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Geothermal-DHC, European Research Network on Geothermal Energy in Heating and Cooling Networks

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ABSTRACT

Since 2019, the European COST funding agency supports the Action CA18219 Geothermal-DHC on the implementation of geothermal energy into heating and cooling networks across Europe. Geothermal-DHC represents a pan European research network participated by more than 30 countries also including non-European countries. Geothermal-DHC aims at investigating both, technological as well as non-technological concepts for a better integration of geothermal energy into heating and cooling networks by covering the whole spectrum of geothermal technologies from ambient (shallow) geothermal towards deep- and unconventional geothermal (e.g. CCUS-Geothermal). The scientific focus of the network addresses the match between the different geothermal concepts and the requirements of heating (and cooling) grids from generation 2 until generation 5. In this context, Geothermal-DHC not just focuses on new grids but also considers existing heating grids, which require a transformation from fossil fuels to renewable energy sources in the upcoming 10 to 30 years in order to fulfill the EU energy and climate goals. Geothermal-DHC wants to demonstrate that geothermal energy has the capacity to raise the renewable energy share including geothermal energy in heating in cooling grids from currently less than 20% to 30% in 2030 and 50% in 2050.

1. INTRODUCTION

1.1 The current role of geothermal heating and cooling networks in Europe

A district heating or cooling system is represented by a network of fluid filled pipelines connecting heat and cold sources to heating and cooling consumers from the residential and commercial sector. The network itself is neutral to heating and cooling sources but controlled by the temperature level and acts as a local market place for energy. It moreover founds on the basic idea to recycle heat which would be otherwise lost, such as combined heat and power (CHP) or Waste-to-Energy (Werner 2017). Heating networks may cover capacity ranges between less than 100 kWth and more than 1 GWth. Currently around 80,000 district heating networks are globally counted, thereof 6,000 systems are located inside Europe. Still, the share of cooling networks are way smaller than the share of heating networks (Werner 2017).

The history of local heating networks can be traced back to medieval ages and is strongly connected to geothermal energy. In 1334 the first geothermal heating network was introduced in Chaudes Aigues (France) using naturally outflowing hot thermal springs in pipe network to supply heat for housing and manufacturers in a nearby village. The system was operated by a local landlord constituting the first energy supplier in the world. The first modern public district heating networks were introduced in the US in the 1870s and 1880s (Lockport and New York), in Germany in the 1920s and in the Soviet Union and China in the 1930s and 1950s (Werner 2017). As indicated in Figure 1, district heating networks developed to different generations of technological types regarding its temperature level. Starting at generation 1 - hot steam networks at temperature levels of up to 200°C, the continuous lowering of networks temperatures down 50°C (generation 4) led to a decrease of energy losses and a decentralization of heat sources inside the network. Since the 2010s, 5th generation district heating and cooling networks emerge in Europe, which further pursuit the concept of decentralization. At network temperatures below 30°C, the network may preserve heating and cooling shifting energy conversion to decentralized heat pump stations at the consumer, who also might act as a producer (prosumer) by draining waste heat from space cooling into the network (Boesten et al. 2019). 5th generation district heating and cooling networks in general benefit from a very high system efficiency since they enable the integration of low temperature renewable sources such as ground source heat, lake/river water or solar as well as waste heat from low temperature sources such as data centers or supermarkets. Furthermore, they exhibit low heat losses inside the network due to the low temperature level of heat carrier inside the pipelines. In addition, the low network temperature enables that both, the higher temperature in the hot pipe and the lower temperature in the cold pipe can be used for either heating or cooling purposes. Thus, attractive temperature levels for both heating and cooling can be provided by one two pipe system (Franzén et al., 2019). Therefore, depending on the variable ratio between cooling and heating demand within the network, the flow direction within 5th generation networks can change during the year (Bünning et al., 2018). In turn, such networks are harder to control and their capacity is driven by mass flow instead of temperature. The reduction of network temperature levels also led to a change of the topology itself introducing a shift from “tree-based” hierarchical networks related to central heat and cold sources towards unstructured cycled networks and meshes connecting decentral heat sources and sinks.

The heating and cooling sector currently covers around half of the EU energy consumption and has been recognized as a priority to achieve decarbonisation targets set for the European energy sector (Kavvadias et al. 2019). Inside the heating and cooling sector low temperature heat demand for non-industrial purposes, such as households and the service sector, cover 63% of the total heat demand in the EU (Ragwitz et al. 2016), which, in general, would suit the application of geothermal energy. As for 2019, the renewable energy share inside the heating and cooling sector in the EU reached 22.1% (source: Eurostat, https://ec.europa.eu/eurostat), whilst fossil fuels still represent the dominating heating source. The actual EU policy framework given by the EU Green Deal (EU Commission 2019, COM(2019) 640) aims at decoupling the economy from resource consumption and environmental pollution and sets ambitious aims for the reduction of Greenhouse Gases (GHG) in the energy sector for 2030 (at least minus 50%) and 2050 (net zero GHG). Still, the heating and cooling sector is affected by low efficiencies leading to large amounts of waste heat (Kavvadias et al. 2019). However, EU energy statistics reveal a correlation between energy efficiency as well as the integration of renewable sources inside the heating sector and the share of district heating networks inside a Member State. As shown in Figure 2, the average share of district heating networks in the EU was around 10% in 2015. Countries having a strong tradition in district heating, such as Scandinavian of Eastern European countries show lower shares of individual fossil boilers and hence higher national heat supply efficiencies[1]. This effect gets amplified when district heating is combined with efficient use of electricity through heat pumps and renewables inside heating networks. In that context Sweden and Finland show efficiencies above 90% (Kavvadias et al. 2019). This goes in line with an overall share of district heating systems inside the heating and cooling markets of 40% to 50%.

