In the past decade, the EU has made giant steps towards accelerating the decarbonisation of the electricity sector. It is now time to address the hidden part of the iceberg: heating and cooling!

The size of the challenge is unprecedented: heating accounts for half of Europe’s energy demand and remains heavily dependent on fossil fuels. However, as always, there is a bright side to it. The potential of local clean and renewable heat sources is significant in Europe and heavily untapped. The EU is also home to leading clean heating technologies and infrastructure, such as district heating and cooling, heat pumps and high-efficiency cogeneration. We have the solutions at our fingertips, but where do we start?

A venerable Socrates once said, “To know thyself is the beginning of wisdom”.

This is exactly the ambition of Euroheat & Power’s DHC Outlook. This publication sheds light on the development of European district heating and cooling markets, identifies key political and business trends shaping the future of our sector, and supports our members and policymakers to take informed decisions about the future.

The DHC Market Outlook is already a well-established deliverable, but the 2023 edition brings significant improvements.

First, aggregated indicators on district heating and cooling at the European level are fully updated, including new data on waste heat in some surveyed countries. Some results are striking, hinting at the true potential of our sector! Who knew there are nearly 190 000 kilometres of district heating pipes in our cities, supplying 70 million citizens across Europe? The updated data sets on renewable and waste heat are also very exciting: in 2021, more than 43% of our supply came from renewable and waste heat sources!

Second, the outlook integrates qualitative chapters on the impact of the energy crisis, recent EU policy developments and the latest DHC innovation trends.

As the energy transition continues, district heating and cooling is more relevant than ever. It enables the combined use of local renewable heat sources (e.g., sustainable bioenergy, geothermal, and solar thermal), renewable electricity, and excess heat recovery from industrial and urban sources. Coupled with thermal storage and large-scale heat pumps or e-boilers, district heating and cooling becomes a precious ally to support the resilience and flexibility of the future energy system.

The heat revolution is underway, and it starts with you!

We hope that you will find this 2023 edition useful and inspiring, and we take the opportunity to thank all our members and partners for their unwavering support.

Best regards,

Aurélie Beauvais, Managing Director
Eloi Piel, Market Intelligence Director
Foreword by Energy Commissioner Kadri Simson

Kadri Simson,
EU Commissioner for Energy

The new geopolitical and energy market realities require us to accelerate our clean energy transition drastically. In March [2023], as part of the European Green Deal and the REPowerEU Plan, the EU provisionally agreed to stronger EU laws to speed up the rollout of renewable energy.

This includes more or less doubling the existing share of renewable energy in the EU by raising the EU’s binding renewable target for 2030 to 42.5% with the ambition to reach 45%.

At the last G7 meeting in Sapporo, leaders agreed on a target for 150 GW of offshore wind and a collective increase of solar PV to more than 1TW by 2030. When talking about renewables, the focus is often on power – wind, solar PV.

However, renewable heat may hold the key to achieving our objective of climate neutrality.

About half of all the energy we consume in the EU today is used for heating and cooling. Over 70% of that is still fossil fuel-based, mostly natural gas. Renewable technologies such as heat pumps, geothermal and solar thermal are still very limited, although 2022 saw a record increase in heat pumps as a result of high gas prices.

Without further dedicated EU action, 22 million old individual heating appliances and several thousand large old fossil-based heating units are at risk of being replaced by fossil boilers.

Close to 80% of all energy used by households is for heating and cooling!

The cost-effective potential is there, and the benefits are not only long-term security of supply but will also be felt directly in the form of more secure and affordable energy for consumers.

The REPowerEU Plan encourages frontloading investments in renewables and energy efficiency to reduce fossil fuels imports as well as doubling the current deployment rates of heat pumps in buildings. It also calls for faster deployment of large district heating and cooling network heat pumps.
Earlier this year, the Commission announced a Heat Pump Action Plan to accelerate heat pump deployment and markets in the EU to make this possible. It will include a partnership between the European Commission, Member States, the sector itself, financial institutions and training providers across the whole heat pump value chain, targeted communication and a Heat Pump Skills Partnership. It will also help focus the ongoing policy work and facilitate access to financing.

Delivering these objectives also requires sharply reducing energy use from new and existing buildings.

The Renovation Wave Strategy set out measures aiming to at least double the annual energy renovation rate by 2030.

The ongoing revision of the EU regulatory framework on buildings will be an essential building block in decarbonising heating and cooling. It will increase the renovation rate, modernise the building stock and allow strong synergies with heat pumps, district heating and other renewables.

There is a provisional agreement between the European Parliament and the Council on new, tighter targets for renewable heating and cooling and district heating and renewable energy use in buildings.

The new rules established in the Energy Efficiency Directive will drive the decarbonisation of district heating and cooling and be a powerful vehicle for clean energy use in the sector.
The decarbonisation of heating and cooling is critical to curb carbon emissions in the building sector. In 2021, heating was responsible for around 80% of buildings’ direct emissions, with fossil fuels accounting for more than 60% of heating energy consumption. At the same time, space cooling will expand more rapidly than any other building end-use, adding 2.4 billion households air-conditioners as incomes and temperatures rise.

In 2021, the IEA published its landmark report Net Zero by 2050 which shows a possible pathway on how to transition to a net zero energy system by 2050 while ensuring stable and affordable energy supplies, providing universal energy access, and enabling robust economic growth.

The report highlights clean district heating and cooling (DHC) networks as critical systems for the transition towards zero-carbon-ready buildings, in particular.
In the Net Zero by 2050 Scenario DHC is expected to cover 20% of global space heating needs by 2030, up from 15% in 2020.

However, as highlighted in our Tracking Clean Energy Progress page, DHC systems are currently not on track to meet the Net Zero by 2050 Scenario targets. While several networks are showcasing “best practices” towards low temperature and clean DHC operation - as highlighted by the finalists of the Global District Energy and Climate Awards - nearly 90% of district heat globally was produced from fossil fuels in 2021.

To fully play its role in the transition, the DHC system requires significant efforts to improve the energy efficiency of existing networks rapidly, integrate renewable heat sources (such as bioenergy, solar thermal, heat pumps and geothermal), integrate secondary heat sources (such as waste heat from industrial installations and data centres), and to develop high-efficiency infrastructure in areas with dense heat demand.

In our IEA Future of Heat Pumps report, we particularly emphasise the contribution that large-scale heat pumps can provide to reduce the dependency on the DHC network from fossil fuels, for example, by allowing heat recovery from wastewater or by increasing temperature at local substations where needed.

The transition of DHC systems can also highly benefit from technological innovation. The expertise provided by the IEA Technology Collaboration Programme (TCP) on district heating and cooling (DHC TCP) has been advancing research in DHC since 1983.
With more than 80 research projects completed, the program is dedicated to innovate and share knowledge on multiple aspects of DHC systems touching on distribution systems, operations, and customers, addressing both technical and policy-related issues. Jointly with IEA, in 2022, buildings-related TCPs published a report to provide the strategic vision of experts from the IEATechnology Collaboration Programmes (TCPs) on how to help achieve some of the most impactful short-term milestones for the buildings sector outlined in the IEA’s Net Zero by 2050 Roadmap. The report also includes an article on DHC, highlighting the main innovation themes, challenges and recommendations associated with DHC systems – highlighting the role that international collaboration can play.

