District energy

The backbone of a flexible, resilient and efficient energy system

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DISTRICT ENERGY
The backbone of a flexible, resilient and efficient energy system

Version 1.0
November 2024

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FOREWORD

From energy independence to the future integrated energy system

BY KRISTOFFER BÖTTZAUW, DIRECTOR OF THE DANISH ENERGY AGENCY

District heating has a long history in Denmark, with the first system being built in a part of Copenhagen, Frederiksberg, in 1903. In the 1970's, the global energy crisis forced Denmark to change its path on energy policy. District heating was an important part of the Danish answer. In this endeavor, heat planning supported the roll-out of district heating, which, combined with cogeneration, provided an alternative that delivered both affordable heating and high fuel efficiency.

Five decades later, during the most recent energy crisis, district heating was once again an important part of the response. While the heat price for many European households skyrocketed, the average price for a household supplied with district heating in Denmark stayed stable. Now, in the aftermath of the crisis, we continue to rely on district heating to provide secure, affordable, and increasingly green energy.

District heating continues to expand in Denmark, and more than two-thirds of households are now connected to district heating. Where district heating once relied on oil and coal, Danish district heating production is now based on more than 75 percent renewable energy. It has adapted to the policy challenges of our time, supported by an established sector through ongoing innovation and knowledge sharing.

Looking ahead, I expect Denmark to continue to be a green frontrunner in global climate action that inspires and encourages the rest of the world. Our goal is 70 percent emissions reductions by 2030 and climate neutrality by 2045. District heating is a key component of the future energy system, which must transition to renewables, but also integrate new technologies such as carbon capture, utilisation and storage and power-to-x.

Through its long history, district heating has proven its resilience and changed in accordance with the needs of our citizens and energy systems.

Simply put, it has been and will continue to be a key technology in Danish green transition. With the recent revisions to key directives, the European Union has now accelerated the push for energy efficiency and renewable energy integration in buildings, underlining the potential for district heating to be a cornerstone technology for the green transition across Europe as well.

This publication shines a light on the benefits of district heating, the key elements of Danish regulation and planning of heating, how we have used district heating to enable sector coupling and the district energy systems of tomorrow. Throughout, you will have the chance to explore how Danish strongholds and solutions across the district energy sector are making a difference both nationally and internationally.

I hope you will feel inspired and join us on the journey towards a more secure, more resilient, and integrated energy system.

Kristoffer Böttzauw
Director of The Danish Energy Agency

FOREWORD

Time to bring heat home

BY AURÉLIE BEAUVAIS, MANAGING DIRECTOR OF EUROHEAT & POWER

In February 2024, the adoption of the EU Fitfor55' package paved the way for a stronger recognition of district heating and cooling as a critical solution to accelerate the EU energy transition. The mandatory development of local heating and cooling plans in cities above 45,000 inhabitants, will ensure that district energy is always considered, and that local sources of renewable heat and waste heat are used. The revised Energy Efficiency Directive set a clear decarbonisation pathway for heating networks by 2050, a necessary step to build trust with decision makers. Finally, the Renewable Energy Directive puts waste heat on an equal footing with renewable heat and proposes concrete measures to improve the integration of energy systems.

Combined with the momentum generated by the energy crisis and REPower EU, the Fitfor55' package has rekindled the ambitions of many European countries to develop heating and cooling networks. Germany, France, Austria, and the Netherlands, announced ambitious measures and funding to further harness the potential of this essential energy infrastructure.

Still, we must do more.

The Draghi report threw a spanner in the works, pointing out the risks posed by rising energy prices to the EU's competitiveness and prosperity. 'The EU must spend twice as much as it did after WWII', he said, recalling the urgent need to escape economic stagnation with a massive investment plan in clean technologies and energy infrastructures.

Then let's spend wisely. Whether we're talking about climate, energy security or energy prices, heating and cooling decarbonisation must be a priority. We need a massive investment plan to deploy renewable heat sources, recover waste heat sources, and roll-out efficient clean heating solutions such as district heating and cooling networks.

With the forthcoming implementation of the European Directive on the energy performance of buildings and the entry into force of the ETS2 mechanism in 2027, millions of households and property owners will need to invest in building retrofits and phase-out fossil heating. We now have the responsibility to make clean heating and cooling solutions and building renovations not only accessible, but affordable for all.

In this context, the second Von der Leyen Commission is off to a good start, with the appointment of Dan Jørgensen, Denmark's previous Minister of Climate and Energy and Utilities, as Energy and Housing Commissioner, with a clear mandate to decarbonise heating and cooling, and bring down energy prices for households. The proposed 'Citizen Energy Package', 'European affordable housing plan' and 'Action plan for affordable energy prices', are three pivotal initiatives to make clean heating and cooling solutions and building retrofits more accessible and affordable.

With a new Commissioner for Energy and Housing at the helm, it is time to bring heat home!

Aurélie Beauvais
Managing Director of Euroheat & Power

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About this white paper

The energy system of tomorrow calls for solutions that are green, flexible, resilient and socioeconomically feasible. Few solutions embody these qualities as well as district heating and cooling (collectively district energy). And while power often takes the spotlight in the green transition discourse, it has perhaps never been more fitting to put our heat supplies centre stage.

Heat comprises half of the world's total energy consumption and accounts for more than 40 percent of global energy-related CO_2 emissions. All the while, the global demand for sustainable heating and cooling is rapidly increasing as the effects of climate change are unfolding, populations are growing and incomes are rising.

This white paper unpacks district energy as a key solution in a futureproof energy system. With more than 100 years of experience, Denmark is a showcase for how district heating can provide cost-effective, energy efficient and resilient heating. From governance tools to technical solutions, this white paper presents the case for recognising district energy's immense potential in the green transition of our societies.

CHAPTER 1

District heating at its core

The way we produce and distribute heat is essential to societal sustainability and welfare. District heating is resilient. Its use dates back over 100 years ago. Even so, its many advantages have perhaps never been more pressing to utilise.

District heating is a highly efficient and sustainable method of providing heat to communities. At its core, a district heating system uses heat sourced from central locations and distributes it through pipelines to end users in residential, commercial and industrial buildings. Opting for a district heating system as opposed to individual solutions has major economic, environmental and social benefits.

A flexible and sustainable solution
Individual heating solutions allow only one specific type of fuel, e.g. oil or natural gas. For the end user, this means that their heating bill is exposed to price increases on a specific fuel. District heating, however, is fuel-agnostic and fuel sources can be changed quickly and easily.

This makes it possible to take advantage of market forces driving price changes across different types of fuel markets. For instance, electricity can be used to produce heat when prices reach virtually zero due to high production from wind turbines and other renewable sources. District heating also permits the use of low-temperature heat, especially when combined with heat pumps. Thus, heat with low or negative value in one place, e.g. industrial surplus heat, can create significant value elsewhere by substituting fossil fuels and increasing energy efficiency.

Established district heating systems often starts small and grow, merging over time to gradually cover entire urban communities. District heating systems are inherently local and can be adapted to various urban and suburban settings, making them versatile and applicable across diverse regions.

Societal resilience to the benefit of us all
In the ongoing green transition of our energy systems, it is less costly to change fuel sources in a centralised system than to replace boilers in thousands of individual households. On a societal level, the fuel flexibility of district energy increases the security of supply and production efficiency. In turn, societal ambitions and political targets of increased independence from fuel imports and reduced CO_2 -emissions can more easily be achieved.

This is especially true when district heating systems are equipped with the monitoring and control mechanisms that enable smart energy management and system maintenance. Crucially, the benefits of an intelligent centralised system are felt by the consumer: Optimising energy use and reducing heat loss and consumption increase comfort, leading to long-term energy savings and lower energy bills.

Globally, there is an urgent need to optimise the use of all available sustainable energy resources. From a heating and cooling perspective, this requires a system that is flexible, resilient and intelligently connected to the energy system. District energy provides an answer to these challenges and should therefore be considered the energy backbone of tomorrow's communities.

