crucial. Support can take several forms: financial (purchase agreement, crowdfunding, heat contracts...), political and regulatory (permitting, decisions...), promotional (advertising, awareness...)

- **Stakeholder acceptance and resilience towards risks:** this factor is seen neutral in terms of impact. Public acceptance is required to develop a project. Risks must be mapped and well communicated.

5 CONCLUSIONS

Geothermal energy has the characteristics to play a crucial role in our future energy mix: decarbonised, providing affordable energy for society, and allowing competitiveness of European industry.

Key market drivers, highlighted in chapter 4, show technical, policy and regulatory, and socio-economic strong hindering factors.

For the issues regarding the supply chain (casing materials, drilling rigs..), a proper geothermal industrial action plan must be launched.

On policies and regulations, more attention to geothermal has to be given, and key legislation adopted in the EU Green Deal and the RepowerEU Plan must be implemented.

Concerning the socio-economic aspects, several factors are influencing the business models. Innovative business models will overcome the barriers identified.

Regarding stakeholders engagement and acceptance, one factor is seen strongly hindering project development: Environmental impact, Noise, Disturbances. Therefore, stakeholder engagement and public acceptance is seen important but not key.

Geothermal heating and cooling networks (geoHC) can supply energy at different temperatures (low or high temperature), at different loads (it can be base load and flexible) and for different demands (heat and cold: starting around 500 kW_{th} to a tenth of MW_{th}). Geothermal is a renewable energy source which is local, manageable as well as scalable and flexible. It should be integrated in a regional approach which reduces costs for society (system costs: infrastructures and storage facilities, and externalities, GHG emissions etc.) and improves local security of supply. Smart thermal grids will develop with geothermal as a key technology, as depicted in the figure 6 below.

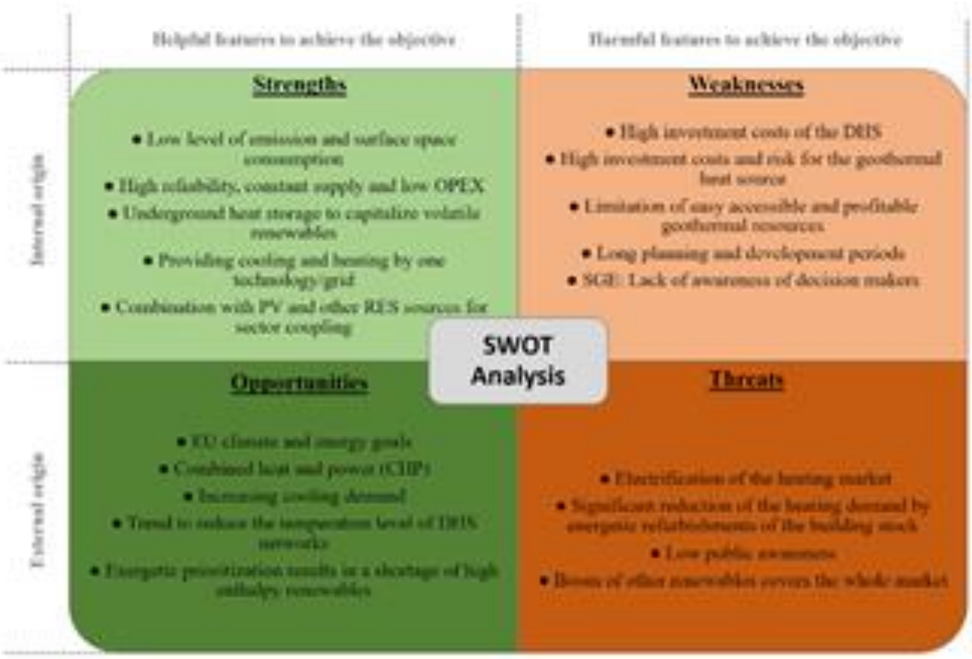

Figure 6: SWOT analysis linked to the integration of geothermal energy in heating and cooling networks, based on the outcomes of a Geothermal-DHC workshop in 2020. (taken from EGC paper of Goetzl at al, 2022).

The next stage is then to go towards a full energy system integration in the cities. It means firstly a combination of heat/cold and electricity, with for example storing excess electricity in form of heat. This combined energy grid will also be integrated with communication technologies using common infrastructure. A link with the transport sector is also planned with electric cars as power storage.

The key issues to make smart energy grids work are to develop the right system architecture and to develop the operation strategies and control hardware and software.

6 REFERENCES

EGEC: EGEC Market report 2021.

GEODH, GeoDH Final Report, (2014), available at www.geodh.eu.

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

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

EGC paper of Goetzl at al, 2022 "COST Action Geothermal-DHC - Roadmaps for integrating geothermal energy in its full technological spectrum into heating and cooling networks across Europe"

IPCC, 2014: Summary for Policymakers

EC Communication (2016) " EU Strategy on Heating and Cooling"

IEA (2022), District Heating, IEA, Paris https://www.iea.org/reports/district-heating, License: CC BY 4.0

Stichting Platform Geothermie, DAGO, Stichting Warmtenetwerk & EBN (2018): Master Plan Geothermal Energy in the Netherlands.

7 ANNEX

Summary of the answer to the experts consultation.