Stronger international collaboration also facilitates the exchange of data collection, best practices and the harmonisation of reporting, an area which would greatly propel the transition of DHC systems. Improving statistics and reporting of data associated to district heating and cooling systems and their benefit for the environment and the community would enable clearer understanding on the potential of DHC systems. Currently, data reporting on DHC is fragmented, being scarce in the case of district cooling systems and highly heterogeneous in the case of district heating systems. While this is a challenging and complex task, it is also a crucial aspect to ensure informed policy decisions and investments in the sector. This market outlook is an important resource towards a better understanding of the status and potential of DHC in Europe.
About the report

This report is a publication of Euroheat & Power’s Unit Market Intelligence. It is based on the contributions from both our internal Committee on Market Intelligence/Statistics and external contributors.

The report was prepared to establish a state of play of the district heating and cooling sector and present its expected deployment in Europe and beyond. It can be quoted as ‘EHP DHC Outlook, May 2023’.
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The war in Ukraine has exposed the dependence of Europe on fossil fuels and created a new impetus to decarbonise the heating sector. Space heating and hot water heating represent roughly half of Europe’s final energy demand, with over 60% coming from fossil fuels[1].

The momentum for clean heat technologies has come, unleashing new opportunities for the district heating and cooling (DHC) sector. As an energy infrastructure, DHC is a Swiss army knife for decarbonisation, enabling the combined use of local renewable heat sources (e.g. sustainable bioenergy, geothermal, solar thermal), renewable electricity, and the recovery of excess heat from industrial and urban sources.

District heating today meets about 12% of final energy use for space and water heating for households, service and industry sectors[2]. The Heat Roadmap Europe[3] project highlighted the significant potential of district heating to cut imported fossil fuels by using renewable energy and waste heat sources: the sector could grow to meet 50% of demands for space and water heating from the service and residential sectors!

DHC is also a critical infrastructure to provide energy storage, enabling the deployment of a greener and more resilient energy sector. Large-scale thermal storage is 100 times cheaper[4] than battery storage and the only proven and available energy technology to provide monthly and even seasonal storage.

The current survey shows that 43 % of European district heat is supplied[5] from renewable and waste heat sources, highlighting the capacity of district heating to reinforce Europe’s energy independence and decrease CO2 emissions. The decarbonisation DHC roadmaps for the various countries – available to members in the country chapters – show that the sector is expected to further decarbonise its supply sources in the near future, to grow and support the decarbonisation of the respective heat markets in Europe.

[1] Source: Eurostat
[3] Heat Roadmap Europe 4 - Quantifying the Impact of Low-Carbon Heating and cooling Roadmaps, Aalborg University, 2018 and Excess heat is world’s largest untapped source of energy, Danfoss, 2023
[5] The reference to Europe in the document refers to the surveyed countries: Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Portugal, Serbia, Slovakia, Slovenia, Spain and Sweden.
2. Scope and methodology

As in previous years, the DHC outlook aims to provide a comprehensive overview of the state of play of district heating and cooling markets in Europe and beyond.

This year’s edition presents many essential changes compared to the previous ones. The geographical scope is broadened: Poland, Iceland, Ireland, Belgium, the UK and Qatar are now included in this publication.

The country chapters are complemented by new ones. A section on the current energy crisis is added to help understand better its impact on the heat sector. A new section on the legislative and regulatory frameworks covers key aspects of the development of DHC schemes. This is meant to support the DHC community in comparing and benchmarking the different markets and help share best practices on regulatory instruments. There are indeed lessons that can be drawn from countries moving faster to transform the heat market!

Like its previous edition, the district heating and cooling outlook is published as an online tool. This flexible format allows Euroheat & Power’s Market Intelligence team to edit content and add updated information as it becomes available to keep track of new developments.

The district heating and cooling market outlook is based on an extensive questionnaire completed by members and associates of Euroheat & Power at the international level. As a result of the improved feedback and support from our members, the questionnaire was amended to improve the comparability of data across countries and focus on the most relevant indicators.

Quantitative data is supplemented by qualitative descriptions of the market environment for each country, providing insights about the latest industry trends, regulatory frameworks and differentiated challenges and opportunities. This edition also covers a dedicated section presenting the evolution and role of DHC in the decarbonisation pathways for the different countries based on scenarios from national associations and/or authorities.

It is important to note that some information is still missing for some countries due to different national data collection practices. Despite progress, this remains, in particular, true for the use of waste heat and for district cooling where less information is available – in comparison to heating. Nevertheless, this outlook already provides an improved overview of the use of waste heat compared to previous editions.
3. District heating in Europe

3.1 Market share

The share of district heating in the final energy use for space heating and water heating is evaluated at 12% at the EU level. There are over 17 000 district heating networks[6] in Europe supplying heat to 70 million[7] citizens.

As illustrated in Figure 1, the share of district heating also varies significantly across the continent. District heating is by far the most common heating solution in Northern and Eastern Europe. However, it still has a large potential to grow in these countries, which developed in the 1980-2000 a heat market relying greatly on natural gas and/or electric heating (e.g. Germany, the Netherlands, the UK, and France).

District heating is experiencing a real renaissance in some markets. In 2021, 22% of new buildings in Germany were connected to district heating. In September 2022, a new support scheme (BEW) entered into force with the objective of greening the fuel mix of existing schemes and developing new ones.

[6] Following the definition of district heating in Article 2 (19) of Directive 2018/2001 on renewable energy sources ‘district heating’ or ‘district cooling’ means the distribution of thermal energy in the in the form of steam, hot water or chilled liquids, from a central or decentralised sources of production through a network to multiple buildings or sites, for the use of space or process heating or cooling’

[7] This figure is an evaluation based on the number of households supplied in the surveyed countries: Austria, Belgium, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, The Netherlands, Norway, Portugal, Serbia, Slovenia, Spain and Sweden and the UK. For Slovakia and Bulgaria, figures for 2019 are used. For Poland the latest figure available (16.5 million citizens) is from 2017.
The sector is also growing in France, with an increase of 70% of buildings connected to heat networks within the last ten years. In both countries, the current energy crisis has led policy-makers to consider new ways to accelerate the pace of change on the heat market.

The Netherlands is another example of a country where change is about to happen. Natural gas has been traditionally very strong in the heat market: it represents 82% of the heating for residential/service sectors. This country has developed a new legislative framework to provide cities with opportunities to roll out district heating. More detailed information is provided in the individual country chapters.

### 3.2 District heating sales

Heat sales are a key indicator for the sector. Sales can vary from season to season based on weather variations, like the warm winter of 2020, which caused a logical decrease in heat demand.

**In Europe, district heating sales amount to nearly 500 TWh in 2021.** For countries with comparable statistics, the year 2021 saw increased heat sales due to colder seasonal temperatures, the end of the COVID-19 lock-downs - which reduced demand from the secondary sector - and new connections (Figure 2).

Over the last decade, growth can be reported on the different market types.

In Northern Europe, the share of district heating continues to progress. District heating has accompanied the growth of urban centres - e.g. Helsinki or Stockholm areas – and will be instrumental in phasing out the small remaining share of fossil-fired individual heating – e.g. Finland and Denmark.

In Eastern and Central Europe, incremental growth is occurring while the competition with individual solutions has been very harsh, particularly with natural gas boilers.
3.3 Installed capacity

The total installed capacity within the European district heating sector is about 300 GWth (2021) for the countries surveyed[8].