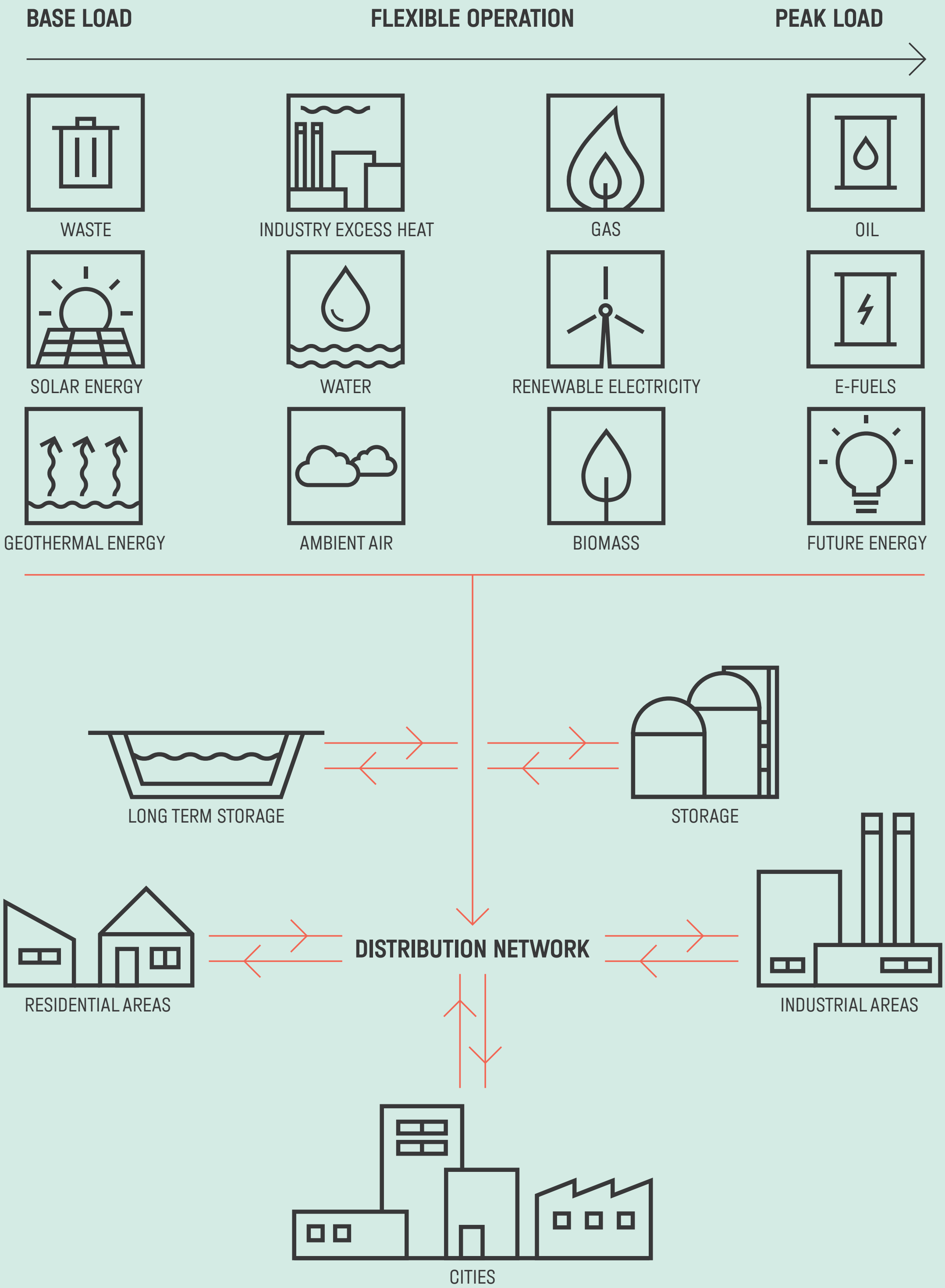


Illustration of a district heating system

A district heating system can deliver cost-efficient heating to consumers from various energy sources. All Danish district heating systems use at least two sources to balance loads and operations most efficiently. Depending on the local system design, sources can be used in combination for baseload production, others provide flexibility and some are reserved for peak loads. Some energy sources like waste, fuels or electricity are transformed through a heat production unit like a CPH plant or heat pump, while others such a solar thermal or sufficiently high temperature waste heat are applied directly. Some of the energy is stored at a storage facility, which makes it possible to decouple the production from consumption over shorter or longer periods of time – even months. No matter the source, the heat is ultimately distributed through a network of energy efficient pipes to the end-users in homes, industrial areas and cities who need it.

Timeline of district heating in Denmark

1973 — 1976-79 — 1981-82 — 1985-86 — 1990 — 1990

1973

The high energy prices caused by the international energy crisis increase focus on fuel independence and motivate improvements in energy efficiency.

1976-1979

Denmark's first overall energy plan lays the basis for a long-term energy policy, and the Danish Energy Agency is established. The first law on heat supply begins a new era in public heat planning, which still exists today.

1981-1982

National heat planning takes place throughout the country. The heat plans include "zoning" with the purpose of establishing cost-efficient energy systems.

1985-1986

Parliamentary decision on public energy planning without nuclear power. Coal is excluded from heat planning.

1990

Political agreement on increased use of both natural gas-fired CHP plants and biomass for heat in district heating. The agreement also increases the installation of wind power.

1990

Revision to the law on heat supply introduces a new planning system. Planning directives and guidelines for fuel choice and CHP are provided to all local authorities/municipalities.

1992 — 1993-2000 — 2012 — 2019 — 2022 — ~2030

1992

A range of subsidies is introduced to support energy savings, CHP plants and renewable energy sources.

1993-2000

Political agreement on promoting the use of biomass in power production. Revision to the law on heat supply, in which Parliament decides to improve conditions for 250 small and medium-sized CHP plants outside the major cities.

2012

Broad political agreement on Danish energy policy 2012-2020. The agreement includes initiatives within energy efficiency, renewable energy and the energy system. The agreement is renewed in 2018 to cover the period 2020-2030.

2019

Denmark's first national climate law and binding climate targets reiterates the need for a green and energy efficient heat supply and district heating's key role in the energy system.

2022

The energy crisis prompts a broad political agreement on accelerating the phase-out of gas and the roll-out of green district heating. Additionally, an agreement is made with the municipalities that they must engage in heat planning in order to inform all gas and oil users when they can expect to have a green solution.

~2030

Projections from the Danish Energy Agency suggest that by 2030, the district heating sector will be close to fossil-free.

CHAPTER 2

Consistent regulation – A prerequisite for district heating

Since 1979, the Danish Heat Supply Act has mandated local authorities to plan heat infrastructures based on socio-economic analyses, ensuring consumer protection, efficiency and alignment with national energy ambitions.

Clear roles and responsibilities
The Danish Heat Supply Act sets out heating sector legislation and regulation. It mandates local authorities to engage in local heat planning, decide on energy infrastructures and prioritise resources. Energy efficiency principles ensure that combined heat and power is prioritised for electricity and heat production. The local authority uses local knowledge to evaluate and decide on heating system designs and individual heating projects while relying on nationally centralised and provided policy and technical frameworks. This ensures that district heating projects are in line with the overall national ambitions for the development of the heating sector and maximise socio-economic benefits.

