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HARNESSING THE DECARBONIZATION POTENTIAL OF DISTRICT HEATING IN EUROPE

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District energy systems are critical solutions for the decarbonization of heat. These systems have the potential to move towards low-temperature heat, operate with 100 per cent renewables, and offer flexibility services to the electric grid. District heating and cooling networks are promising solutions, especially in urban areas where individual solutions would not make it possible to fully integrate available clean energy sources or operate efficiently for several reasons, including space or noise constraints. According to the International Energy Agency, in 2021 global district heat production added up to nearly 16 EJ (exajoules), an increase of more than 10 per cent over the previous decade, but accounting only for 8 per cent of total final heat consumption globally.

Despite its potential for decarbonizing heat, district heat today still relies on fossil fuels. In 2021, 90 per cent of district heat globally was produced from fossil fuels, primarily coal (45 per cent), natural gas (40 per cent), and oil (3.5 per cent). However, even now, the carbon intensity of district heating systems is often much lower than that of individual boilers, due to the widespread application of combined heat and power generation as a backbone.

District heating systems are heterogeneous across countries and across systems with several countries leading the path towards clean district heating, in particular in Europe, which represents 20 per cent of global district heating production.

This paper discusses the opportunities for the European district heating market to exploit untap its decarbonization potential and to contribute to broader climate objectives within the region.

The European market and its decarbonization potential

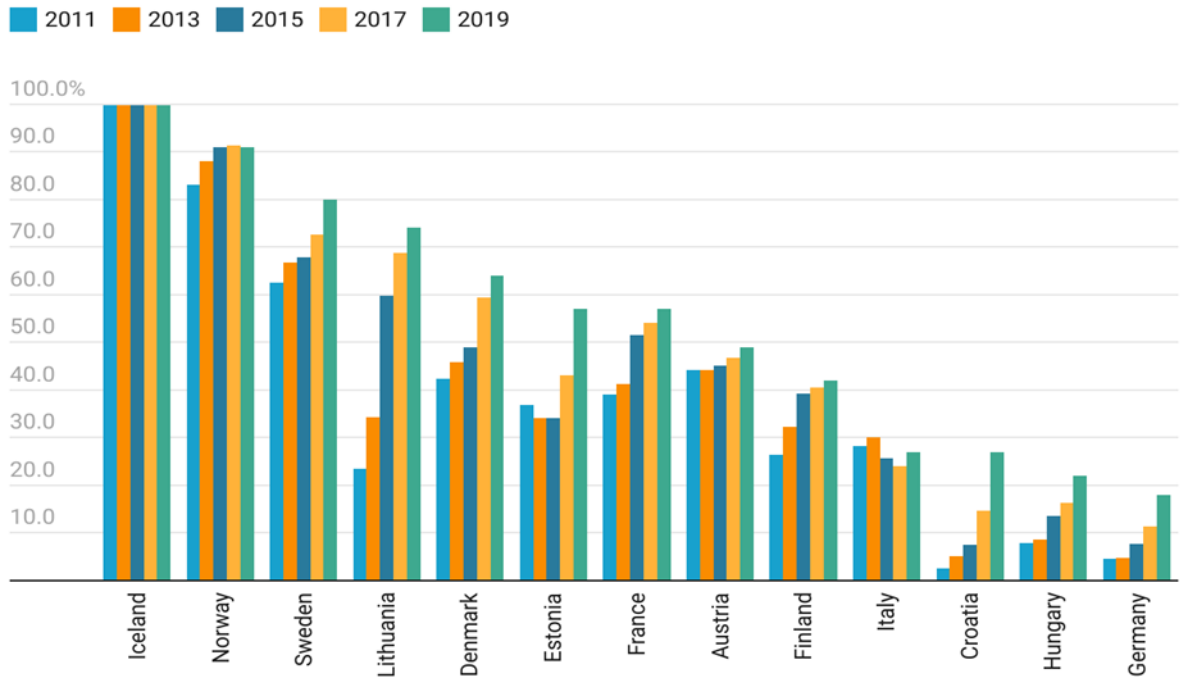
The share of district heating in Europe varies significantly from one region to another. District heating is by far the most common heating solution in the cold-winter countries in northern and eastern Europe (e.g. the Nordic and Baltic regions and Poland), whereas it still plays a minor role in southern (e.g. Spain and Greece) and some western (e.g. the Netherlands and the United Kingdom) European countries. Overall, Germany harbours the largest district heating market in Europe, followed by Poland and Sweden.