Poland and Germany have the largest installed capacities, followed by the Czech Republic, France, Denmark, Finland and Austria (Figure 3). Sweden is not covered in the aggregated figure, as the national association does not collect data on capacity.

[8] Austria, Bosnia Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden and Switzerland. No figures for Belgium, The Netherlands and UK.
As illustrated in the DHC roadmaps in the country chapters, the installed capacity of district heating installations is set to grow to provide a pathway for the decarbonisation of heating[9].

3.4 Energy networks

The distribution networks represent 186,590[10] km across Europe. The growth of networks is correlated to the increase in heat sales.

The size of networks varies greatly between large ones – over 1000 km in capital cities such as Berlin, Vienna, and Bucharest – and smaller ones which connect a few municipal buildings and/or blocks of dwellings in communities and rural areas.

As shown in Figure 4, it is worth highlighting that the upward trend for infrastructure development continues, with variations across countries. In France, the network length nearly doubled between 2009 and 2021.

The analysis shows that DHC infrastructure still grows in mature markets. Finland has shown a 20% increase over the last decade.

[9] district heating Infrastructure Deep Dive, IEA, 2022
[10] This figure covers: Austria, Belgium, Bulgaria (figures for 2019), Bosnia and Herzegovina, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Sweden (2019), Switzerland and the Netherlands (2013).
The evolution for Germany in the graph below – the increase from 2017 to 2019 – may reflect network growth. However, its main explanation is a change in the scope of data collection. For 2019 onwards, the data have been provided by the Federal Statistical Office.

Compared to other countries, data for the Czech Republic show a slight decrease in trench length over the last ten years.

This situation is explained by recent investments to upgrade networks, which aim systematically at system optimisation by re-deploying networks around the largest points of heat delivery – hence leading, in some cases, to a reduction of the overall length of heating infrastructure. Figure 2 above shows that this decrease has occurred while district heat sales kept growing in the Czech Republic.

3.5 Fuel mix

3.5.1 A diverse and changing fuel mix

The fuel mix of district heating systems still varies very much across countries (Figure 5), depending on fuels available at regional levels and the regulatory conditions. The DHC roadmaps available in the country chapters show a sector in the middle of a transition towards sustainable fuels and identified by many Governments and cities as the infrastructure of choice to decarbonise heating.
At European level, the heat sources used in district heating (Figure 6) have evolved over the last 20 years to integrate a higher share of renewable and waste heat.
3.5.2 Combined heat and power

Combined heat and power (CHP) has always played a key role in the portfolio of generation assets within the district heating sector in Europe. These installations ensure the co-production of power and heat with the highest efficiency compared to electricity-only production or decentralised heating systems (e.g. individual boilers and block heating). Although low wholesale power prices have impacted the economics of CHP installations within the last decade, this solution still plays an important role in heat production on mature, upgraded and growing markets, as seen in the graph below.

The share of heat generated in CHP installations varies across the surveyed European countries, as illustrated below in Figure 7. The information for Portugal (100%) refers to two installations using mainly natural gas and bio-energies.

![Share of CHP in the District Heating sector (2021)](image)

For the European countries with the largest established district heating sector, CHP represents over 66% of the total district heat production, as illustrated in Figure 8, based on information sourced by national associations.
In the context of the transition towards climate neutrality, CHP remains a strong option to use fuels most efficiently. This solution will also be increasingly relevant to provide critical services in day-ahead and frequency regulation, accompanying a fast-changing energy system to integrate rising shares of intermittent renewable electricity production. This is particularly true when these installations are coupled with large-scale thermal storage and heat pumps/e-boilers.

In Germany, hydrogen and climate-neutral fuels are expected to be used in new and refurbished gas-fired CHP installations to supply heat and provide flexibility to the power grid, especially in winter. It is particularly difficult to anticipate the amount of hydrogen that will be available for the heat sector due to high demands from other sectors. Cautious analyses predict district heat production on the basis of hydrogen to represent 5 TWh by 2030 and between 14 to 30 TWh, respectively, by 2045 and 2050 [11].

In the Czech Republic, the decarbonisation of the heat sector will imply a diversification of sources using CHP fired with natural gas (until 2040) and an increasing share of sustainable biomass, biogas, and municipal waste.

In Austria, the Energy Agency forecasts an increasing share of supplies from bioenergy (biomass, biogas and green gases) by 2030 and 2050[12]. It is expected that CHP will play a significant role in ensuring both high-efficiency production and system stability.

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[12] Updated Roadmap to the decarbonisation of district heating in Austria, Austrian Energy Agency, 2022
3.5.3 Fuel mix: a rising share of renewable energy sources

The share of renewable energy sources in the DHC sector continues to grow, driven by policies aiming at both decarbonising the heat supply and increasing energy security by valorising local resources.

In total, bio-energies, geothermal, solar heat and the output of heat pumps (including e-boilers) represent today 43% of the European countries surveyed[13]. The shares of renewable sources vary substantially across countries. Iceland has a 93.4% share of renewable heat (geothermal), displaying the full potential of district heating.

Between 2011 and 2021, the combined amount of renewable heat within district heating doubled for France, Austria, the Czech Republic and Denmark, where comparable data from the last ten years are available. The evolution of these markets provides a clear indication of the transition pathway of the sector. Sustainable bio-energies represent the first renewable fuel in district heating systems. The new policy measures under the Fit-for-55 Package proposed by the Commission in July 2021 to ensure the sustainable use of biomass will secure the use of sustainable bioenergy sources in Europe while pushing for a diversification of the renewable sources used in district heating.

The evolution of bio-energy use in district heating reflects the diversity of local markets. For example, in the Czech Republic, the growing biomass share in district heating is explained by converting existing electricity-only biomass plants to cogeneration plants. In France, important investments are planned to harvest the country’s highly untapped potential for the use of sustainable bio-energy sources, in particular in rural areas. In Sweden, recent developments show an interest from utilities in fitting bio-energy plants with carbon and capture storage facilities to develop negative-emission projects.

Other renewable heat sources, in particular solar thermal and geothermal energy, are making a strong breakthrough in district heating and cooling systems. In Europe, 13 new geothermal heating and cooling plants connected to district heating were announced in 2021. In Aarhus (Denmark), the development of Europe’s largest geothermal district heating facility was announced at the beginning of 2022, to be partly operational by 2025[14].

[13] Austria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Norway, Poland, Serbia, Sweden and Switzerland. Bulgaria, Portugal and Spain did not report data, although bio-energies are being used in these two countries.
[14] IEA, district heating – Analysis - IEA
In Iceland, where 90% of homes are heated with geothermal, the city of Höfn inaugurated a new system at the end of 2021.

In France, according to the ‘Transitions 2050’ study developed by ADEME (French Agency for Ecological Transition), the share of geothermal in district heating is set to increase from the current 5.5% share to 16-18% of the fuel mix in a context where the market share of district heating increases from the current 5 to 20%.

In the Czech Republic, the share of geothermal is set to become the third largest heat source after solid biomass and biomethane by 2050, rising to 417 in 2030 and 3056 GWh by 2050.

According to projection studies, in Germany, the share of geothermal and solar thermal within the mix of a growing district heating sector will increase significantly. Geothermal is expected to reach 10 TWh in 2030 and 18 TWh in 2045; solar thermal is 6 TWh in 2030 and 13 TWh in 2045. More detailed information on these projections is available in the country chapters.