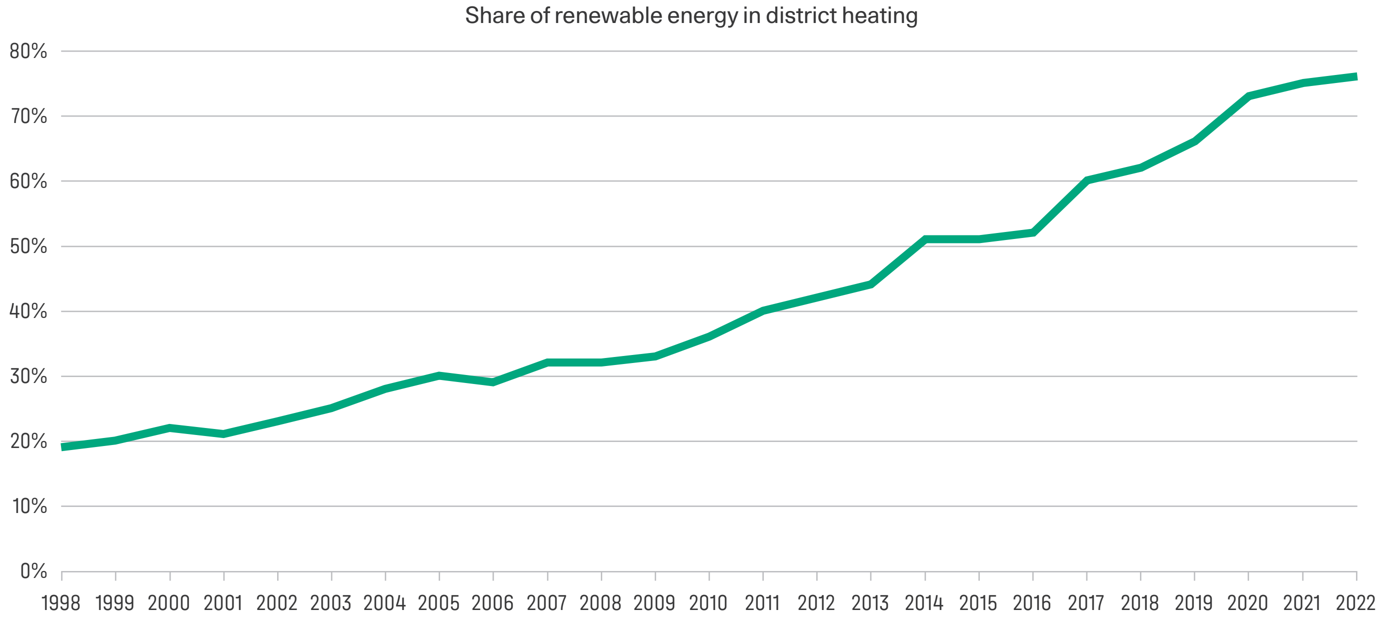
Planning heat infrastructures
The benefits of district heating networks, like other infrastructures, depend on economies of scale for both heat production plants and network costs. The Heat Supply Act ensures zonal planning, eventually designating specific areas for district heating and natural gas supply. This avoids ineffective parallel grids to supply heat to individual consumers. Thorough local planning creates reliable investment conditions for a technology that plays a major role in the green transition and ensures consumer protection as well as benefits for society.

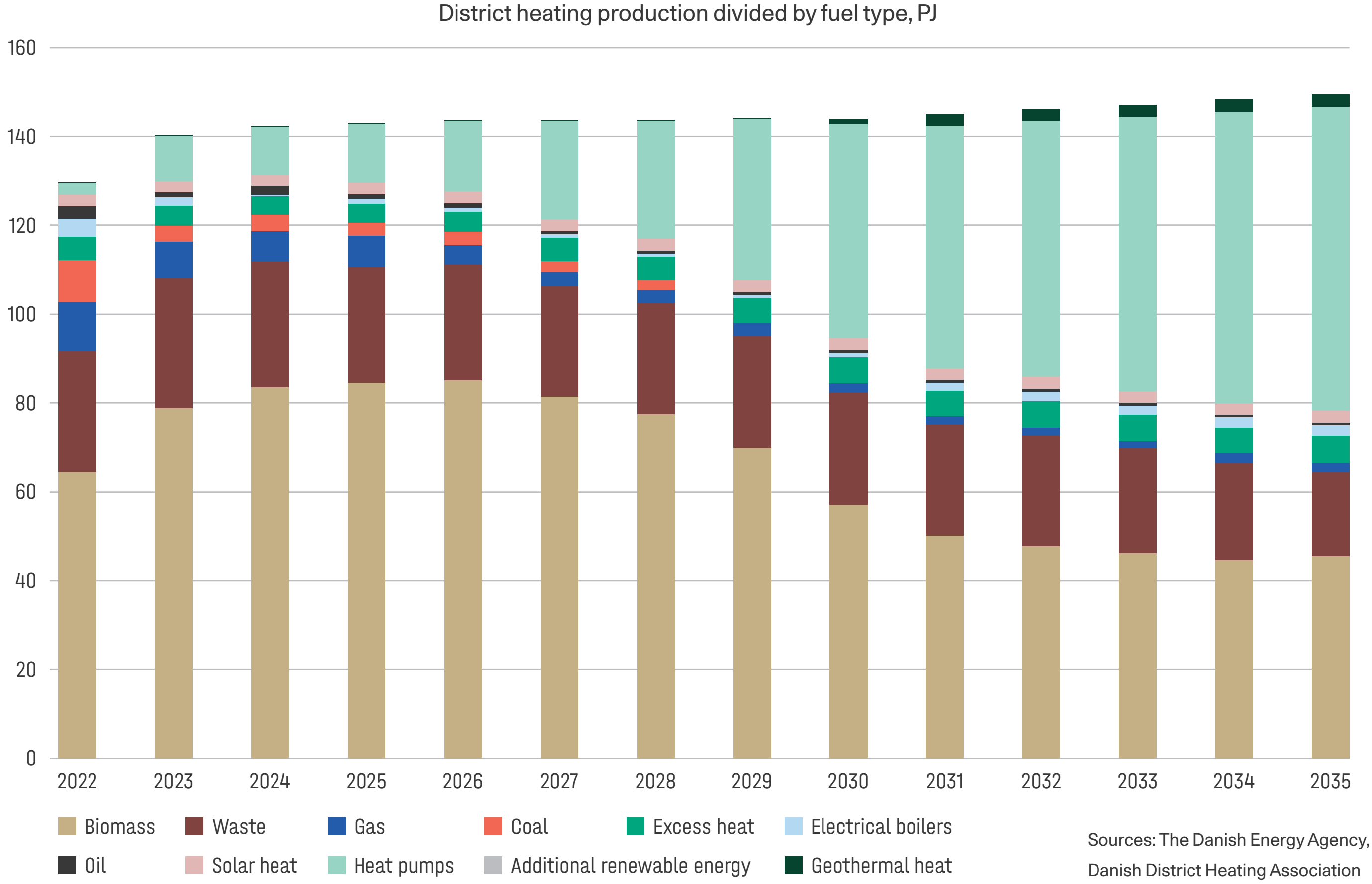
Choice of heat supply based on socioeconomics
The local decision-making process is guided by standardised socio-economic cost-benefit analyses.

The Danish Energy Agency provides guidelines and methodologies for socio-economic assessment. Parameters include fuel prices, electricity prices, externality costs of emissions, interest rates and, if needed, reference technology data. Methodologically, socioeconomic analysis is done over the full life cycle, to ensure that the long-term nature of infrastructure investments is recognised along with the use of high-quality components to reduce long-term operation and maintenance costs. This forms a uniform basis for assessing the heat supply possibilities for local authorities nationwide and prevents excessive investments in district heating networks where an individual solution like heat pumps would be more viable and vice versa.

Regulation of consumer prices
The principles for setting consumer prices are mandated by the Heat Supply Act and are uniform across district heating companies. District heating companies must only charge the necessary and actual costs of producing and transporting heat to consumers, including depreciation of assets and financing costs. These should be transparently shared and published, and are overseen by the Utility Regulator.

Consequently, the price of heat is not the same in all Danish district heating areas since it relies on the design of the district heating system. In practice, it also means that Danish district heating is non-profit and remains low-cost by law.