In 2019, district heating and cooling represented 12 per cent of the European heating market. Despite this, a significant share of fossil fuels is still present in the district heating fuel mix, with almost half of it being natural gas. Meanwhile, nearly 30 per cent of district heating production is covered by renewables and industrial excess heat, which makes Europe the world leader in the field of renewable district heating. District heating and cooling has been a gateway to deploying more renewables in home heating: the seven European countries with the highest national shares of renewable heating and cooling also have the highest shares of district heating in their heat markets (Iceland, Sweden, Estonia, Finland, Latvia, Denmark, and Lithuania).

The *DHC Market Outlook* data of Euroheat & Power shows that many countries have made considerable progress over the last few years in integrating renewable sources into their district heating systems:

- The share of renewable heat in Denmark grew from 42 per cent in 2011 to 64 per cent in 2019.
- More than 40 per cent of district heating is now carbon free in Finland, compared to 26 per cent in 2011.
- In France, the average renewable and recovered energy rate exceeded 60 per cent in 2020.
- Lithuania reported a decrease of around 70 per cent in CO_2 emissions from the heating and cooling sector since 2000.
- Both Sweden (17 per cent) and Croatia (24 per cent) have seen considerable growth in the share of renewable energy in district heating compared to 2011.

Figure 1: Share of renewable energy in district heating in selected European countries (2011–2019)



Source: Euroheat & Power (2022), *DHC Market Outlook 2022*, created with Datawrapper.

Note: the 2015 figure for Estonia and the 2019 figure for Iceland were not available; in these cases, figures from 2013 and 2017, respectively, were used. Percentages are based on district heating energy supply composition data provided by participating countries.

Approximately 60 million citizens within the European Union are currently served by district heating, with an additional 80 million living in cities which are already equipped with at least one district heating system. These numbers highlight the strong potential of district energy networks to expand and, in combination with a renewables-based generation mix, to serve as an alternative way to meet the challenge of urban densification and support the transition of the European buildings stock away from fossil-fuel heating.

In the next decade, deploying district heating and cooling will be critical to gradually phase out fossil fuels supply in heating. A recent assessment by the think tank Agora Energiewende with the help of Artelys, TEP Energy, and the Wuppertal Institute found that district heating could have the technical potential to achieve around 125 TWh (~12.5 bcm) in gas savings in Europe by 2027.

Several studies are in agreement that there is a great potential for expanding clean district heating in Europe. According to Agora Energiewende, district heating could supply 20 per cent of heat in buildings by 2030, with 50 per cent of it supplied by renewables and waste heat. According to Heat Roadmap Europe data, if the urbanization trend continues and appropriate investments are put in place, district heating could meet almost half of Europe's heat demand by 2050.

However, to realize this potential, the heating and cooling sector must accelerate its transition away from fossil fuels. On this journey, there are at least three well-proven strategies for district heating:

1. Support the deployment and integration of **sustainable renewable heat sources** (such as geothermal, sustainable bioenergy, and solar thermal). These can be integrated swiftly into existing and future district energy networks to replace polluting fossil fuels. Some policies can foster the development of renewable district heating—such as the French Heat Fund (Le Fonds Chaleur), administered by ADEME (French Environment and Energy Management Agency), which provides €520 million per year for renewable heat, including investment aid for heating infrastructure.
2. Foster integration of the electricity and heating sectors—also known as **sector coupling**.
    - District energy networks coupled with large heat pumps and thermal storage can convert excess renewable electricity into renewable heat, providing cost-efficient balancing and storage to the electricity grid. According to Euroheat & Power's 2022 *DHC Market Outlook*, power-to-heat could become a major supply source for district heating and cooling networks by 2050, reaching around 30 per cent of the energy supply in Germany and around 45 per cent in Denmark.
    - Combined heat and power can provide heat from fossil fuels and renewable sources at maximum efficiency and help balance the power grid in times of additional power needs.
    - District cooling can also play a key role in smoothing out peak demands from increasing electrification shares across sectors. It reduces the need for electrification as it can tap into alternative sources, such as free cooling from rivers and the sea. This flexibility is expected to yield significant benefits as demand for cooling increases.
3. Encourage the **recovery of waste heat** from industrial processes like paper and cement, energy production such as electrolysis, or tertiary activities like data centres. According to Heat Roadmap Europe, up to 25 per cent of district heating could be supplied by industrial heat. Furthermore, urban waste heat from data centres, metro stations, tertiary buildings, and wastewater treatment plants can meet more than 10 per cent of the EU's total energy demand for heating and hot water (ReUseHeat). The substantial potential of waste heat recuperation from hydrogen should also be considered.

