Think Denmark White papers for a green transition

DISTRICT ENERGY

Green heating and cooling for urban areas

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DISTRICT ENERGY

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Cover photo showing Sorø Fjernvarme Credit: AffaldPlus Photo: Steen Knarberg

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DISTRICT ENERGY - THE FOUNDATION OF A STRONG GREEN ECONOMY

District energy is a state-of-the-art technology that supports a green growth economy.

Dan Jørgensen, Danish Minister of Climate, Energy and Utilities

District energy is a central solution to reaching the Paris Agreement

Reaching the objective of the Paris Agreement to keep the rise in global temperatures well below 2 degrees Celsius and to pursue efforts to limit temperature increases to no more than 1.5 degrees Celsius, require that nations around the world implement proven green technologies. District energy is part of the solution and contributes to a competitive, green economy that employs limited resources in the most cost-efficient way.

The Danish example is a global showcase

Denmark is a showcase for how district energy can provide cost-effective, energy efficient and climate friendly heating and cooling in urban areas. Almost two out of three homes in Denmark have their heat and hot tap water needs met by district energy. When producing heat and power together, the total efficiency is significantly higher than producing heat and power separately. In this way, district energy played a key role in Denmark's green transition.

Opportunity for leapfrogging

Today Denmark cooperates with countries around the world such as Ukraine, United Kingdom, Turkey, Germany and China on the development of strong, clean, district energy systems.

As an example of this global cooperation, Denmark has worked with the Chinese government on energy efficiency and district heating for more than half a decade. The collaboration focuses on capacity building for local decision-makers and technical staff in the areas of energy planning and district heating. District energy has the potential to cover roughly 50 per cent of the heating demand in China. The focus on thermal comfort will continue to increase together with technical improvements and a transition away from fossil fuels. The heating sector will, at the same time, provide increased flexibility to other sectors, facilitating the integration of higher shares of renewable energy and thereby reducing GHG emissions.

This White Paper describes the policy framework for district energy, provides insight into key elements supported by best-case examples and paints a picture of the future of district energy through the development of areas such as low temperature heating and district cooling.

I hope you will be inspired. 🖊



64.5 per cent of Danish households are connected to the district energy network and in Denmark's four largest cities, more than 95 per cent of the heat demand is covered by district heating.



More than 60 per cent of the Danish district heating is produced from renewable sources: biomass, biogas, solar heating, geothermal energy, and electricity.



The Danish district heating network spans 60,000 kilometres and it contains one billion litres of hot water.

ABOUT THIS WHITE PAPER

District energy is how value is created by supplying heating and cooling collectively instead of individually and at the same time helping in reaching our climate goals. Heat (or cold) that has no - or very little - value in one place, becomes highly valuable by being transported to a place where it is needed. District energy is the system that takes care of this value creation. Heated or chilled water is used as a carrier. Put simply, district energy is about moving energy in water, with a valuable temperature, from a place of production to the place of consumption.

District energy is feasible many places where there is a concentrated need for heating or cooling, e.g. in industrial zones or densely populated areas both in larger and smaller cities. A large part of the initial investment in district energy is creating the infrastructure by laying pipes in the ground. Using high quality pre-insulated pipes ensures that this investment will last for decades and over time becomes a small part of the overall cost of operating the district energy system. Proper installation, metering and heat regulation on the consumer end leads to hassle-free use and payment, as well as a highly improved indoor climate.

This White Paper draws on competencies built up through more than 100 years of experience with district energy in Denmark and around the world. It highlights some of the main learnings to consider when wanting to expand the use of district energy, such as the system, regulatory framework, planning, efficiency and flexibility of energy source, storage and future perspectives, by including relevant cases from around the world.

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OVERVIEW OF A DISTRICT HEATING SYSTEM



Overview of a district heating system

Heat is either produced or collected as surplus heat from many sources (bottom part of illustration), then pumped through highly effective district heating pipes to the end users. Through the storage facility, it is possible to decouple production over short or longer periods of time - even months.

With several production facilities, the economy of the district heating system can be optimised continuously. The end user will enjoy heat delivered from the best available source and not be stuck with just one fuel option.

DISTRICT ENERGY AT ITS CORE

Fuel flexibility and secure supply

District heating is extremely resilient. Its usage dates back to over 100 years ago. Today it is a vital element in the development of sustainable cities.

Jan Strømvig, Managing Director, Fjernvarme Fyn and Chairman of DBDH

Essentially, district heating systems make use of heat produced in central locations and distribute it through pipelines to a large number of end users. In this way heat, that has no or very low value in one place, e.g. industrial surplus heat, can be transformed to high value, in places where there is a high demand for heat, such as small towns or large urban communities.