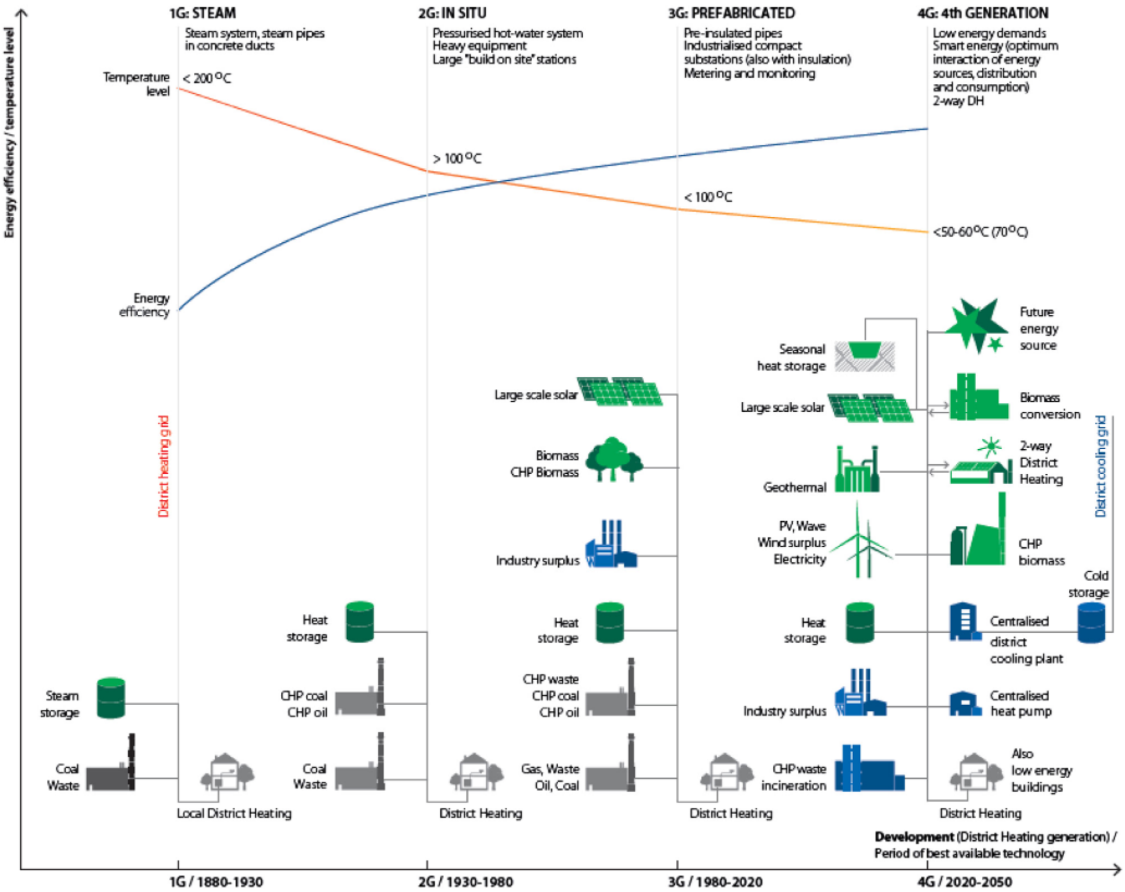

Figure 1: Evolution of district heating and cooling networks with regard to temperature levels, energy efficiency and heat as well as cold sources (taken from Lund et al. 2014, p.9).

According to the 2019 market report of the European Geothermal Energy Council (EGEC), capacities for geothermal district heating and cooling reached around 5.5 GWth in 327 geothermal plants across Europe (Garabetian et al. 2020). As geothermal district heating, often in combination with CHP, is dominated by Iceland and Turkey, the geothermal district heating capacity inside the EU is reduced to 2 GWth in 233 operating systems, which indicates an average capacity of 8.6 MWth per unit. However, just five countries, namely France, Hungary, Germany, Italy and the Netherlands cover 82% of all installed geothermal capacities for geothermal district in the EU. Still, direct geothermal energy use covers a niche inside the EU district heating and cooling network supplies at an estimated level of less than 1% (Werner 2017).