Solar-based district heating is also developing with projects across Europe. Denmark hosts the largest capacity with 1.5% or 623 GWh of District Heat produced based on solar energy (2021).

Figure 9 below shows a correlation between a high share of renewable energy in gross final consumption for heating and cooling and the share of district heating for various European countries.

Figure 9: Compared shares of district heating (in energy sources to meet heating demands from residential/service sectors) and shares of renewable energy in gross final consumption for heating and cooling – source: Euroheat & Power and Eurostat (2021)
3.5.4 Waste heat

District heating and cooling provides the infrastructure of choice to use and valorise a wide range of heat flows that are by-products of industrial processes and would otherwise be wasted – without DHC.

Based on the statistical feedback to the survey, the analysis establishes that waste heat represents 2.5% of district heat deliveries for 2021. This figure refers to the use of waste heat from both secondary and tertiary sectors.

The highest shares of waste heat (Figure 10) are found today in markets where district heating is well established and where both heat planning and taxation provide a context leading to these projects.

There is a large untapped potential for waste heat in Europe. The Heat Roadmap Europe Project[15] assessed that waste heat from power generation, industrial and waste-to-energy installations amounts to 2,860 TWh/y in the EU, almost corresponding to the region’s total energy demand for space and water heating in the residential and service sector buildings.

The waste heat from heavy industrial sites in the EU amounts to over 267 TWh a year, which is more than the combined heat generation of Germany, Poland and Sweden in 2021. The sEEnergies Project estimates the potential of waste heat sources over 95°C located within 10 km of existing district heating infrastructure at 64 TWh already, corresponding to 12% of the energy supplied to EU district heating infrastructure annually[16].

In Germany, Europe’s industrial powerhouse, waste heat represents only 0.1% of total district heat supplies. However, the potential in some specific urban areas is significant. Approximately 50 industrial sites in the areas around Essen produce 11.98 TWh/year of waste heat. This is about the amount of heat required to heat 1,200,000 households – or close to half of the households in the area.

The evolution of technology, particularly the development of efficient large heat pumps, has broadened the scope of available sources, including new urban waste heat sources. The project ReUseHeat[17] established the potential for low-temperature waste heat that can be used with the medium of heat pumps. In particular, the project looked at the potential of wastewater treatment plants, data centres, and buildings from the residential and service sectors. The project estimated that ‘accessible’ sources of low-temperature waste heat located ‘inside or within’ 10 kilometres of existing district heating areas could represent over 300 TWh or about 12% of the total European heat demand for buildings.

Data centres appear particularly promising among new sources available for district heating. In 2020, these installations consumed 100 TWh of electricity or around 3.5% of the EU’s final electricity demand. The electricity is principally used by the equipment and cooling units, which basically remove the excess heat from the air and replace it with cooler air. The ReUseHeat project counted 1269 data centres in the EU (+UK), representing a total of 95 TWh/year of accessible excess heat.

The DHC roadmaps, available in the country chapters, show rising shares of waste heat in all national scenarios.

[16] Excess heat potentials of industrial sites in Europe, sEEnergies Project, 2020
### 3.5.5 Large heat pumps

As a reaction to the crisis between Ukraine and Russia, the Commission identified heat pumps in the REPowerEU communication (May 2022) as key solutions to phase out imported fossil fuels, along with deploying other renewable and waste heat sources. The report on ‘The future of heat pumps’ published by the International Energy Agency (IEA) in November 2022 highlights that while individual units fit perfectly in rural and low-heat density areas, district heating is the infrastructure of choice to support the deployment of large heat pumps in urban areas.

According to a report by Euroheat & Power [18], large heat pumps already play a crucial role in district heating and cooling networks in some markets, upgrading sources such as waste and renewable heat to a temperature suitable for heating and cooling buildings (Figure 11).

Combined with thermal storage, electric boilers and CHP heat pumps enable the integration of sustainable sources into the energy system and open up sector integration. Additionally, they also maximise the decarbonisation potential of intermittent renewable electricity sources and provide stability to the energy system.

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**Figure 11: Production and capacity of large heat pumps in DHC systems (2021)**

Large heat pumps are versatile in their capacity to use a wide range of low-temperature heat sources, enabling energy diversification and accelerating the decarbonisation of heating. Combined with efficient and intelligent buildings, large heat pumps open the way for high energy performance and the deployment of 4th and 5th-generation district heating.

The main energy sources which can be harvested via the means of large heat pumps include:

- Renewable heat sources (geothermal and ambient energy)
- Waste heat from industrial processes
- Urban excess heat (e.g. from service/residential sectors – supermarkets, underground metro, data centres etc.)
- Sewage water treatment facilities

Large heat pumps in district heating help reduce the overall electricity demands for heating and cooling. In the context of electrifying many usages, they will further contribute to freeing up capacity for other sectors such as mobility and industry.

Together with city-scale thermal storage, large heat pumps can absorb excess renewable electricity (for direct or postponed use) and modulate production to ensure grid balancing with a quick ramp-up/down of generation and provide weekly and even seasonal flexibility.
The use of large heat pumps within district heating is set to increase across Europe. Based on the investment plans of some of the largest DHC systems in Europe, this capacity is expected to increase by at least 80% by 2030, representing changes in the generation portfolio and growth of networks.

The projections made by associations and/or national authorities in the DHC roadmaps anticipate an important contribution from large heat pumps in the perspective of a growing and changing sector.

The market uptake will be driven by the opportunities related to low-temperature sources, whether from waste heat or renewable energy sources.

In France, the geothermal district heating network in Arcueil/Gentilly (Paris region) was developed in only 2 years and provides a heat supply based on a share of 60% renewable energy with geothermal and large heat pumps replacing heating previously based on fossil fuels. With the optimisation of the secondary circuit (heat distribution within the buildings), the overall return temperature of the water in the network was lowered, increasing the uptake of geothermal heat.

In Denmark, the network in Odense is another example of the significant potential associated with large heat pumps. Here the waste heat from a data centre owned by Meta is valorised by heat pumps. This approach, coupled with renewable electricity, delivers a 100% renewable heat supply and provides grid stability.
4. District heating and the energy crisis

4.1 Competitiveness and consumer protection

The economic rebound following the end of the COVID-19 lockdown in 2021 led to an increase in energy prices across Europe, in particular natural gas. The crisis in Ukraine and the phase-down of fossil fuel imports from Russia reinforced the upward evolution of fuels and power prices. Increased energy costs impacted the competitiveness and liquidity of DH operators, in particular, those still relying on natural gas. Investment costs for all new energy projects rose over the last two years. The increase was fueled by the shortage of important components with the economic rebound along with general inflationary pressure. The inflation in the Eurozone reached 8.5% in February 2023 year to year (source: Eurostat). The conflict in Ukraine had also impacted industrial sectors - including energy - with a disrupted supply of important inputs to projects – cable, steel etc. - leading project developers to search for alternative providers.

If the crisis has resulted in a more difficult environment for all energy operators, it has also demonstrated the resilience of district heating in such a crisis.

Despite project cost increase DHC was actually less exposed to price volatility depending on the fuel mix of individual systems. In particular, networks using already a large share of renewable and waste heat have been able to provide customers with fair and stable prices and have faced increasing requests for connections from new customers.

Figure 12 below provides evidence that consumers connected to district heating using renewable and recovered heat were well sheltered from volatile prices for fossil fuels.