Sources: The Danish Energy Agency, Danish District Heating Association

The Danish heat supply in numbers

The share of renewable energy sources in the Danish heat supply has increased significantly over the past 25 years. Today, around 75 percent of Danish district heating is based on renewable energy. Certified sustainable biomass currently fuels the majority of the district heating production. In the coming decade, however, electrified heat pumps are set to aid the phase-out of biomass significantly, decreasing the reliance on imported biowaste.

CHAPTER 3

Heat planning – Now a priority set by the EU

For many years, systematic heating planning at the national level has not been practiced in many countries. There has been a lack of a clear thread from national energy visions and policy to the planning in regions, municipalities and energy companies.

Planning for district heating and cooling - a prerequisite for a greener future
The planning of future district heating and cooling (DHC) systems requires active involvement at the municipal level. This means that municipalities must have clear guidelines from national governments, which ensure the realisation of national energy policy, within the framework set by the European Union (EU) regarding energy savings and CO_2 reductions.

For the individual citizen, it is crucial that DHC planning ensures an energy supply that is simultaneously competitive, green and stable. This is also known as the energy trilemma, as it can be difficult to keep all three parameters in balance.

Heating planning in Denmark
Since the end of the 1970s, successive Danish governments have focused on the necessary legislation to deal with the challenges of the energy trilemma - and this has been achieved with great success:

- 68 percent of all homes are provided with district heating.
- 75 percent of district heating is based on renewables.
- The costs of district heating are lower than alternative heat sources.

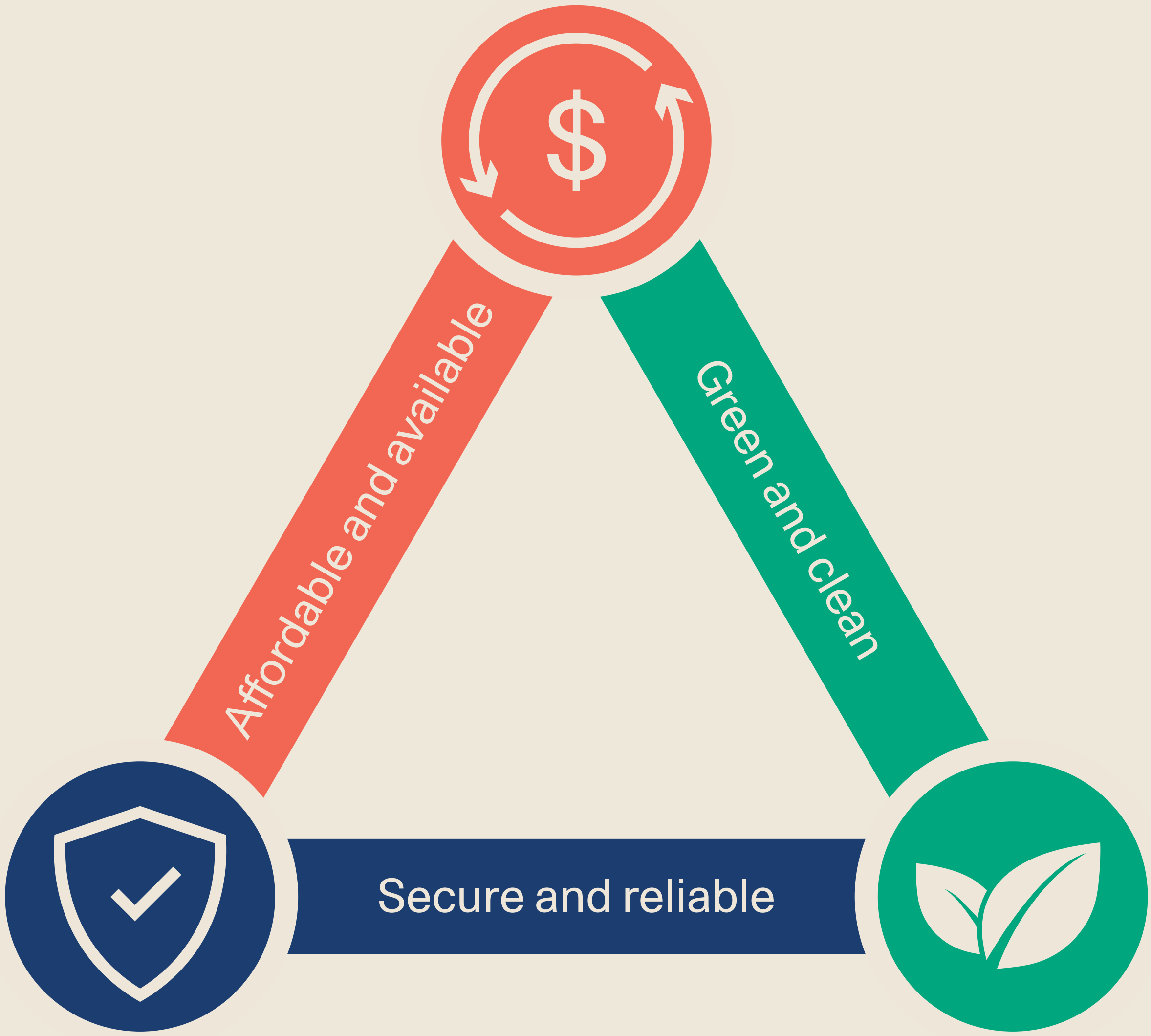
This success is based on a national long-term, stable political framework, municipal involvement and responsibility for the realisation of the national policies and local ownership of the infrastructure. The energy agreement of 22 March 2012 was the starting point for initiating strategic energy planning at the municipal and regional level everywhere in Denmark.

In the Greater Copenhagen area, for example, 29 municipalities came together under the common umbrella "Energy across the board" to develop an implementation plan, which contains 34 concrete measures that must be implemented by 2025 to create a robust development towards a fossil-free energy system. This illustrates the Danish belief that planning across municipalities, sectors and company boundaries is the way forward.

EU's Energy Efficiency directive
With the revision of the Energy Efficiency Directive (EED), the EU is also signalling the importance of strategic DHC planning. Compared to its predecessor from 2012, the new directive raises ambitions for DHC by, among other things, focusing on:

- The definition of efficient district heating systems - new requirements have been set with a view to CO_2-neutral district heating and cooling (DHC) by 2050 at the latest.
- Requirements for DHC planning in all municipalities with over 45,000 inhabitants.

Still, how the directive must be implemented is only described in general terms by the EU. This means that it is ultimately up to the individual member states to carry out the DHC planning in a way that is strategic, future-proof and sustainable.



The energy trilemma

The energy trilemma describes the difficult choices politicians, authorities and DHC companies face when planning the energy supply. Everyone agrees that the DHC supply to be:

- Affordable and available (Competitive),
- Green and clean (Sustainable),
- Secure and reliable (Resilient)

But, says the energy trilemma, these three challenges often imply a trade-off when choosing one over the other. As the geo-political events of recent years have shown, it is a puzzle that's difficult, but imperative, to solve.

Germany's Heat Planning: A Danish-Inspired Shift

Germany's energy system is undergoing significant changes as the government phases out nuclear power, reduces natural gas dependency and aims to eliminate coal power by 2038. This necessitates a rapid transition to renewable energy, particularly in the heating sector. To this end, the state of Baden-Württemberg has taken decisive steps in heat planning inspired by Denmark's experiences and achievements.

Since 2017, Baden-Württemberg has collaborated closely with Danish energy authorities and knowledge partners under the German-Danish Energy Dialog, focusing on a sustainable heat transition. In 2020, the state amended its climate law, mandating its 103 largest cities to develop a fossil-free heat supply roadmap for 2050. During a visit to Denmark, a ministry delegation from Baden-Württemberg observed the effects of an obligation for municipal heat planning firsthand. The Danish example was then successfully adapted to German boundary conditions.