In 2019, the milestone of 2 million geothermal heat pumps was surpassed in Europe (Garabetian et al. 2020) leading to estimated heating capacities of around 25 GWth, which is five times higher than the value for direct geothermal energy use. Despite of the still growing numbers of shallow geothermal systems in Europe, a strong competition by aerothermal systems inside the European heat pump market can be observed, which especially applies to small-scale, single family home systems. For instance in Austria, the dominance of shallow geothermal systems inside the domestic heat pump market is limited to heat pump units above 30 kWth (Goldbrunner and Goetzl 2019). The application of ground source heat pumps can result in a significant higher annual average Coefficient of Performance (COP) than air source heat pumps and therefore reduce the required electricity demand (Petrovic and Karlsson, 2016). The share of shallow geothermal energy in 5th generation district heating and cooling networks is not exactly known.

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[1] The national energy efficiency is defined in Kavvadias et al. 2019 as the ration between the delivered useful heating energy to the end energy consumption.

However, this emerging district heating and cooling concept has yet been applied at some tens of locations in Europe (Buffa et al. 2019).

According to the geothermal market numbers presented by Lund and Toth (2020), a similar situation can be observed at a global level. Geothermal heating is dominated by heat pump use (72.5% of total geothermal heat produced), followed by balneology as well as bathing. Direct heat use for space heating is just found at rank #3 (16% of total geothermal heat produced). In 2014, geothermal energy provided around 30 PJ to district heating networks around the globe at a total consumption level of 14 EJ (Werner 2017). From these figures a share of geothermal energy inside district heating networks of around 0.2% can be derived. From a global perspective, district heating networks were strongly dominated by fossil fuels at a share of 91% in 2014 (Werner 2017). Similar to the situation in the EU, the share of district heating systems in the global heating market is around 10% (Kavvadias et al. 2019).

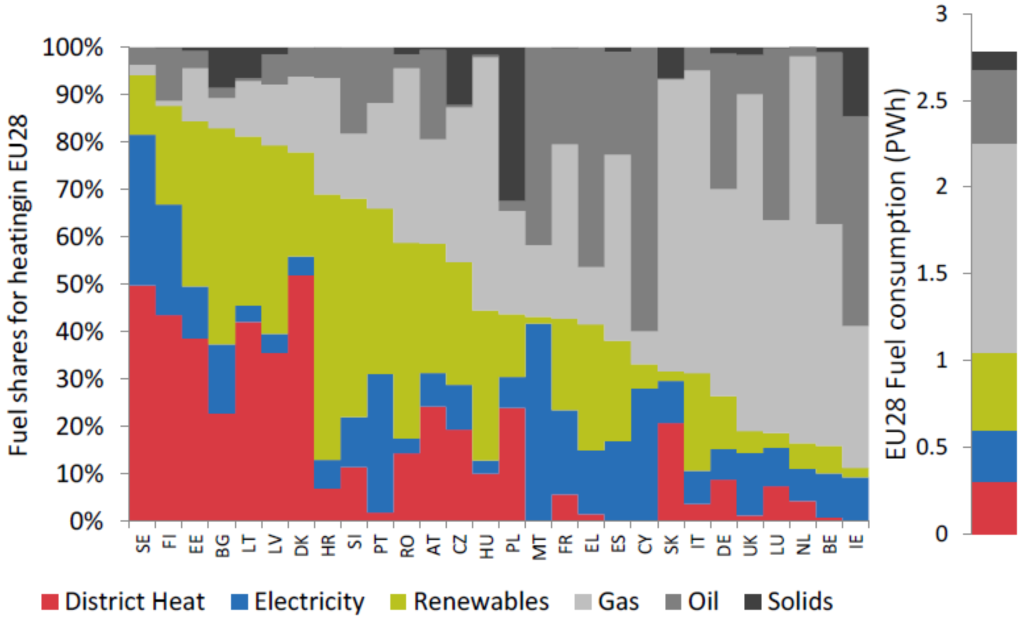

Figure 2: Fuel consumption for space heating in the EU in 2015 (taken from Kavvadias et al. 2019, p.8).

In general, the commitment to the fundamental idea of district heating and cooling (DHC) is still moderate (Werner 2017) as its ecological as well as socio-economic benefits are often not visible at the first glimpse. For individual heat consumers, DHC offers lowering heating costs, especially when international prices for fuels are high. For that reason, the international oil crises of the 1970s as well as the need to import hydrocarbons have been driving factors for the introduction of district heating networks in the past. On a community level, DHC offer the opportunity to significantly lower the environmental and climate impact by raising the share of renewables and energy efficiency. In both cases, DHC systems benefit from ecological and economical upscaling effects, which might be further amplified when environmental and climate impacts are linked to international or external damage costs by national taxes or fees (Werner 2017).

1.2 The COST Action CA18219 Geothermal-DHC

In autumn 2019, the COST Action CA18219 "*Research network for including geothermal technologies into decarbonized heating and cooling grids (*Geothermal-DHC*)*" went into operation. Unlike conventional research projects, COST, financed by the EU H2020 programme, limits funds to networking and scientific capitalization measures without financing staff costs. In that context COST offers various tools such as travel and conference grant support, staff exchange programs (Short Term Scientific Missions – STSM), self-organized academic training programs and joint scientific publications. Operational lifetimes of COST Actions are limited to 4 years based on annual grants according to the size of the network. Instead of conventional work packages, COST Actions are organized in so called Working Groups (WG) addressing different aspects of the research network.