Click on the active table below to have it with a large size:

- https://www.egec.org/wp-content/uploads/2023/04/Status-report-on-key-market-drivers-related-to-the-implementation-of-geothermal-Heating-and-Cooling-network_-public-answers.xlsx

Technical // Delay in the supply materials

	Casing materials - Impact	Casing materials - Relevance	Rigs availability - Impact	Rigs availability - Relevance	Pumps - Impact	Pumps - Relevance	Heat pumps - Impact	Heat pumps - Relevance	Piping - Impact	Piping - Relevance
Results	2.1 Hindering	4 Strong	2 Hindering	4 Medium-Strong	2 Hindering - Neutral	3 Medium	2 Hindering - Neutral	3 Low - Medium	2 Hindering - Neutral	3 Medium

Technical // Technical and environmental risks

	Identification / Exploration - Impact	Identification / Exploration - Relevance	Drilling / Testing - Impact	Drilling / Testing - Relevance	Exploitation / Development - Impact	Exploitation / Development - Relevance	Post-closure - Impact	Post-closure - Relevance
Results	2.4 Hindering - Neutral	4 Strong	2 Hindering	4 Strong	2 Hindering - Neutral	3.3 Medium	3 Neutral	3 Low - Medium

Technical // New technological developments

	Heat Pumps - Impact	Heat Pumps - Relevance	Closed loop systems - Impact	Closed loop systems - Relevance	Drilling design - Impact	Drilling design - Relevance	New heating systems - Impact	New heating systems - Relevance	Industrial process heat at low-medium temperature - Impact	Industrial process heat at low-medium temperature - Relevance
Results	3.3 Neutral - Supportive	3 Medium	3 Neutral - Supportive	3 Medium	3 Neutral	3.3 Medium - Strong	3 Neutral - Supportive	3 Medium	3 Neutral	3 Medium

Policy and Regulation // Market conditions

	Gas market - Impact	Gas market - Relevance	Electricity market - Impact	Electricity market - Relevance	Availability of local, renewable energy and decarbonisation plans - Impact	Availability of local, renewable energy and decarbonisation plans - Relevance	Local authority planning - Impact	Local authority planning - Relevance	DSO management of grids and heating systems - Impact	DSO management of grids and heating systems - Relevance
Results	3 Hindering - Supportive	4 Strong	3 Neutral - Supportive	4 Strong	3 Neutral - Supportive	3.5 Medium - Strong	4 Supportive	4 Strong	3 Neutral - Supportive	3 Medium

Policy and Regulation // Legislations and policies

	EU and national Plans & Roadmaps, regional and cities RES targets (e.g. SEAPs) - Impact	EU and national Plans & Roadmaps, regional and cities RES targets (e.g. SEAPs) - Relevance	Policy Signals: References to geothermal or DH in speeches - Impact	Policy Signals: References to geothermal or DH in speeches - Relevance	Energy and climate policies - Impact	Energy and climate policies - Relevance
Results	4 Supportive	3 Strong	4 Supportive	3 Medium - Strong	4 Supportive	3.6 Medium - Strong

Policy and Regulation // Regulations/permitting

	Provisions on liberalisation of the DH market - Impact	Provisions on liberalisation of the DH market - Relevance	Definition of efficient DH - Impact	Definition of efficient DH - Relevance	Permitting for geothermal: level of complexity and duration (e.g., one stop shop) - Impact	Permitting for geothermal: level of complexity and duration (e.g., one stop shop) - Relevance	Geological data availability - Impact	Geological data availability - Relevance
Results	3.2 Hindering - Supportive	4 Medium - Strong	3 Neutral - Supportive	3 Medium	3 Hindering - Neutral	3.7 Stong	3 Hindering - Neutral	4 Strong

Policy and Regulation // Support schemes

	Risk mitigation scheme - Impact	Risk mitigation scheme - Relevance	Investment fund - Impact	Investment fund - Relevance	Operational aid - Impact	Operational aid - Relevance	Awareness campaign - Impact	Awareness campaign - Relevance
Results	3.2 Neutral	4 Strong	3 Neutral	4 Strong	4 Strong	3.7 Strong	4 Supportive	4 Strong

Socio-economic conditions // Business Models

	Legal statutes of the project developer/operator - Impact	Legal statutes of the project developer/operator - Relevance	Heat sales - Impact	Heat sales - Relevance	PPP and heat purchase agreement - Impact	PPP and heat purchase agreement - Relevance	Taxation and carbon pricing - Impact	Taxation and carbon pricing - Relevance	Investment Risk associated - Impact	Investment Risk associated - Relevance	Regional / national income levels, GDPs – availability of public/private investment capital - Impact	Regional / national income levels, GDPs – availability of public/private investment capital - Relevance	Regional energy supply profile – cost profile of competitive heating / cooling supply technologies - Impact	Regional energy supply profile – cost profile of competitive heating / cooling supply technologies - Relevance
Results	3.2 Neutral	4 Strong	3 Neutral	4 Strong	3 Neutral	3.7 Medium - Strong	3 Neutral	4 Strong	3 Neutral	4 Strong	3 Neutral	3 Medium	3 Neutral	3 Medium

Socio-economic conditions // Engagement and Acceptance

	Stakeholder support: local communities (Citizens, residents, future clients), policy makers - Impact	Stakeholder support: local communities (Citizens, residents, future clients), policy makers - Relevance	Stakeholder acceptance: resilience towards risks, which appeared - Impact	Stakeholder acceptance: resilience towards risks, which appeared - Relevance	Environmental impact, Noise, Disturbances - Impact	Environmental impact, Noise, Disturbances - Relevance
Results	3.7 Neutral - Supportive	4 Strong	3 Neutral	4 Strong	2 Hindering	3.7 Medium - Strong