The amendment includes compulsory heat planning for cities with over 20,000 residents and mandatory submission of data on the energy consumption of the municipal building stock for all of the state's 1,100 municipalities. This legislation will ultimately provide fossil-free heating to 5.5 million people, and it has made Baden-Württemberg a pioneer of municipal heat planning in the EU. Additionally, these state-level efforts have inspired the introduction of a national Heat Planning Act, which mandates comprehensive municipal heat planning throughout Germany from 2024.

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LOCATION

Baden-Württemberg, Germany

Photo credit: Rambøll

Heat planning with waste heat from the Underground

London's Islington borough is tackling energy security and fuel poverty through innovative heat planning, focusing on district energy and heat networks. A key project in this effort is the Bunhill 2 Energy Centre, which repurposes waste heat from the London Underground to provide greener, more affordable heating.

Located atop a disused tube station, the Bunhill 2 Centre uses heat pump technology to extract warm air from the Underground tunnels via a large underground fan. This warm air heats water, which is then circulated to nearby buildings. Beyond heating, the Centre's combined heat and power system generates green electricity for communal lighting and lifts in a neighbouring tower. The fan can also reverse to cool the Tube tunnels during summer, enhancing the Underground ventilation system.

Bunhill 2 has connected 550 additional homes and a school to the existing Bunhill Heat and Power district heating network, which already served two leisure centres and over 800 homes. The Centre's infrastructure is designed with extra capacity, allowing for future expansion to heat up to 2,200 homes.

Plans are in motion to further expand Bunhill's network by integrating waste heat from a local data centre, enhancing the system's sustainability and resilience. This expansion aims to support more buildings across Islington, reducing reliance on backup boilers and addressing fuel poverty while promoting affordable warmth throughout the borough.

CONTRIBUTORS

Islington Council , Rambøll

LOCATION

London, The United Kingdom

CHAPTER 4

How district heating enables sector coupling

With the green transition, an increasing share of our power is produced from fluctuating sources such as solar and wind. District heating has been and will continue be key in ensuring that they are integrated successfully and optimally into our energy systems.

The electricity supply of the future will primarily be based on intermittent renewable energy sources. For those sources to be utilised in the most efficient, economic and secure way, a lot of integration, balancing and storage efforts are required, which has fostered an increased focus on the potentials of sector coupling.

Interconnecting energy producing and consuming sectors
Sector coupling refers to the coordinated planning and operation of the energy system across multiple sectors (electricity, heating, cooling, transport and industry) to maximise the use of renewable energy, enhance system flexibility and achieve greater energy efficiency and security. In this integration, district heating can play a central role due to its versatility.

In Denmark, the first steps towards sector coupling were taken with the initial implementation of combined heat and power (CHP)-based district heating systems, driven by the need for efficiency and cost-effectiveness. CHP plants are a prime example of sector coupling, as they can generate both electricity and heat, optimising fuel use and reducing emissions. Here, heat pumps serve as a complementary solution, as they can absorb electricity when it is cheap and abundant, efficiently producing heat to support the stabilisation and balancing of power markets.

Making the most of all types of heat
Surplus heat from industrial processes and low-quality heat from sources like wastewater and data centres are often wasted. By connecting sectors, these can become a valuable resource that can easily be utilised in a district heating system. Where industrial or commercial buildings are near a thermal grid, it can be beneficial to collaborate with the local utility company in utilising the surplus or low-quality heat. Not only is there a financial gain, but surplus heat will also replace the use of less efficient sources in heat production.

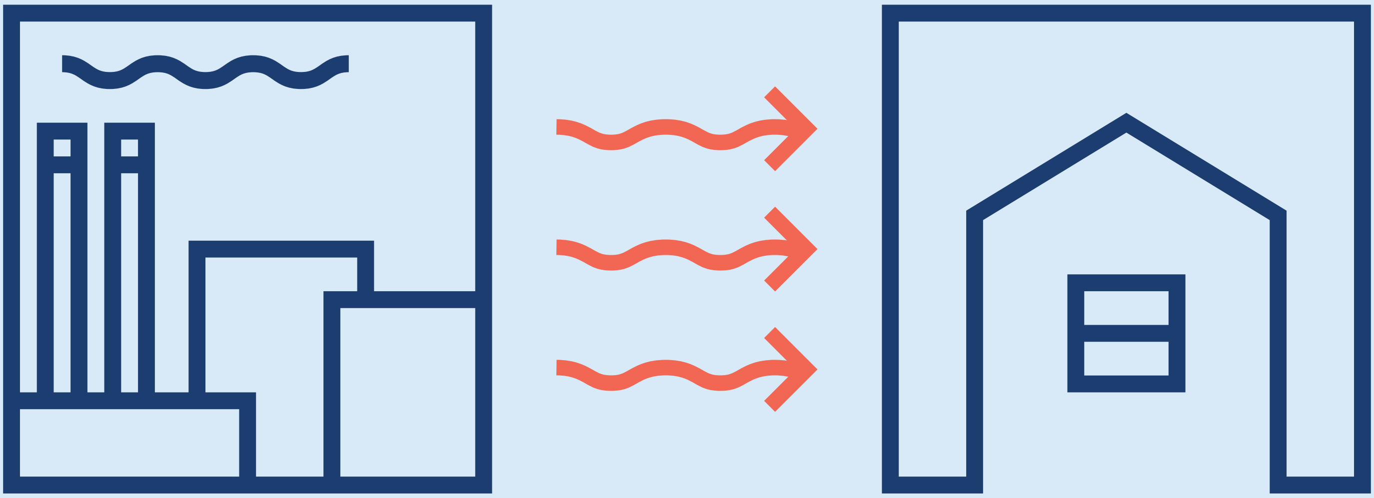
Additionally, using district heating for sector coupling can help the development of enabling green technologies like power-to-x and carbon capture and storage, by reducing the energy intensity and improving business cases.

The necessity of storage
Integrating more intermittent energy sources into the energy system also calls for increased storage capacity within the system to decouple production and consumption times. District heating allows for cost-effective thermal storage on relatively large scales from day-to-day and season-to-season. This allows heat to be produced when the production cost is low, and further enables the absorption of cheap renewables into the energy system.

In Denmark, all district heating systems have access to some form of thermal storage to manage heat availability from CHP plants, solar collectors, surplus wind electricity, and industrial heat. Short-term heat storage allows for optimised production management of CHP plants and heat pumps based on demand forecasts and power prices. Larger-scale storage, such as pit and groundwater systems, can be used for seasonal storage, saving excess summer heat for use in colder seasons, but also for weekly or monthly storage to accommodate shorter weather patterns. This is crucial not only for the green transition but for our security of supply and economic stability.

The untapped potential of excess heat from industry

Excess heat from industry has the potential to heat up millions of homes. Currently, the amount of heat wasted in the EU industry corresponds to the heat demand of 10 million single-family households. This is one of the reasons why it is imperative to engage in sector coupling from a district heating perspective.



Wasted **excess heat** from the EU's industry...

could heat up **10.000.000** homes

Source: Danish Industry

Want to learn more about sector coupling?

Download our white paper **Sector coupling - Unlocking renewable energy's full potential**

Photo credit: Loannis Sifnaios

Storing heat for a cold day

Balancing energy consumption and production is crucial for an energy system reliant on fluctuating renewable sources. The Copenhagen district heating system includes four CHP plants and three waste incineration plants, generating heat and electricity simultaneously. Additionally, Copenhagen district heating systems are increasing the capacity of heat pumps, which can use electricity to generate heat. This can lead to excess heat production; either when electricity is needed on the market via CHP plants, or when excess electricity needs to be balanced via heat pumps.