Geothermal-DHC aims at the integration of geothermal energy into district heating and cooling (DHC) networks based on a technologically open bottom-up approach. This implies all different generations of DHC networks (generation 1+/2 to 5) and different geothermal technologies (shallow- to deep geothermal). Moreover, geothermal may not just represent a heat or cold source but also provides storage underground thermal energy storage (UTES) options to DHC networks. The Action very much refers to analyses of existing archetypes and topologies of geothermal heating and cooling networks to identify technological and conceptual gaps, which need to be addressed by science. For that purpose, Geothermal-DHC aims to learn from at least 30 case studies across Europe. The activities performed in Geothermal-DHC address technological as well as non-technological challenges, such as social inclusiveness, sustainability and environmental rebound effects caused by the integration of geothermal energy into DHC networks In that context, Geothermal-DHC is not just gathering at new DHC systems but also needs to account for existing early generation district heating networks, which need to be retrofitted in the upcoming years in order to comply with EU policies. A special interest is also given to the introduction of efficient and environmental friendly cooling networks supplied by geothermal energy (geo-cooling) as well as the upgrade of conventional district heating networks to DHC networks. Finally, Geothermal-DHC wants to identify pathways compiled to roadmaps for a better integration of geothermal energy into DHC networks so that the current niche position will be left in the upcoming decades.

Geothermal-DHC applies a flexible work structure consisting of 4 “Permanent Working Groups (PWG)”, associated by a flexible number of “Ad Hoc Working groups (Ad Hoc WG)”. The PWG are operating over the entire lifetime of the Action and cover the thematic aspects of integrating geothermal energy into DHC networks (PWG 1), external communication and outreach (PWG 2), young researcher support (PWG 3) as well as capitalization and uptakes of the network (PWG 4). In contrast, Ad Hoc WGs address specific topics or activities inside the network and are flexible in operational periods. They might be linked to just one PWG or connect several PWGs with each other, as indicated in Figure 3.

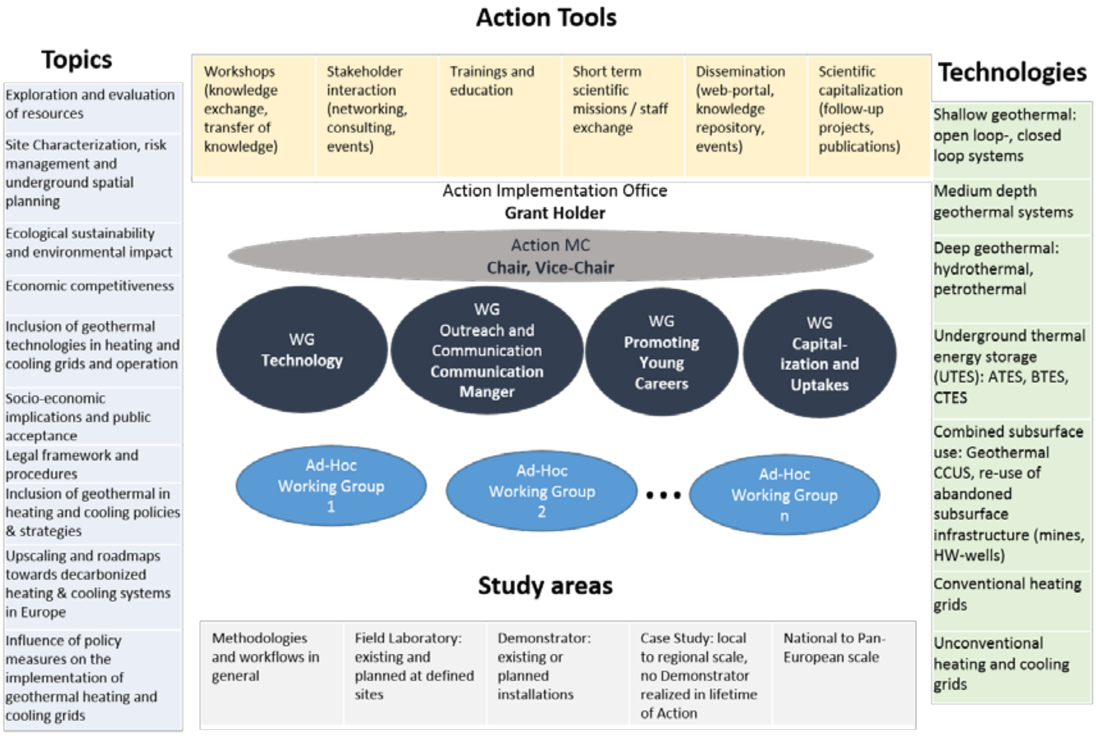

Figure 3: Organizational structure of CA18219 Geothermal-DHC.

As for December 2020, the research network of Geothermal-DHC included around 150 researchers from 38 European and non-European countries. Still, the network is dominated by the academic sector with backgrounds in geosciences and engineering (around 80% of all participants). However, the network also aims to better involve stakeholders outside the academic sector (e.g. energy suppliers, manufacturers or communities) as well as social scientists to stronger emphasize non-technological aspects of the transformation process into geothermal DHC networks. Geothermal-DHC follows inclusive access policies based on voluntary contributions. For more information please visit https://www.geothermal-dhc.eu/community/join-in.