![Figure 12: Compared evolution of price for France, with and without State intervention (source: AMORCE)](image-url)
The Figure 13 below shows the compared evolution of energy prices in Denmark within the last ten years. District heating prices have remained stable for 2020-2022 when the prices for other heat sources skyrocketed.

Figure 13: Evolution of Energy Prices for Denmark 2012-2022 (source: Danish Statistics Office)
4.2 European and national responses

In such a context of uncertainty that clearly impacts households and industries, national Governments have taken action and implemented measures to shield consumers from rising energy costs. Governments implemented measures such as reduced taxation rates, direct compensations, aid to address liquidity and bail-out in extreme cases.

The European Commission took measures to provide a framework for Member states to address the impact of rising energy costs on undertakings and households. The State Aid rules were modified three times to this effect, the last time with a proposal in February 2023. In March 2023, new legislative proposals were published to reform the electricity market and address price volatility.
Rather than postponing the energy transition, the current crisis has provided a new impetus to accelerate the transformation of the heat sector. Next to responses to address the crisis’ short- or medium-term impact, measures with more durable effects were taken in many countries to quicken the pace of the heat transition. The focus was, to a great extent, on small heat pumps. However, it also features in many markets a renewed interest in accelerating the growth of district heating. This is very well illustrated in the country chapters.

Based on national objectives and estimates from the sector (see table below) to reach the national energy and climate goals of selected countries, over 5 million additional households are expected to be connected to district heating by 2030. This growth is particularly important in new and growing markets. In mature markets, the crisis has confirmed the choice of district heating to decarbonise the heat supply well before 2050. In Denmark, where district heating is well established, authorities decided to accelerate the phase-out of the remaining boilers using natural gas.

This estimation is very likely an underestimation as it does not cover all of Europe. Many Governments are working to accelerate the heat transition in response to the current energy crisis.

When this report was finalised, discussions were underway in several countries. In France, for example, discussions are ongoing regarding the law on programming investments in energy infrastructure, which may increase the target for growing the share of renewable energy sources, including heating. In Germany, a federal law is under discussion to accelerate the transition towards renewable heating.

This projection shows a growing awareness that district heating and cooling networks are critical infrastructure to phase out imported fossil fuels and reduce the risk of volatile prices for households.

While these are encouraging, implementing new projects could be impacted by the lack of skilled workforce in many countries. Dedicated measures in the field of education and training should accompany all ambitious national/regional objectives.
<table>
<thead>
<tr>
<th>Countries</th>
<th>Expected growth by 2030</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>France</td>
<td>+ 215k households/year</td>
<td>Estimate by the national association</td>
</tr>
<tr>
<td>Scotland</td>
<td>+ 650k households</td>
<td>Heat network (Scotland) Act, (2021)</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>+500k households</td>
<td>Climate agreement between Government and sectors klimaatakkoord (2019)</td>
</tr>
<tr>
<td>Germany</td>
<td>Between 300-600k households/year</td>
<td>Estimate by the national association</td>
</tr>
<tr>
<td>Denmark</td>
<td>+250/300k new households by 2028 (Phase out of 400k gas boilers to be replaced by district heating and individual heat pumps)</td>
<td>Estimate by stakeholders</td>
</tr>
<tr>
<td>Austria</td>
<td>+ 350k new households</td>
<td>Forecast of Austrian energy agency (2022)</td>
</tr>
</tbody>
</table>

Figure 14: Project connections of new households to District Heating by 2030
6. Country focus: Austria, France and Germany

6.1 Austria

District heating is a success story in Austria. Heat sales have been multiplied by 3 between 1990 and 2021 - and by 20% within the last ten years. The growth of heat networks has been instrumental in phasing down the use of fossil fuels and valorising local bio-energy resources. Today district heating has a market share of 30% in the residential and service sectors. This success is explained by policy instruments such as investment aid, a commitment to developing sustainable bioenergy as well as the strong role of cities.

The current energy crisis incentivised Austrian authorities to boost the country’s heat transition. Under a new Renewable Heat Law (2022), funding will be available to end the use of fossil fuels with dedicated support for end-users to switch fuels and operating aid to develop heating infrastructure.

In total, 252 million EUR are expected to be allocated by the Government for district heating and cooling for 2023-2026 out of a total of 5.7 billion EUR allocated for the ‘green transformation’ in the residential, service and industrial sectors.

The Austrian Energy Agency forecasts an expansion from 1.4 to 2.1 million building units supplied with district heating by 2040, with networks reaching 13,000 kilometres in total, be it an increase of 37% compared to today. The Agency forecasts a total of 10 billion EUR of investment by 2040 to carry out the heat transition, as illustrated in Figure 15.

<table>
<thead>
<tr>
<th>Cumulated investment 2021-2040 (EUR million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waste-to-Energy</td>
</tr>
<tr>
<td>Biomass</td>
</tr>
<tr>
<td>Biogas</td>
</tr>
<tr>
<td>Green gas (e.g., hydrogen and synthetic gases)</td>
</tr>
<tr>
<td>Heat pumps</td>
</tr>
<tr>
<td>Geothermal</td>
</tr>
<tr>
<td>Infrastructure</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Heat storage is not covered.

Figure 15: Investment forecast for district heating 2021-2040 by Austrian Energy Agency [19]

[19] Roadmap to decarbonise district heating in Austria, Austrian Energy Agency, July 2022
6.2 France

France belongs to the category of fast-developing markets. District heating has experienced a renaissance since adopting an unprecedented package of measures[20] covering efficiency and renewable sources that followed a broad consultation of stakeholders on ways to drive the energy transition in 2007. With a 5% market share, there is still a large growth potential to replace fossil-fuel heating (over half of the heat consumption for the residential sector[21]).

Since 2009 the length of heat networks has nearly doubled, from 3450 to 6529 km (2021), and systems have halved their CO2 emissions thanks to the introduction of renewable and waste heat sources.

The Heat Fund, providing investment aid, has been the key instrument to drive the heat transition. Between 2009-2020, the fund supported 6000 projects – including 1200 district heating projects - for a total budget of 2.5 billion EUR. The efficiency of the Heat Fund - managed by ADEME - to accelerate decarbonisation has been praised twice in reports published by the French Court of Auditors.

At the average gas price in 2021, the national agency ADEME estimates that the 39 TWh of renewable energy produced by all the projects supported by the Heat Fund since its creation allowed savings on the annual fossil fuel import bill of around 1.6 billion EUR in 2021.

The current energy crisis highlights the benefits of efficient district heating in providing sustainable heat at a fair and stable price. As a result, demands for connections to district heating have significantly increased compared to previous years, according to French district heating operators.

In this context, French authorities have taken new measures in 2022 to accelerate the heat transition.

On top of already existing measures, the most impacting decision was to increase the amount of funding available under the Heat Fund to 520 million EUR for 2022. The Government also took steps to incentivise the ‘quick connections’ of buildings located in areas supplied by an existing efficient district heating. A decree adopted in April 2022 also set out the principle of a mandatory connection to efficient district heating for new and renovated buildings. These new measures are expected to provide an additional boost for new projects.

Despite the high growth, France will still need to increase the level of funding to exceed the objective[22] of 39,5 TWh of renewable heat by 2030. According to FEDENE, this objective implies the development of 1600 new district heating projects (211 extensions and 1337 new systems) and will require an estimated 25 billion EUR of new investment.

When this report was being finalised, the French Government was holding talks with stakeholders on updated objectives for 2030, which may include an increased ambition for renewable and recovered heat.