To add flexibility, Høje Taastrup District Heating and Vestegnens Kraftvarmeselskab I/S (VEKS) jointly built a heat storage facility with subterranean cavity lined with a plastic membrane and a sealed and insulated lid. The intention is to empty and refill the storage around 20 times per year, depending on electricity and heat markets. While Denmark already has several pit thermal energy storages, these mainly serve as seasonal solutions linked with solar.

The storage facility holds 70,000 m^2 of water at up to 90°C, requiring a new type of membrane and changes in district heating management. It has a 30 MW charging/discharging capability and can store 3,300 MWh, contributing approximately EUR 1.75 million annually to Copenhagen's district heating. This is achieved through flexible CHP and heat pump operations, natural gas replacement during peak loads and efficient use of waste incineration year-round.

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VEKS, Wicotec Kirkebjerg

LOCATION

Høje Taastrup, Denmark

Photo credit: Rambøll

Data centre's excess heat provides district heating

Datacentres are an inescapable feature of modern society. At the same time, they are widely known to consume energy. As the number and size of datacentres grow, there is an urgent need to explore how to increase their energy efficiency through innovative means, such as using excess heat for district heating. A collaboration between Meta (formerly Facebook) and Fjernvarme Fyn, Denmark's third-largest district heating company, does just that.

In 2020, Fjernvarme Fyn launched the world's largest district heating production unit using excess heat from a data centre, in collaboration with Meta. Ramboll, a Danish engineering, architecture and consultancy company, designed and consulted on a heat pump installation that transfers energy from Meta's data centre to the district heating network of the city of Odense.

A water-based above- and below-ground piping circuit moves surplus heat to the heat pump installation, where electrical ammonia heat pumps raise the temperature to 70-75°C, suitable for district heating. Distribution pumps then supply the recovered heat to the network.
Excess heat from Meta's data centre provides about 125,000 MWh of district heating, equivalent to nearly 7,000 households in Odense, reducing coal dependence and aiding Fjernvarme Fyn's 100 percent renewable energy goal by 2030. The heat pump installation recovers data centre heat on a previously unprecedented scale. Meta is considering doubling the size of Odense data centre, which may potentially benefit thousands of additional households.

CONTRIBUTORS

Fjernvarme Fyn, Rambøll

LOCATION

Odense, Denmark

Photo credit: EMD International

Resilient district heating using multiple heat sources

For the green transition to succeed, consumer prices for district heating must remain low, regardless of the energy source. The district heating system in Hvide Sande features multiple energy sources, including a solar thermal plant, a heat pump, three 3 MW wind turbines and heat storage tanks. While this mix allows for cost-effective renewable district heating, managing daily operations and electricity procurement is challenging due to the fluctuating nature of renewable energy.

To address this challenge, Hvide Sande installed the energyTRADE software solution from the global software and consulting company EMD International at the district heating plant. This intelligent control system continuously calculates the most optimal operational approach for the plant in real-time, enabling optimal decisions about which units to activate and whether to sell or purchase electricity across the different markets.

The energyTRADE solution provides Hvide Sande District Heating with an overview of the most efficient operational schedule of the entire plant. This has meant that the residents of Hvide Sande have paid only one-tenth of the annual average heating price in Denmark in 2022, and enabled Hvide Sande District Heating to produce 92.4 percent of the heat using renewable energy sources.

CONTRIBUTORS

EMD International,
Hvide Sande District Heating

LOCATION

Hvide Sande, Denmark

Photo credit: Grundfos

From industrial cooling to district heating

In 2013, the industrial company Grundfos and the local utility company GEUS inaugurated a joint system to exploit heat extracted from the cooling compressors in Grundfos' factories for district heating. Operating compressors requires a lot of energy and is therefore expensive. Additionally, a large amount of surplus heat has to be emitted into the atmosphere via cooling towers. At least, that is how it used to be.

The system operates in three stages: During the summer, Grundfos doesn't require heat. Therefore, all the excess condenser heat from the cooling compressors is transferred to a storage aquifer, where the heat is put "on stock". In autumn, when the district heating system requires heat, 80-85 percent of the heat stored during summer is still available. To raise the temperature to the level needed in the district heating network, GUES uses a heat pump. In winter, the district heating company gets the surplus heat from both the storage and directly from the compressors.

In total, EUR 5.5 million has been invested by the partners, who have split the costs 50/50, and EUR 457,000 will be saved in energy costs annually. The saved costs on water can be added to this amount. This corresponds to a payback time of 10-12 years. Additionally, it prevents the release of 3,700 tonnes of CO_2 annually, supporting Grundfos' and GEUS' commitment to reducing their carbon footprint.

CONTRIBUTORS

Grundfos, GUES

LOCATION

Bjerringbro, Denmark

CHAPTER 5

Digitalisation throughout the value chain

With its potential to optimise operations and mitigate uncertainties, digitalisation can be regarded as an enabler of an efficient, reliable and resilient district energy system.

For the full benefits of a district heating system to be reaped, it must be geared towards the optimum interaction of energy sources, distribution and consumption. This requires data collection and smart system management across the entire value chain - from planning, procurement and production to distribution, consumption and customer interaction.

Why digitalisation?
The relevance of digitised and AI-based tools in district energy becomes clear when considering the complexity of designing and managing modern district heating systems. Transitioning from the single heat source model to one with diversified sources, including intermittent renewables and waste heat, combined with the upgrade to a sector-coupled energy system, is no small feat.

To this end, digital solutions can help optimise production costs and planning through weather forecasting, customer demand estimation and electricity price analysis. By doing so, heating systems can adequately respond to energy and price fluctuations. Additionally, digital twins and prescriptive analysis enable district heating companies to consider different scenarios or options for investment, production, planning and maintenance, thereby mitigating uncertainties.

Data-driven and digitalised operation benefit both providers and consumers. For instance, district heating companies can utilise data from remotely read heat meters for temperature optimisation, thereby reducing network losses by 5-10 percent as well as consumer prices. Companies can also minimise the investment required to convert gas customers to district heating, as remotely read data enables better utilisation of the existing distribution system and installations.

Towards a greener, more digitised utilities sector
Today, more than 60 percent of district heating companies in Denmark use hourly or daily data from meters in their operations, even though they are only required to read meters once a month for billing purposes. Most district heating companies can share this high-quality data with their customers without additional costs.

The digitisation of the district heating and utilities sector is supported by the Danish government. In 2022, the government presented a new strategy for digitisation across all areas of society. Among other things, the strategy focuses on transparency and data protection towards better utilisation of digital resources and infrastructure across value chains and different utilities.

Ultimately, such efforts can generate significant savings. A conservative estimate in Denmark is that increased use of data for the district heating sector has a saving potential of approximately EUR 134 million annually.

Data-driven operations can:

Help accelerate the green transition and sector coupling through effective integration of renewable energy, power-to-x and other sources of waste heat

Integrate the heat capacity of buildings to reduce peak loads

Enable better heat planning and system design decisions

Perform condition-based maintenance

Utilise existing production and distribution capacity in connection with conversions from gas

Free up administrative resources for increased customer service

Reduce heat loss and required pump performance in distribution networks

Contribute to innovation and development of new digital services

Want to learn more about digitalisation in district heating?

Together with the Danish District Heating Association (DDHA), Danish Board of District Heating (DBDH) and the think tank Brundtland (formerly Grøn Energi), we have assembled a catalogue showcasing how the Danish district heating sector is approaching digitalisation across the entire value chain. Get inspired by 18 cases of digitalisation and data-driven operations from Denmark's district heating sector.

Photo credit: Danfoss

Reducing peak loads with AI-based heat control

Heat consumption in buildings fluctuates throughout the day, peaking at certain times, such as in the morning. However, directly responding to these peaks is inefficient and can lead to higher CO_2 emissions.

This is why Danfoss, HOFOR and Københavns Ejendomme (a large housing association) have come together to optimise the CO_2 neutral baseload production in Copenhagen by utilising AI-based heat control.