2. THE POSSIBLE FUTURE ROLE OF GEOTHERMAL ENERGY IN HEATING AND COOLING NETWORKS

2.1 Opportunities

A shift of paradigm needed for the heating and cooling sector

Fulfilling the EU energy and climate goals for 2030 and 2050 requires solutions to integrate renewable energies and increasing the energy efficiency of the heating and cooling sector to replace currently used fossil fuels. The recently accomplished EU project Heat Roadmap Europe 4 (HRE4) concluded that the decarbonisation of the heating and cooling sector in Europe can be achieved with existing technologies and without a massive increase of the use of bioenergy (Mathiesen et al. 2019). The decarbonisation pathways developed in HRE4 mainly refer to efficient DHC systems in urban and suburban areas as well as on individual use of heat pumps in rural areas, which may lead to a reduction of 86% of GHG in the EU heating and cooling sector until 2050 (q.v. Figure 4, right side).

In order to avoid negative lock-in effects, the transformation towards a decarbonized heating and cooling sector requires a strategic shift from economic optimization towards exergetic optimization by exergetic prioritization (q.v. Figure 4, left side). This covers the reduction of heat losses by a better matching between the enthalpy level of the heat demand with the sources available. Low temperature applications should be covered by on-site available renewables such as geothermal, solar thermal and waste heat, while high temperature applications, mainly required for industrial heat, get supplied by high enthalpy renewables, such as biogenic gas or by electricity, which might be imported or transported over great distances. Kavvadias et al. (2019) conclude that the transformation of the heating sector will lead to an increased electrification of heating in both, district- as well as individual heating as it follows the principle of energy efficiency first. In this regard, electricity use for space heating should focus on heat pumps, which are considered superior towards other power to heat or power to fuels applications. Similar considerations may be applied to biogenic heat sources at higher exergetic range unless they are sufficiently available on site to cover the demand. Moreover, available biomass resources in Europe are not large enough to substitute all current fossil fuel uses in district heating networks (Werner 2017).

Considering the electrification of the heating sector, one not just needs to look at annual balances but also at heat load curves. Electrification leads to a stronger dependency of the heating market on the weather conditions, which also influence the availability of electricity from onsite produced variable renewable energy sources (VRE), hence leading to amplification of the stress on the European electricity networks at certain periods during the winter time, when firm capacity levels may significantly be exceeded. Scenario modelling performed by JRC revealed that countries already having a well-established heating network infrastructure, like Sweden, are less sensitive to winter times electricity peaks (Kavvadias et al. 2019).

The increasing degree of urbanization in the world will also facilitate the implementation of district heating and cooling networks. This especially applies to Europe, which already faces a degree of urbanization of around 75% with an expected raise towards 85% in 2050 (United Nations 2018). Werner (2017) concluded that the heat demand in densely settled urban areas is high enough to establish district heating networks even in countries with milder climates. In addition, increasing urbanization also provides pressure on sustainable and environmental space cooling solutions for mitigating urban heat island effects by avoiding waste heat dumping to the streets. In addition, higher standards of living in the future are expected to increase the demand for cooling in addition to climate change effects.

New topologies offer opportunities for geothermal to leave the current niche

Geothermal energy at its full range from shallow to deep sources is capable to contribute to DHC and individual heat pumps. From the geothermal resource point of view, the authors postulate that at least 50% of the space heating and 100% of the space cooling demand could be covered, whereas its actual share is around 3%. The EU project GeoDH (Dumas et al. 2014) concluded that 25% of the population of the EU could be supplied by direct geothermal use in district heating networks. This coverage only accounts for hydrogeothermal use and neglects geothermal heat pumps. In fact, geothermal energy at ambient temperature levels, stored in the shallow subsurface and used in closed loop systems is not limited by resources if enough space for the instalment of probes is available. Recent studies for Austria and Germany revealed that even in urban and suburban areas facing low availability of surface space for the drilling of geothermal probes, more than 50% of energy demand for space heating could be covered if geothermal energy is used in 5th generation DHC networks (Pfefferer et al. 2020).