Advantages of district energy compared to individual solutions

Individual heating solutions only allow one specific type of fuel, e.g. coal, oil or natural gas. For the end user, this means that their heating bill is fully financially exposed to price increases of a specific fuel. With district heating, it is possible to take advantage of market forces driving price changes on different types of fuels. District heating also makes it possible to achieve other societal preferences and political goals, e.g. independence from fuel imports and CO_2 targets. In short, it is much simpler to change fuel from, e.g. natural gas originating from one central place, than it is to change boilers in thousands of individual houses. Today, even electricity is used to produce heat, when prices reach virtually zero due to excess capacity from e.g. wind turbines.

Flexibility is one of the key advantages

Production of district heating or cooling at central units gives access to several fuel types. This makes district heating production very flexible. In turn, this increases both the security of supply and production efficiency. Should one unit break down, there are alternatives available, where at any given time the district energy company can choose the cheapest fuel. Establishing a district heating network also permits the usage of low-quality heat in society. This could be surplus heat from industry and waste incineration, and heat from combined heat and power (CHP) production.

100 years old technology

- and still as vibrant as the first day The world needs to increase focus on exploiting all available sustainable energy resources in the most optimal way. This means that advantage must be taken of surplus heat from any source, replacement of fossil fuels with renewable energy, such as solar and biomass, as well as ensuring systems integration between electricity and heat.

The future will also increase the possibility to store heat from summer to winter in the form of large-scale seasonal storage. District heating provides an answer to these challenges and should therefore be considered as the backbone of tomorrow's urban communities and smart cities. The establishment of district heating can start on a small scale and over time gradually cover the entire urban community. Copenhagen is a good example. Here it all started with one small local system in 1903 and now 98 per cent of the city is supplied by district heating.



MODERN DISTRICT HEATING PIPE SYSTEMS - THE MOST EFFICIENT WAY TO SAVE ENERGY

Total cost of ownership is crucial for future district heating projects

Design of and choice of system for district heating networks have a major influence on performance in terms of energy efficiency, CO, emissions and operating costs.

Jørgen Ægidius, Sales Director, District Energy & Peter Jorsal, Product Manager, LOGSTOR

Financial results and environmental impact are influenced by the piping system

The pipe systems for transmission and distribution of district heating are capital goods for society and the district heating company. The pipe system is a way to provide customers with heat and by extension, comfort and convenience.

The functionality of the district heating network has a major influence on how the district heating company performs in relation to energy efficiency, CO₂ emissions and operating and maintenance costs. The technical life span for today's pre-insulated pipe systems is over 30 years. Therefore, it becomes important to review and optimize the long term Total Cost of Ownership (TCO) and thereby ensure the functionality and improve the energy efficiency of the pipe systems and the district heating operations over time. In that way, a modern pipe system safeguards the considerable investments related to transmission and distribution of district heating.

Total cost of ownership is the key to choosing an optimal pipe system

The long technical service life of a pipe system means that choosing a high quality solution far outweighs the initial higher cost. Calculations, tests and experience prove that the major part of the TCO stems from heat losses from the pipe systems. Thus, minimizing heat loss during the entire operating period of the system will significantly improve efficiency and thereby lower the operating costs of the network. This is also illustrated by the example from Hillerød in Denmark below.

Low Total Cost of Ownership in the City of Hillerød

The TCO was applied in the selection of the pre-insulated pipe system installed in the Danish city of Hillerød.

Project details:

- 14 km of trench primarily in DN80 DN150
 Operating conditions, Tf/Tr:/Ta 80/40/8 °C
- Energy costs: 27 EUR/MWh

Required system: TwinPipe

The different solutions considered by LOGSTOR:

TwinPipe insulation series 1, 2 or 3

The chosen solution:

The basis for evaluation of the incoming tenders included, in addition to the direct capital costs, operating costs related to the heat loss from the transmission system during a 30-year period, which makes up for approx. 40 per cent of the total capital costs. The technical value of the proposed products and solutions was also included in the evaluation.

The project owner decided to install a pipe system based on TwinPipes in insulation series 2 offered by LOGSTOR. This system provided the lowest TCO taking into consideration the investment cost and the heat loss cost over 30 years.

Benefits:

An energy efficient system with approx. 20 per cent energy savings in comparison to a solution based on Twin pipe series 1 and +40 per cent savings in heat loss in comparison to a traditional pair of single pipes in insulation series 2.

The key issues in optimization of a pipe system.

Total Costs of Ownership is influenced by several parameters:

The design of the pipe system must be based on the real operating assumptions in a way that secure the minimum expected life span of more than 30 years. This is secured by using the guidelines in the European standard EN 13941 resulting in simplifying the system and reducing the number of compensators, U-loops etc.