Danfoss Leanheat Building is an AI-based system that learns building behaviour and leverages thermal flexibility to reduce peak loads. During peak periods, it lowers space heating demand while recharging the buildings in off-peak periods. During the heating seasons of 2021-2022 and 2022-2023, the system was applied to 120 municipal buildings to make heat consumption more flexible.

Results showed that the average morning peak load fell by 13.2 percent at building level, while the overall heating consumption was reduced by 5-7 percent, thanks to AI-based predictive solar compensation.

In the reference buildings, total peak power dropped from 1703 kW to 1323 kW, resulting in a 22.3 percent reduction. This calculation compared the highest peak during peak load displacement with the highest peak from the previous year under similar outdoor conditions, excluding any outliers. Today, the collaboration continues to demonstrate proof of concept in up to 700 buildings, aiming to quantify the financial and environmental benefits of flexibility on a larger scale in the district heating system.

CONTRIBUTORS

Danfoss, HOFOR

LOCATION

Copenhagen, Denmark

Photo credit: Næstved Fjernvarme

Data-driven reduction of system temperatures

District heating companies adjust pressure and temperature based on the needs of the customer in the least favourable position to ensure all buildings receive adequate heat. For energy efficiency, it is crucial to minimise the return temperature, thereby maximising the cooling of district heating water.

In 2017, Næstved Fjernvarme partnered with Næstved Municipality to reduce energy loss by enhancing the management and monitoring of system temperatures at the customer level.

All of Næstved Fjernvarme's customers have Kamstrup heat meters that submit hourly data to a central database. Based on this data, customers with poor energy utilisation or high return temperatures were contacted for a visit. After each visit, they received a report detailing deficiencies in their heating system.

During the project, 1,221 visits revealed common issues like defective valves. Subsequently, Næstved Fjernvarme introduced financial incentives for customers to repair defects including a 1 percent tariff increase per degree Celsius when return temperatures exceed 50°C.

As a result, from 2017 to 2020, the average supply temperature dropped by 13.6 percent, and the return temperature decreased by 8.4 percent. Additionally, over 300 new district heating units were installed, resulting in energy savings of 4,936 MWh and CO_2 emission reductions of 627 tonnes. Næstved customers have collectively saved approx. EUR 536,000 annually, and approx. EUR 3.5 million was saved municipally by avoiding new infrastructure investments.

CONTRIBUTORS

Kamstrup, Næstved Fjernvarme

LOCATION

Næstved, Denmark

CHAPTER 6

The future of district energy

District energy systems are expected to grow in the years to come due to increased urbanisation, technological advancements, a stronger focus on resource efficiency and consumers' increasing demand for comfort – as well as a societal drive towards decarbonisation.

Growing demand ahead
According to Euroheat & Power, Europe is home to approximately 19,000 district heating systems with a combined trench length of 200,000 km and an installed capacity of 300,000 MW, covering 13 percent of Europe's heat demand.

District heating is poised for expansion, driven by market forces and regulations like the Energy Efficiency Directive, which mandates heating and cooling plans, the Energy Performance of Buildings Directive, and the ETS, which will introduce a carbon price on fossil fuels used in buildings from 2027. Additionally, national heat legislation in countries like Germany and the Netherlands is propelling the development forward.

Euroheat & Power projects that approximately 8 million more European households will be connected to district heating by 2030, in line with national climate and energy objectives.

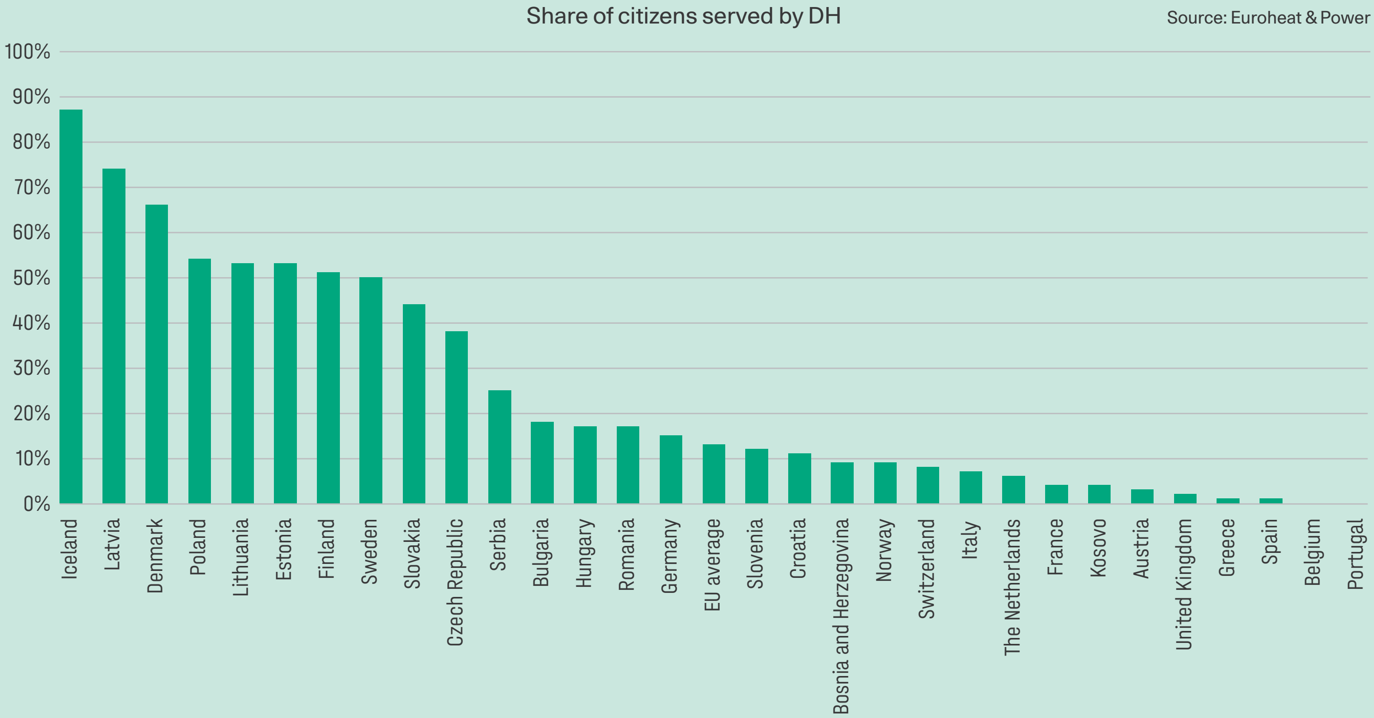
Greener, more efficient and cooler
The share of renewable energy in district heating, currently at 40 percent, is set to grow as fossil fuels are phased out. Large heat pumps, fuelled by renewable electricity, are key drivers, along with increased integration of geothermal energy, which currently accounts for 3 percent of the mix. Solar thermal energy, though modest in its current contribution, is also expected to expand as more projects take shape across Europe.

Waste heat, which presently makes up less than 10 percent of district energy, is another area of growth. Euroheat & Power identifies sewage water, industry, data centres, electrolysis, and food retail as the sources with the greatest immediate potential to increase the share of waste heat in district energy systems.

The potential for thermal storage is expanding rapidly, in response to the increasing need for energy storage driven by renewable energy integration. Thermal storage offers a technologically viable and economically sound alternative to gas and electricity storage, providing flexibility for both short- and long-term storage solutions.