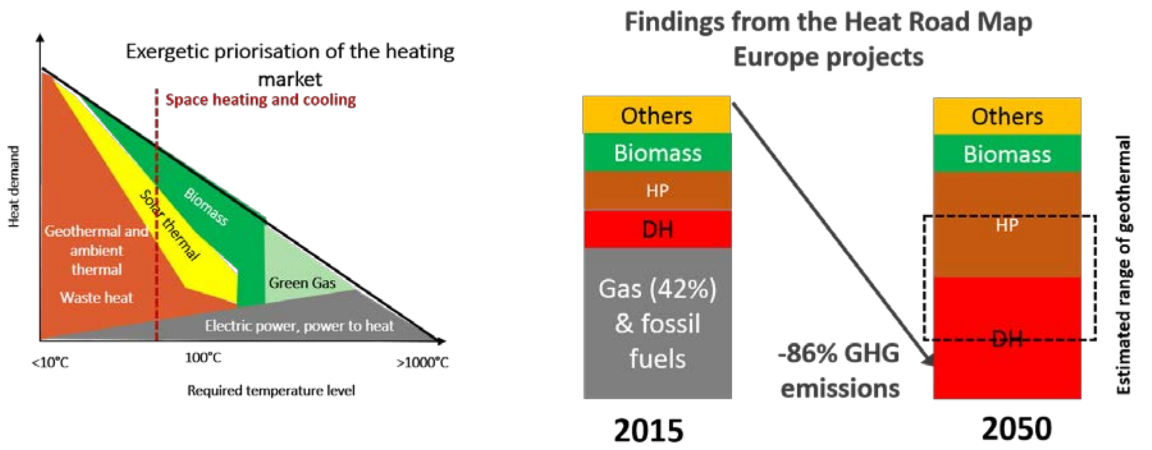

Figure 4: Basic concept of exergetic prioritization (left) and pathways towards the decarbonisation of the heating and cooling market in Europe based on figures published by the Heat Road Map Europe project (https://heatroadmap.eu).

As shown in Figure 5 (left side) future low GHG emission DHC topologies may differ from conventional ones in the following way to fulfill the requirements of (1) energy efficiency, (2) supply security, (3) affordability and (4) stability and resilience: Base load supply must be characterized by low and stable operational costs (OPEX), two characteristics geothermal energy use is able to provide. The integration of fluctuating on-site renewables, such as solar thermal or waste energy or power to heat (P2H) into the network requires the application of short- and long term (weekly to seasonal) storage. This offers future opportunities for underground thermal energy storage, especially for high temperature deep aquifer storage (HT-ATES). Peak load supply as well as back-up systems in contrast should be characterized by low investment costs (CAPEX) and might also be provided by mobile supply units in case of small DHC networks. The transformation of networks require a temperature reduction of the heat carrier fluid inside the pipelines to enlarge the portfolio of possible heat sources. Remaining gaps between the network and the different sources or between the network and consumers might be modulated by large-scale high temperature heat pumps, which will also be applied to temperature levels of more than 100°C and which have gained increasing attention in recent year. In order to stabilize energy balances individual networks can be joint to communicating meshes in both hierarchical cascade- (lower generation to higher generation networks) or unstructured meshes of networks at the same temperature level.

In low temperature heating and cooling networks of the 5th generation a shift of role of geothermal energy sources from a source or a sink towards a seasonal storage can be expected. By doing so, the efficiency of geothermal use can significantly be elevated by thermal recovery of the subsurface and lower interspaces needed between geothermal heat exchangers as thermal plumes of balanced use are limited in extension. Moreover, setting the initial starting point of a low temperature borehole thermal energy storage (BTES) allows for controlling the annual temperature variation of the subsurface and therefore helps to optimize heat or cold storages. Due to the low network temperatures below 30°C 5th generation DHC networks using decentralized, consumer sided heat pumps are able provide heating and cooling to clients at the same time with the same infrastructure.

However, future DHC topologies might also require energy efficient upgrades of elder generation heating networks towards combined heating and cooling supply. Decentralized absorption- or adsorption based chillers might offer a cost effective opportunity for such upgrades, if applied in an efficient way. This might be achieved by dumping waste heat from chillers into the heating network linked to a seasonal large volume storage, which in turn could be provided by geothermal resources (e.g. HT-ATES).

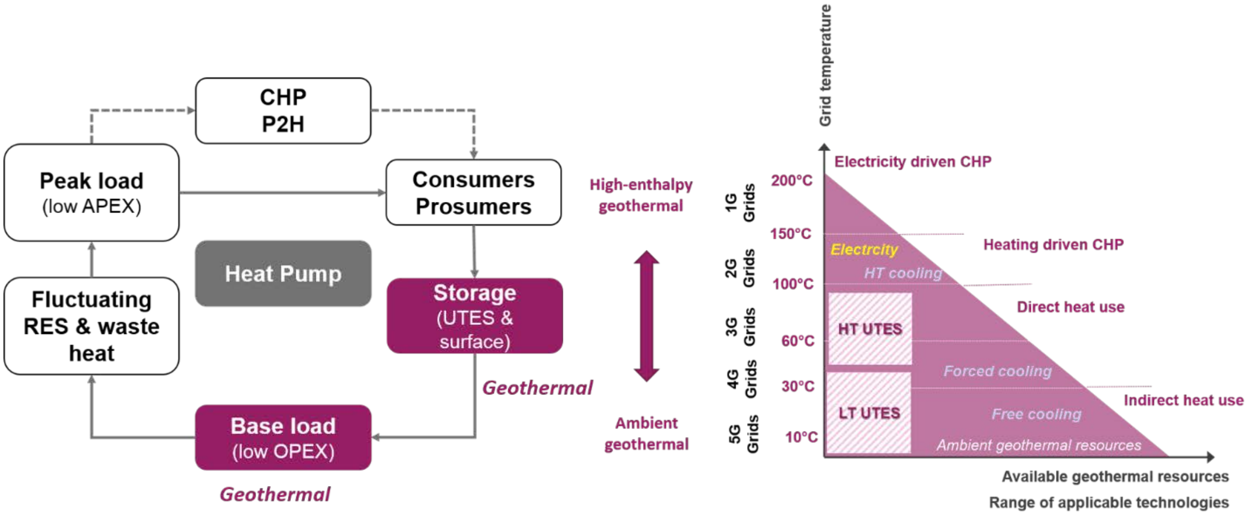

Figure 5: The possible role of geothermal energy into modern DHC network topologies (left) and the match between geothermal energy sources and heating networks of different generations (right).