### 6.2 Germany

District heating has a long tradition in German cities and currently accounts for 14% of households and 10% of the energy used to satisfy heat demands from residential and service sectors. The sector has significant potential to grow to replace individual oil and gas boilers representing 75% of the heat market.

Current levels of energy prices and uncertainty regarding future developments have impacted the whole energy sector in Germany, including the district heating sector, where natural gas represents 48% of heat production (BDEW, 2020).

In terms of projection, the objective of climate neutrality by 2045, set in the 2021 National Climate Change Act, will lead to the expansion of decarbonised district heating systems in urban areas and the deployment of heat pumps in areas with less density.

A new financing scheme BEW (Bundesförderung für effiziente Wärmenetze), started operations in September 2022 to support the transition in the district heating sector. Based on the available budget (€ 3 billion until 2026), the scheme is expected to mobilise over 1 billion EUR of additional investment per year. According to the German Ministry of economic affairs, the scheme's implementation will lead to the installation of an additional annual capacity of 681 MW of renewable heat, representing a reduction of 4 million tCO2/y until 2030.

**BEW** aims to support the conversion of existing district heating systems to alternative sources (renewable and waste heat) and to develop new schemes with a share of renewable/waste heat of at least 75%. The whole energy chain, from production facilities to buildings, is eligible for support through investment and/or operating aid.

[22] This objective was laid down in the Energy Transition and Green Growth Law (2015)
According to Government forecasts conducted before the energy crisis, hard coal and lignite are expected to be replaced with natural gas, which will peak at 53% in 2025. Climate-neutral sources such as heat pumps, hydrogen, renewable energy, and waste heat are expected to replace natural gas between 2030 and 2045.

There are several studies on the future of heating, notably from BMWK, Prognos and Ariadne, with slightly varying projections. Overall, the heat supplied to buildings by district heating is expected to rise to approximately 18% by 2030 and to around 26% by 2045. This is equivalent to almost doubling the current share by 2045. According to several projection studies from BMWK, district heating will play an important role in decarbonising the heating sector and achieving climate goals, especially in larger cities and more densely populated urban areas.
7. District cooling

7.1 Introduction

At the global level, energy demands for space cooling increased more than twice as fast as the overall energy demand in buildings over the last decade. This rush for cooling is driven by higher temperatures caused by climate change, increasing incomes and growing populations[23].

Cooling demands are one of the main contributors to electricity demand growth in emerging and developing economies; the STEPS scenario (keeping current policy options) by the IEA forecasts an extra 2 800 TWh globally for space cooling by 2050 to be necessary to meet these demands or ‘the equivalent of adding another European Union to current global electricity demand[24]’.

In Europe, the repeated summers with extraordinary seasonal temperatures combined with rising consumers’ expectations in terms of comfort are leading to growing demands for cooling. These demands are largely embedded in power demands, generally met with building-bound units supplying a large building, typically in the secondary sector. The diffusion of air-conditioning units in the residential sector has also developed dramatically across the surveyed countries within the last 20 years.

Functioning along the same principle as district heating – with a central production unit supplying thermal energy through a network of pipes, district cooling offers a high-efficiency alternative to stand-alone air conditioning units providing access to new resources such as renewable (free cooling from sea/lake water) and waste heat sources and the capacity to offer flexibility to the power grid.

This capacity of district cooling to offload the last kilometre of the grid becomes a strong asset in the context of high-density urban centres engaged in the ‘electrification of all things.

Additionally, district cooling networks offer optimal climate solutions as they use less working fluids (in heat pumps and chillers) than small units. Generation units sited within a cooling network can also strictly control all working fluids to avoid leaks and comply with dedicated regulations that do not apply to small units.

[23] International Energy Agency, Sustainable, Affordable cooling Can Save Tens of Thousands of Lives Each Year, March 2023
Sales of district cooling amounted to 3 TWh, with over 150 systems across Europe in 2021 (Figure 16). District cooling supplies nearly exclusively buildings from the tertiary sector but can provide integrated solutions for other sectors, such as storage sites requiring constant cold temperatures (e.g. food sector).

In terms of infrastructure, the cooling networks in Europe represent 1358 kilometres of pipes, with 70% of the total based in 3 countries – Sweden, France and Finland (Figure 17).
7.2 Outlook for district cooling

Existing European schemes are expected to grow to accompany new urban developments.

After a strong growth first in Sweden (early 2000s) followed by Finland (after 2010), district cooling is now growing swiftly in Denmark and Norway. Projects are also recorded in France, Germany and Austria.

New projects are materialising in southern Europe after a lost decade following the financial crisis when all projects were stopped. For instance, in Barcelona, the Ecoenergies network supplying the Zona Franca will start to use the residual cold waste from the regasification of liquid natural gas by Enagás. By November 2023, this new capacity (18 MW) will come in addition to the existing generation assets of the network. This system will be the first district cooling network at the global level to make use of surplus cold from an LNG terminal.

This example shows the versatility of district cooling to adapt to local contexts and its ability to valorise energy streams that would otherwise be wasted- or, in this case, dumped into the sea.

In Sweden, district cooling is expected to reach a 25% market share by 2030 based on operators' investment forecasts. In France, under the new concession agreement, the Paris network length should double within the next 20 years. In Austria, after strong growth over the last decade – since 2009, cooling sales were multiplied by 7 – developments will continue in many cities. In Vienna, the operator plans to double the network by 2030.

However, the analysis shows factors that may generate uncertainty and limit investments into capital-intensive infrastructure such as district cooling networks. Under current conditions, a proper framework to recognise and address the cooling challenge is missing at the European level. The contribution of district cooling networks to developing sustainable and resilient urban areas is not recognised. At the end of 2020, Member States delivered their heating and cooling strategies[25].

The analysis of the first 21 countries to deliver their plans showed that only 6 countries mentioned cooling demands.

[25] The Energy Efficiency Directive (2012) requires Member States to deliver every 5 years a plan (or ‘comprehensive assessment’) highlighting the potential for district heating and cooling as well as High Efficiency Combined Heat and Power.
The war in Ukraine has put pressure on the EU to accelerate further its efforts to deploy energy efficiency and renewable energy sources. The REPowerEU Plan and successive emergency measures aimed at accelerating the pace of the energy transition by facilitating funding and establishing renewable projects. The crisis occurred when the European Union negotiated the Fit-for-55 package (FF55) presented by the European Commission in 2021. This package provides the regulatory instruments for the European Union to reduce its greenhouse gas emissions by 55% by 2030 in line with the pathway towards climate neutrality goal by 2050.

The package is expected to drive forward the integration of sustainable heat sources and enhance synergies with other energy grids. It further recognises the importance of DHC networks to achieving energy and climate goals, enabling the decarbonisation of heat supply while increasing the overall system's efficiency.

Provisions dedicated to DHC build on previous EU legislation bringing some positive evolutions while considering the sector's specificities (e.g. integrating third-party supplies of sustainable heat in larger systems is encouraged within the conditions of technical and economic feasibility).

While many files have been agreed upon, including the EU Emissions Trading System (EU ETS), some others will be finalised by the end of 2023. The revisions of the Renewable Energy Directive (RED) and the Energy Efficiency Directive (EED) are expected to be formally adopted and published in the coming months, following the informal agreement reached by institutions in Q2. Negotiations on the Energy Performance of Buildings Directive (EPBD) will continue until this fall.