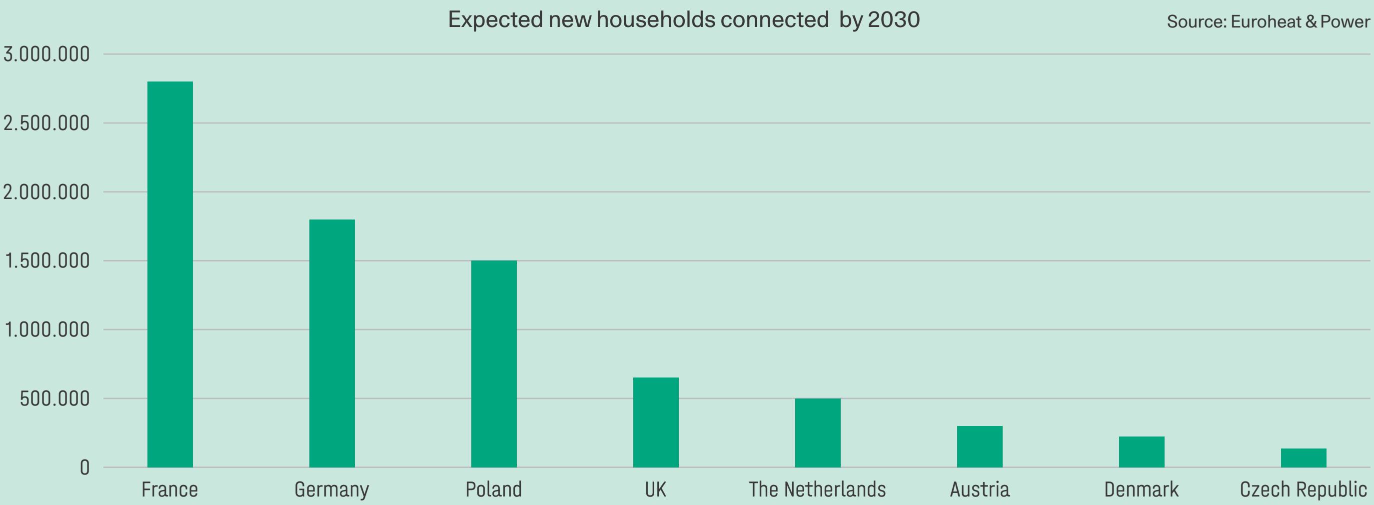
The development of 4^{th} generation district heating lowers water temperatures, improving energy efficiency and enabling greater use of waste heat and storage. These efficient, low-temperature systems will play an important role in future district energy networks, both new and retrofitted, requiring advanced monitoring and optimisation. Digital tools will increasingly be used to optimise performance and ensure reliability.

Cooling currently accounts for around 20 percent of global electricity demand, according to the International Energy Agency. The demand for cooling is expected to grow, particularly in warmer countries, as the effects of climate change, populations, and incomes increase. District cooling systems, which operate on the same principles as district heating, are becoming an attractive alternative to individual cooling solutions. They provide higher energy efficiency, save valuable urban space, and simplify the operation of cooling systems.



Share of citizens served by district heating (2022)

The use of district heating varies widely across countries due to factors such as climate, urban density and energy resources available. However, differences in regulatory frameworks, building traditions and energy policies are the main reason behind variations in the uptake of district heating. This is why the regulatory developments currently happening at both the EU and national levels will be crucial for the future of district heating.



Additional households connected to district heating by 2030

The current energy crisis has provided new impetus to accelerate the transformation of the heat sector. Alongside necessary measures to address the short-and medium-term impact of the crisis, many European countries have developed longer-term strategies to accelerate their heat transition, featuring a renewed interest in developing district heating and cooling systems. This is vital to the green transition: According to a study by Aalborg University, district heating networks should supply 48 percent of the EU's heat demand by 2050, to stay on track with the objectives set by the Paris Agreement.

Cooling down a capital city with seawater

District cooling has a lower energy footprint compared to conventional electrically powered air conditioning systems. Additionally, the value proposition of district cooling is space-saving for building areas, as it is decentralised, allowing customers to use, for example, basements or roof areas for purposes more valuable than large air conditioning systems.

District cooling is not a newly established service. Since 2009, the utility company HOFOR has included it as one of its areas of responsibility. The cooling method is built on the same principle as the district heating system but with the opposite effect: delivering cold instead of heat. District cooling uses the seawater that surrounds the city, which, via a closed loop, sends seawater to cooling production plants, and then on to cooling customers. District cooling is used both for comfort cooling in e.g. commercial properties, banks, hotels and museums, as well as for cooling server rooms that require precise temperature control.

HOFOR currently supplies over 100 megawatts of district cooling to major customers, serving approximately 3 million square meters. District cooling is now represented in several parts of Copenhagen, with future expansions planned as soon as 2025. This innovative solution not only meets the city's cooling needs but also enhances urban development by creating space for green infrastructure and initiatives.

CONTRIBUTORS

Brøndum, COWI, Danfoss, Desmi, DI Teknik, Eurocon, Gottlieb Paludan, Grundfos, HOFOR, Isoplus, Johnson Controls, LMbyg, Logstor, NCC, Rambøll, Svedan Køleindustri

LOCATION

Copenhagen, Denmark

Perfecting and expanding pipelines across Hamburg

Having served more than half a decade as a two-unit coal-fired power plant, the Wedel plant with a gross capacity of 289.7 MW, will gradually reduce its burning of coal by up to 30 percent, for the remainder of its operation. Saving around 150,000 tonnes of coal, its closure contributes to a significant reduction in CO_2 emissions. However, the decommissioning of the Wedel plant necessitates alternative heat sources to be identified. This presents an opportunity to increasingly feed climate neutral waste heat into the district heating network. Nevertheless, effectively preserving energy on its way through the district heating network is challenging.

Climate-neutral waste heat generated by industrial processes, along with a planned wastewater heat pump project in southern Hamburg, presents an opportunity for harnessing significant heat resources for the district heating network in the city. To fortify supply reliability for future urban expansions, a cost-effective solution involves the establishment of a 7.6 km transport pipeline. Kingspan LOGSTOR will deliver pre-insulated systems for the majority of the pipeline. By tunnelling under the Elbe, this pipeline will run to Bahrenfeld, where it will be connected to the western branch of the Hamburg district heating network.

The utilisation of Kingspan LOGSTOR's pre-insulated pipes is expected to yield significant energy-saving benefits, potentially reducing energy loss by a substantial 5,000 megawatt-hours annually.

CONTRIBUTORS

Kingspan LOGSTOR

LOCATION

Hamburg, Germany

Amager Bakke: Waste-to-Energy Meets Carbon Capture

Like all other combustion processes, waste-to-energy (WtE) emits CO_2. In supplying electricity and district heating to roughly 90,000 households yearly, Amager Resource Centre ARC emits 560,000 tonnes of CO_2 annually from their WtE plant Amager Bakke. Carbon capture will be crucial for WtE plants of the future, as it allows them to capture and store both fossil and biogenic CO_2, thereby reducing atmospheric CO_2 levels. About two-thirds of CO_2-emissions from Amager Bakke are biogenic.

After successful pilot trials in 2021, ARC inaugurated a state-of-the-art carbon capture demonstration plant in late 2023. The plant captures CO_2 from Amager Bakke, converting it into liquid form. The long-term goal is to harvest the excess heat from the capture process and utilise it in the district heating network. The captured CO_2 is currently sold for industrial purposes. Among other things, the CO_2 is used to cultivate vegetables at Østervang, one of Zealand's largest horticultures.

The demonstration plant has been in operation since late 2023, capturing up to 4 tonnes of CO_2 daily. This is a vital step towards ARC's goal of capturing up to 500,000 tonnes of CO_2 annually at full scale. Furthermore, residual heat from the process at a future full-scale plant could meet the heating needs of nearby areas currently relying on gas boilers.

Ultimately, this project has made Danish history by demonstrating the first entire value chain from capturing CO_2 at a WtE plant and contributes significantly to new knowledge in the field.

CONTRIBUTORS

Amager Resource Center, DTU, Rambøll, Pentair

LOCATION

Copenhagen, Denmark

Learn more about Danish district energy solutions, find more cases from around the world and connect with Danish district energy experts at:

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