To conclude, geothermal energy may offer resources to cover the temperature demand of all almost all generations of heating networks from a theoretical point of view. However, decreasing the temperature level of networks support the integration of geothermal energy into the district heating market as more sources can be used (Figure 5, right side). The temperature level of 90°C (generation 3 district heating networks) marks a critical threshold as UTES technologies can be applied up to this range. For that reason, retrofitting of early generation district heating networks should aim at generation 3 standards at least.

2.2 Challenges

Unleashing the potential of geothermal energy use in heating and cooling networks still faces technological and, moreover, various socio-economic challenges, which will be briefly outlined in this chapter.

Technological challenges

The transformation towards a high efficient and no to low emission heating and cooling sector requires a fundamental change of the existing infrastructure regarding the building stock (Werner 2017), existing heating networks up to generation 3 as well as existing steam power plants, which might be turned into CHP for recycling of waste heat (Kavvadias et al. 2019). The key point is to lower the gap between required temperature levels in the network and on-site available geothermal resources. This either implies a significant renovation of buildings connected to the heating network, which is part of European strategies, and / or applying technological bridges between network- and source temperature levels through heat pumps. As the thermal capacity of early generation heating networks is primarily driven by high temperature shifts between the forerun and return pipelines, a reduction of the overall network temperature leads to a loss of network capacities in case the initial pipeline infrastructure is kept.

With regard to the integration of geothermal energy in conventional heating networks operating at temperature levels above 50°C, a shift of paradigm in planning and utilizing deep geothermal resources towards large portfolios based on multiple patterns and non-conventional geothermal is needed to be achieved. This supports high heat recovery factors in the subsurface, reduction of investment risks and long term stability of geothermal energy use. Moreover, geothermal portfolio management is key for reducing the preparation time and upfront investments of large-scale geothermal projects due scaling effects. In addition, petrothermal energy may become an important technology for substituting fossil fuels and biomass in conventional, high temperature heating networks outside of geothermal aquifer regions, which is especially relevant for eastern European hard rock regions. Finally, network topologies need to be redesigned to bridge possible spatial mismatches between the consumers and prospective geothermal resources (e.g. high temperature aquifers). This requires high efficient and affordable connecting lines of several tens of kilometers to transport geothermal energy from the periphery to urban consumers.

With regard to the integration of shallow geothermal energy into 5th generation heating and cooling networks the greatest technological challenge is given by a large-scale roll-outs of borehole heat exchanger based fields in densely settled urban areas lacking of free space for drillings. Subsurface heat exchangers should therefore be considered as public infrastructure, such as sewage pipelines, which are preferably installed below public spaces like roads, parks or pathways. As the capacity of 5th generation heating and cooling networks are limited by the diameter of pipelines, new topologies are required to allow organic growth of such networks over time to expand capacities connecting individual networks to meshes of equal or different (cascade like) exergy levels.

A successful integration of geothermal energy also aims at maximizing the capacity factors in order to benefit from low OPEX and reduce the specific APEX. For that purpose the role of geothermal energy in future heating and cooling networks need to be expanded from source towards storage (UTES) of fluctuating excess heat from other on-site renewables or CHP. High temperature, high volume UTES in the range between 30°C and 90°C is not yet market ready but offers vital options for the future. New concepts need to be found to make UTES more flexible when it comes to storage charging / discharging periods. In that context PCM technologies or single circle high temperature ATES concepts are considered as vital options.

Non-technological challenges

The lack of awareness related to the concept of district heating in countries without a respective tradition (Kavvadias et al. 2019), amplified by a low level of awareness towards the use of geothermal energy can be considered as the most relevant non-technological challenge. As reported by Werner (2017), district heating and cooling is even not considered as an energy efficiency measures in some EU countries. This results into insufficient legal frameworks and lack of incentive measures to stimulate the integration of geothermal energy into heating and cooling networks. Some countries such as Germany have a high guaranteed feed-in-tariff for geothermal electricity generation, but no (or only strongly limited) financial support for geothermal heating and cooling projects. In contrast to electricity and gas, heat supply is mostly governed on a local to regional level, which impedes the transposition of joint policies, especially on a European level. In that sense, the transformation of the heating and cooling sector will require regionalization approaches demanding tailored instead of uniform and generic concepts involving a high number of local decision makers and actors (Werner 2017).

Compared to other renewables geothermal energy is facing high upfront costs associated with investment risks, which hampers the economic competitiveness in short to medium term investment decisions. However, on the long term also accounting for non-monetary assets like cost stability and supply security, geothermal energy is well competitive and economically valuable. This leads to a certain dilemma between investor- (low APEX) and consumer interests (low OPEX) in heating and cooling solutions. This requires new business models and the right investors having financial stability as well as non-monetary interests. Communities and infrastructure providers would fit the required profiles but often lack of investment capital. Public private partnerships (PPP) including alternative, crowd based financing concepts in combination with public de-risking instruments may represent appropriate concepts for bridging these gaps of interest.