The package reflects several positive trends in legislation and represents opportunities for the growth of the district heating and cooling market (Figure 18). The role of DHC as a key solution to decarbonise heating and bring flexibility to the energy system is further recognised. Co-legislators also agreed on an overall binding renewable target of 42.5% in 2030, with a non-binding 2.5% increase bringing the target to 45%. This ambition is also reflected in the heating and cooling sector, with a binding target for the annual increase of renewables of 0.8 percentage points for 2021-2025 and 1.1 percentage points for 2026-2030.
A new definition of efficient district heating and cooling is introduced, which gradually puts the sector on track to carbon neutrality by 2050 and includes waste heat and renewable targets. It acknowledges the potential of waste heat to complement renewable energy sources in decarbonising heat. Waste heat can also contribute to renewable sub-targets for buildings, industry, heating and cooling, and DHC. With greater recognition of the role of waste heat, the RED outlines a toolbox of measures (risk mitigation frameworks, increased coordination between waste heat actors) to support the exploitation of both renewable and waste heat sources as part of a diversified energy mix.

In addition, the package places greater emphasis on the local level by introducing compulsory comprehensive heating and cooling assessments for cities with populations above 45,000 inhabitants. This requirement will enable cities and municipalities to actively participate in the energy transition by developing and implementing sustainable heating and cooling solutions.

The package includes a carbon price on all fossil fuels used in buildings with the EU ETS2. Although the CO2 price is capped at 45 EUR per ton until 2030 to protect consumers, this is an important development to establish a level-playing field between boilers and larger installations already covered under the Emission Trading scheme.
The combination of targets and incentives outlined in the FF55 package, the new State aid rules, and the Resilience and Recovery Fund have the potential to boost the uptake of renewable and recovered heat significantly. A close follow-up of the implementation at national levels will be important to translate these new measures into opportunities to build a more sustainable heat sector.

Despite the good signals from Brussels, more attention and additional support for the heating and cooling sector will be necessary to achieve the decarbonisation goals of the EU.
The district heating and cooling systems have great innovation potential, especially in reducing greenhouse gas emissions and tackling climate change. There have been many technological advancements in the last two decades, making heat networks more complex and providing many opportunities to improve efficiency and sustainability.

DHC systems have advantages over other energy technologies, especially in integrating multiple energy sources, such as renewable heat and waste heat recovery. Smart grids and digital control systems can optimise the operation of these systems, while thermal storage systems and advanced insulation materials can improve overall performance. By enabling the efficient use of renewable energy sources, DHC systems can accelerate the transition to a decarbonised energy system. New technologies such as AI and energy storage are being explored to optimise the design and operation of DHC systems.

The industry also adapts to local renewable resources, like biomass, solar thermal, and geothermal energy. DHC networks need large-scale, low-cost energy storage solutions to store intermittent energy from renewable sources efficiently. New financial models are being developed to encourage investments in green heating solutions, focusing on delivering heat as a service rather than a commodity. With a centralised digital management system, DHC networks can use multiple and unpredictable heat sources while integrating highly efficient heat pumps and thermal energy storage. This adaptable system can also apply dynamic modelling and machine learning for optimal performance and efficiency. The DHC industry is constantly innovating to create a more sustainable and efficient energy system for the future.

9.1 District heating networks generations

A common and useful way to understand the development of district heating is through the use of "generations", as illustrated in Figure 19. While this approach is not yet universally accepted in the district heating and cooling community, it remains the best approach to provide an overview of the technological advancement of a heat network. Currently, most European heat networks fall under the third generation despite significant differences between individual markets.
Several European countries have made notable progress in incorporating renewable energy sources into their district heating systems, with at least 8 countries achieving more than 40% renewable energy in their district heating supply.

This trend has contributed significantly to the overall increase of renewable energy sources in the region's heat demand. Recently, there has been a shift towards the adoption of fourth-generation district heating (4GDH) or low-temperature district heating to replace third-generation district heating (3GDH) networks. This new technology offers numerous benefits, including reduced heat losses, lower thermal stress and scalding risks, and the ability to use low-temperature waste heat and renewable energy sources.

![Image: The four generations of district heating technologies defined by time periods]

Currently, the Nordic countries have the most advanced heat networks, with fourth and even fifth-generation district heating systems featuring fully decarbonised energy supplies, a wide range of integrated renewable energy sources, low-temperature distribution, and high energy efficiency in heat distribution and consumption.
In central and southern Europe, many innovative heat networks that still rely on fossil-fuel cogeneration. Still, there is a positive trend towards increased integration of renewable energy sources, digitisation, and lower heat distribution temperatures. In contrast, many Eastern European markets still use second or even first-generation heat networks that primarily rely on solid fossil sources with relatively high temperatures.

Although the concept is relatively new and somewhat controversial, there is growing recognition of the potential of fifth-generation district heating (5GDH) in the scientific literature. This innovative approach prioritises individual end-user heat/cold supply through the use of individual heat pumps and leverages a diverse range of decentralised, sustainable energy sources to operate at ultra-low temperatures.

One of the key differentiators of 5GDH is the use of temperature adjustment, such as heat pumps and specialised substations, to enhance the overall efficiency and sustainability of the system. With optimised networks and a high degree of digitisation, 5GDH systems have the potential to revolutionise district heating technology and pave the way for a more sustainable and efficient energy future.

**9.2 Low-temperature district heating (LTDH)**

District heating networks are evolving towards lower distribution temperatures, which reduces heat losses and enables the integration of sustainable heat sources. As mentioned before, this shift from 3rd to 4th generation networks is crucial for decarbonising European cities.

The not-widely accepted concept of 5th-generation networks that operate at ultra-low temperatures has also emerged in recent years. This generational leap impacts all aspects of the thermal energy flow, from generation to end-user consumption. It will change pipe dimensions, network construction and installation methods, and new substation development. These changes will enable the integration of new kinds of sustainable energy sources and network optimisation through digitalisation.

The transformation from 3rd to 4th-generation networks is closely linked to the transformation of the building stock towards high efficiency and reduced CAPEX and OPEX of components, allowing for lower network operating temperatures. Individual heat pumps in buildings can be used to increase water temperatures to supply district hot water and eliminate the risk of legionella.
The lower operating temperature of 4th/5th generation networks enhances system efficiency, lowers distribution heat losses, and increases integration of locally available renewable and waste heat resources. Developing these networks will enable a cost-efficient and technically viable decarbonisation of the European DHC sector.

Several H2020 projects are currently engaged in advanced research on low-temperature district heating and cooling. For instance, the COOL DH project examined and evaluated technological alternatives for utilising low-quality heat sources. In addition, RELATED seeks to decrease the operating temperature of networks by integrating renewables at both the building and district levels. Meanwhile, the TEMPO and REWARDHeat projects are focused on developing fresh business models that offer heat as a service.

### 9.3 Waste heat recovery

Waste heat from industrial processes, data centres, wastewater, and supermarkets can be reused for heat, cold, and domestic hot water via district heating and cooling systems, representing a promising low-carbon energy source.

Despite barriers such as the limited availability of district heating networks in some countries and low interest among waste heat owners, unconventional waste heat sources like sewage water, data centres, and tertiary buildings could potentially cover 10% of the EU’s total energy demand for heat and hot water. In contrast, waste heat recovery can improve industrial energy efficiency.