The above strategies are easier to implement within new networks, but existing networks, 10,000 in total in Europe, also have a large potential to progressively shift to cleaner approaches. In this regard, the district heating system of Bolzano (constructed in 1986) in South Tyrol (northern Italy)—winner of the Global District Energy Climate Awards 2021 in the modernization category—shows a replicable pathway. Starting in 2008 a massive expansion took place and various measures were undertaken to implement a modernization programme, including the integration of a waste incineration plant, the construction of a large buffer storage tank, and the implementation of an innovative district heating net optimization software package (Termis). From 2013 to 2019, the number of customers connected to the district heating network increased by 60 per cent, and a strong reduction of CO2 emission was achieved despite a massive expansion of the network. The maximum value of reduction was recorded in 2018 with 95 per cent compared to 2008. Due to continuous optimization, a high level should be maintained. When the investment plan for Bolzano is complete, expected by 2025, the cumulative investment will add up to €70 million, and around 7.5 million cubic metres of gas will be saved each year, avoiding about 15,000 tonnes of CO2-equivalent emissions, as much as if a virtual forest of 2,000 hectares appeared in the city.

In this particular case, the transition took around 10 years. However, there is not an average time for project deployment, as district heating projects, which occur in urban areas, are citizen-led and involve many actors and often public works. If properly supported, it can take less than three years, as demonstrated by the ArGeo geothermal greenfield district heating project in France, for which drilling work occurred from November 2013 to March 2014 (less than six months), and the construction of the network to connect around 7,500 homes occurred in around one year.

Economics of district heating: an integrated energy system view is necessary

In order to meet the net-zero-emissions ambition, the building sector is required to decarbonize. Reducing energy service demand, shifting towards cleaner fuels, and improving the energy efficiency of the equipment are major strategies in this direction.

Taking into account the broader diffusion of clean energy technologies, the challenge is to determine which solutions are available, and how they compare in terms of societal cost. This goes beyond comparing clean energy technologies with their

fossil counterpart and the decarbonization and expansion of existing district heating systems, and the creation of new district heating systems in many cases appears to be the solution with the least societal cost.

Key solutions that are usually considered are building-based demand reduction (deep or shallow retrofit) and either electrification through building-level heat pumps (an electricity network solution) or district heating (a thermal network solution). There is not one solution that fits all cases, and making the best choice for each case requires full societal cost accounting.

Heating is a seasonal load, in which the average heat demand is much lower than the maximum heat demand. This means that in order to provide heat, significant energy network capacity is required. In the case of a sudden deployment of a large share of individual heat pumps, electricity networks might need to be upgraded significantly, which might increase the societal cost of individual heat pump solutions if widely deployed, beyond the costs of installation and operation. These cost increases, however, will not necessarily be visible on the heating bill, thus opening the door to unbalanced economic comparisons. Heat pumps can also provide district heating. However, district heating typically integrates other sources and can support balancing the electricity grid. All costs involved in heat prices are already included in district heating prices, which makes it easy to compare it with other costs for operation.

Therefore, if individual solutions are not assessed in an integrated way, a comparison between the two solutions can be misleading. District heating can leverage economies of scale and might reduce the requirements for building and electricity grid retrofits, and in many cases, it can come with significantly lower societal costs than individual solutions.

How to compare costs and emissions savings opportunities across different solutions is an interesting future area of research. The old threshold price of current fossil fuel service limited district heating feasibility to higher-density urban areas. With a focus on zero greenhouse gas emissions, that threshold cost of service is raised considerably, and district heating can be very attractive even in lower-density areas.

Conclusions

During the past decade, little has been done to accelerate the clean transition of the heating and cooling industry.

District heating systems can help save natural and financial resources by enabling the integration of heat from sources that are otherwise lost, such as waste heat and deep geothermal heat. The use of these heat sources can also help to keep energy prices low.

Additionally, district heating and cooling systems can help to avoid an extreme and expensive overhaul of the electrical grid, which would be required if all homes were served by electric technologies directly.

The outdated heating and cooling strategy published in 2016 for the European Union (even before its commitment to being climate neutral) requires a proper implementation framework that will match the ambition of achieving climate neutrality by 2050 and responding to the challenges brought by the current energy crisis. The Fit for 55 package is an essential step in this direction, but it is not enough to reap the full potential of renewable and sustainable waste heat solutions.

International collaboration and research can ensure that the latest findings and best practices are the basis of any district heating and cooling development in the future, thus maximizing the societal benefits of district heating and cooling.

Heating and cooling are the next frontier for renewable and sustainable energies growth, and Europe is in a pole position to lead this global race. Locally owned district heating and cooling networks providing sustainable heat are a perfect illustration of this.