Lund et al. (2014) furthermore conclude that it is crucial to provide access for different participants of a smart energy network to consultancy services in order to change behavior for optimizing energy efficiency. Smart heat meters could be a technological promising option to motivate for energy efficiency and reward all participants. Moreover, following the concept of 5th generation district heating and cooling networks will help to empower clients to become “prosumers” (consumers and producers of heat) and therefore support the role of district heating and cooling as a market place for heat and cold.

3. THE LONG-TERM VISION OF GEOTHERMAL-DHC

The COST Action CA18219 Geothermal-DHC defines specifically the following key target indicators for the deployment of district heating and cooling (DHC) and the integration of geothermal energy:

- **30% in 2030** referring to the share of DHC in the EU heating and cooling sector (currently around 10%) at a share above 30% of renewables (currently around 20%) and a share above 10% of geothermal (currently less than 1%) – regarding the large offset periods for the deployment of geothermal energy more ambitioned targets for the integration of geothermal energy might not be realistic,

- **50% in 2050** referring to the share of DHC inside the heating and cooling sector at a share of at least 50% of geothermal energy inside DHC also accounting for UTES.

Geothermal-DHC supports this vision by establishing a scientific competence platform interconnecting research to policy makers and industry. Based on position papers and roadmaps future solutions as well as prevailing research gaps will be communicated to external stakeholder pathing the way for spin-off and follow-up research activities. After the end of the COST Action in 2023, a basic infrastructure including a dedicated web portal will be available to be further capitalized by international organizations like the European Geothermal Energy Council, the Renewable Heating and Cooling Platform or Euroheat & Power.

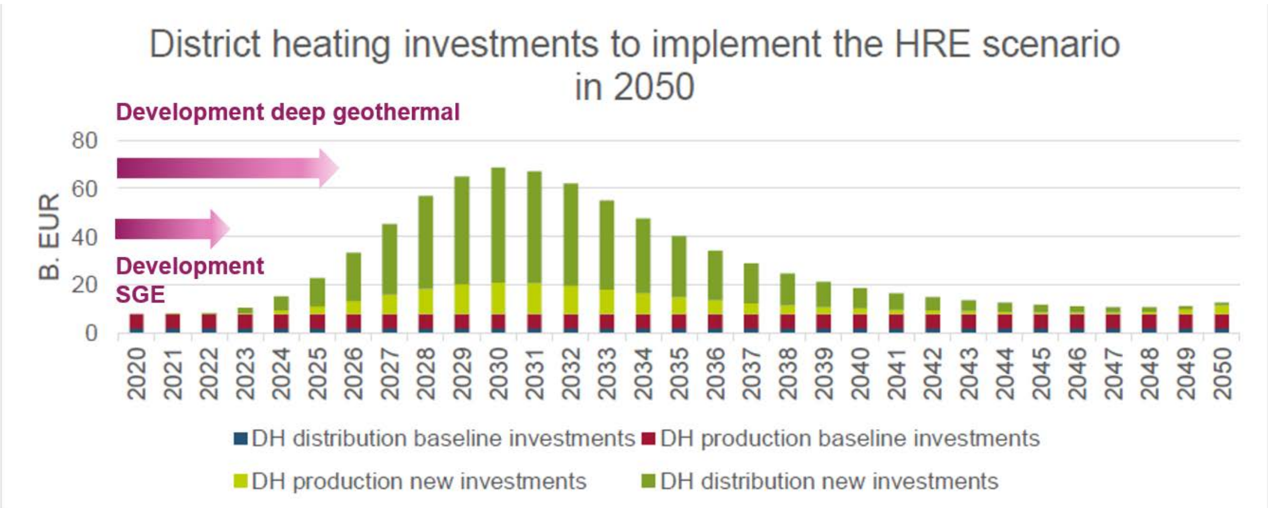

Figure 6: Estimated roadmap of investments into district heating networks according to the Heat Roadmap Europe decarbonisation pathway in comparison with typical development periods of deep- and shallow geothermal projects at large capacities (taken from Mathiesen et al. 2019, p.8, edited).

4. CONCLUSIONS

According to Mathiesen et al. (2019) the focus of future investments into heating and cooling networks need to be realized between 2027 and 2035 in order to fulfill the EU policy framework. Large capacity geothermal projects still require long development periods between 3 and 7 years depending on the size and the legal boundary conditions (see also Figure 6). Therefore, it is vital to set the course for enabling a more suitable framework for the integration of geothermal energy into heating and cooling networks way before 2025. Otherwise, lock-in effects favoring a further electrification of the heating market or the use of biomass will hamper future integration processes. Current resilience crises such as the COVID-19 pandemic should be used as an opportunity to put sustainable long-term concepts above short-term economic concepts. In that sense it becomes even more important to join forces to initiate the geothermal decade as proclaimed by international organization like European Geothermal Energy Council.

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