Waste heat recovery has the potential to displace primary energy demand for heating, reducing GHG emissions and addressing climate change. However, technical and economic barriers such as temporal and locational mismatch and long payback periods pose significant challenges, and legislative and regulatory barriers, such as waste heat not being considered on par with renewable energy sources, must be overcome.

Initiatives like EMB3Rs, INCUBIS, ReuseHeat, Heat4Cool, and RES-DHC are addressing these barriers and accelerating the adoption of waste heat recovery solutions to promote the transition to more sustainable energy systems.
9.4 Thermal storage

Thermal energy storage (TES) is a crucial component in the transition to sustainable energy systems, and several innovative building technologies are currently being developed for this purpose. These technologies are at various stages of development and can be classified into two categories: large, sensible thermal energy storage and compact thermal energy storage.

Large-scale TES is essential for providing flexibility and enabling the increased use of renewable energy sources in district heating and industrial heating up to 100°C. Additionally, it can help absorb excess electricity at short notice, allowing for a higher degree of renewable power generation.

While TES research has historically focused on seasonal storage of renewable energy sources, recent advancements will enable multifunctional use of TES, including seasonal storage of RES, avoidance of fossil fuel-based peak load cover, and integration with the renewable electricity market via sector integration.

![Figure 20: Role of thermal energy storage in providing flexibility to DHC and power sectors. Note: DER = distributed energy resources. Source: IRENA, 2020](image)

Notable TES projects are ongoing in Europe, including giga_TES in Austria for developing next-generation TES systems, HEATSTORE in Denmark for monitoring large TES systems, and the IEA Annex39 program for large thermal energy storage.
Demonstrations of large-scale, sensible TES have been carried out in various European countries, with PIT and TTES developing in Austria, Denmark, and Germany. High-temperature BTES is used in Germany, Denmark, and Belgium, while ATES is being developed in the Netherlands. Compact thermal storage of solar energy is being explored in projects such as COMTES, MERITS, CREATE, SOTHERCO, and HEAT INSYDE, and phase change materials systems are being developed by initiatives like SAM.SSA and EUROPA for low-temperature applications.

9.5 Digitalisation

The integration of digital technologies has revolutionised district heating and cooling, leading to several advancements that have made it easier to optimise network operations while empowering end-users. One of the most significant advancements is using smart meters, thermostats, and sensors, which have become more intelligent and less expensive. This has enabled higher monitoring and control of the system, allowing for real-time optimisation of networks with the help of artificial intelligence and digital twins.

Moreover, stakeholders can leverage the Internet of Things (IoT), automation, AI, and big data to access more field data and obtain a complete digital view of assets. This, in turn, enables district energy systems to fully optimise their operations and empower end-consumers with transparency and benefits. These developments have the potential to lead to new business models, such as incentivising end-users through demand response to reduce system costs and increase the use of renewable energy sources.

However, despite these significant advancements, challenges such as data security and privacy and questions about data ownership still need to be addressed. Additionally, interoperability remains a significant challenge in large-scale systems like district energy systems, which require detailed digital information from sensors and SCADA systems and components and subsystems throughout the plant.

The field of digitalisation for district heating and cooling is seeing several innovative projects that are transforming buildings and heat networks into smarter ones. For instance, the DigiBUILD project aims to create an open, interoperable, and cloud-based toolbox that can help transform current buildings into digital and interoperable ones. Another project, SRI-ENACT, focuses on facilitating the Smart Readiness Indicator (SRI) uptake in Europe.
9.6 Energy systems integration

Energy system integration is a complex and multifaceted process that requires coordinating and optimising various energy carriers, infrastructures, and consumption sectors. District heating and cooling networks are critical to this process. They create connections between different parts of the energy system and provide flexibility through various commercially and technically available technologies.

In recent years, modern low-temperature district heating systems have been designed to connect local energy demand with renewable and waste energy sources and wider electricity and gas grids. By doing so, they contribute to optimising supply and demand across energy carriers, which can help reduce curtailment and the need for direct electricity storage. Additionally, increasing the synergies between electricity and heat networks through multi-energy carrier integration can further maximize the use of renewable energy sources and improve the efficiency of the whole energy supply.

One of the key benefits of coupling the electrical and thermal grids, along with energy storage, is that it leads to more stable electricity demand and a reduction in electrical peaks. This means that DHC networks can also be coupled with the gas grid by using excess heat from fuel cells or other CHP processes involving hydrogen and biomethane. Recovering heat losses from electrolysis processes for hydrogen generation can also increase overall system efficiency.

However, successful energy sector integration requires optimal system control to exploit fuel shift capabilities and energy storage. Innovative business models and market designs are necessary to encourage stakeholders from the heating and cooling sector to develop new control strategies and benefit from the additional flexibility DHC systems can provide. Additionally, improved collaboration, transparency, and communication between stakeholders from different sectors are essential. Standardised monitoring systems, data-sharing protocols, and collaborative platforms can facilitate the development of all sectors towards higher integration.

Several initiatives focus on integrating district heating and cooling systems into the energy system. For instance, projects like SENERGY-NETS, SMILE, MAGNITUDE, and PLANET concentrate on energy system integration, smart grids, and storage solutions to enhance energy system flexibility.
Annex A - References


[5] The reference to Europe in the document refers to the surveyed countries: Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, The Netherlands, Norway, Poland, Portugal, Serbia, Slovakia, Slovenia, Spain and Sweden.

[6] Following the definition of district heating in Article 2 (19) of Directive 2018/2001 on renewable energy sources, ‘district heating’ or ‘district cooling’ means the distribution of thermal energy in the form of steam, hot water or chilled liquids, from central or decentralised sources of production through a network to multiple buildings or sites, for the use of space or process heating or cooling.’

[7] This figure is an evaluation based on the number of households supplied in the surveyed countries: Austria, Belgium, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, The Netherlands, Norway, Portugal, Serbia, Slovenia, Spain and Sweden and the UK. For Slovakia and Bulgaria, figures for 2019 are used. For Poland, the latest figure available (16.5 million citizens) is from 2017.

[8] Austria, Bosnia Herzegovina, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden and Switzerland. No figures for Belgium, The Netherlands and the UK. 2019 figures applied for Sweden.


[10] This figure covers: Austria, Belgium, Bulgaria (figures for 2019), Bosnia and Herzegovina, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Norway, Poland, Portugal, Serbia, Slovenia, Spain, Sweden (2019), Switzerland and The Netherlands (2013).

[12] Updated to the Roadmap to the Decarbonisation of district heating in Austria, Austrian Energy Agency, 2022

[13] Austria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Iceland, Italy, Latvia, Lithuania, Norway, Poland, Serbia, Sweden and Switzerland. Bulgaria, Portugal and Spain did not report data, although bio-energies are being used in these two countries.

[14] IEA, district heating – Analysis - IEA.


[22] This objective was laid down in the Energy Transition and Green Growth Law (2015)

[23] International Energy Agency, Sustainable, Affordable cooling Can Save Tens of Thousands of Lives Each Year, March 2023


[25] The Energy Efficiency Directive (2012) requires Member States to deliver every 5 years a plan (or ‘comprehensive assessment’) highlighting the potential for district heating and cooling as well as High-Efficiency Combined Heat and Power.
Euroheat & Power

The heating and cooling network!

Euroheat & Power is a not-for-profit association headquartered in Brussels, Belgium, which unites the district energy sector.

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