The components must be chosen so that they fulfill the functional requirements for the pipe system. This goes for the pipes, T'ees, valves etc. but especially for the jointing system, where the lifespan relies not only on the product itself but also on a proper installation.

The greatest contributor to the TCO is the heat loss from the pipe system. Therefore, it is essential to choose pipe systems with the optimal insulation properties. In addition, heat loss can be reduced by choosing TwinPipe systems instead of a single pipe system, using higher insulation thickness and choosing pipe systems with a diffusion barrier between the outer PE casing and the PUR foam. The diffusion barrier secures that the initial low heat loss remains unchanged during the life span.

In order to monitor the pipe system continuously over its lifespan, the system should be designed with a surveillance system that can detect at any time if there is a defect in the system and moisture is coming into the foam. If this happens, an alarm will be given immediately and repair can be arranged in good time. This ensures the expected long lifespan.

DIGITALISATION DELIVERS MEASURABLE RESULTS

Tools from Kamstrup allowed a local utility to optimise its operations

Remotely read meters, frequent data and targeted analytics have enabled Assens District Heating to lower the network temperature by 6-8 degrees Celsius. So far, the utility has reduced its annual heat production by 2.5 per cent and pipeline losses by 12 per cent.

Steen Schelle Jensen, Head of Product Management - Solutions, Kamstrup

When Assens District Heating decided to invest in intelligent heat meters and a remotely read network solution back in 2013, digitalisation was still a buzzword to many, and no one knew its true potential. Nevertheless, the utility had a clear expectation that more frequent meter data would provide enhanced opportunities for optimisation.

Data-driven operations optimisation

The first phase of utilising the large amounts of data was optimisation of the distribution network. Specifically, the utility has been able to lower the forward temperature significantly. Previously, it was determined based on the end users who lived the furthest away, resulting in a higher temperature than necessary. Today, it is optimised based on what happens in the network.

Once all the meters were up and running, the utility faced a wall of data. The tools

provided from Kamstrup suddenly allowed it to see - on an hourly basis - the exact temperature throughout the network. Based on continuous digitalisation of the operations, the utility has been able to lower the forward temperature by 6-8 degrees Celsius. The utility has also been able to remove its more than 100 bypasses around the network.

Large savings achieved through digitalisation

By optimising the network operations, Assens District Heating has saved 2,500-3,000 MWh - approximately 2.5 percent - and reduced pipeline losses by 12 per cent over the lastfew years. The data has helped understand the hundreds of kilometres of pipes and what actually happens when, for instance, the temperature is lowered. Even employees with decade's worth of experience have previously not had a full overview of the outcomes when making those kind of changes. The utility expects to gain even more when they commence the next phase soon. Savings to-date have been generated by looking at the volume and temperature of the water pumped out. Only now is the utility beginning to look at individual buildings, end users with poor energy behaviour and inefficient installations.

Frequent data is also used to assess the actual need for renovating the district heating pipes. Previously, the condition of the distribution network was estimated based on factors such as age or water loss. Now that meter data from the network is combined with innovative analytics, it allows continuous monitoring of the capacity and load so that investments in network maintenance can be optimised.



HISTORICAL OVERVIEW OF DISTRICT ENERGY IN DENMARK

FOCUS ON ENERGY EFFICIENCY AND SECURITY OF SUPPLY





1973-74. The high energy prices caused by the international energy crisis increased the Danish focus on fuel independence and motivated improvements in energy efficiency.

1976-79. Denmark's first overall energy plan lays the basis for a longterm energy policy and the Danish Energy Agency is established. The first law on heat supply starts a new era in public heat planning which still exists today.

INCREASED FOCUS ON DOMESTIC FUELS

1981-82. National heat planning takes place throughout the country. The heat plans include "zoning" with the purpose of establishing efficient, low-emission energy systems.

1990. Political agreement on increased use of both natural gas-fired CHPs and biomass for heat in district heating. Furthermore, the agreement increased installation of wind power.

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1985-86. Parliamentary decision on public energy planning without nuclear power. Coal was excluded from heat planning. Energy taxes are increased due to a drop in oil prices. The co-generation agreement emphasizes small-scale CHP plants as a major energy policy priority.

1984. The Danish North Sea natural gas production begins. The Ministry of Energy directs power plants to establish natural gas installations.

CHANGE FROM NATIONAL PLANNING TO PROJECT APPROACH



1990. Revision to law on heat supply introduces a new planning system. Planning directives and guidelines for fuel choice and CHP is provided to all local authorities/municipalities.

1992. A range of subsidies were introduced in order to support energy savings, CHP and renewable energy sources.



1993-2000. Political agreement on the use of biomass in power production. Revision to law on heat supply. A political majority in the Danish Parliament decides to improve conditions for 250 small and medium-sized CHP plants outside the major cities.

THE KEY TO SUCCESS IN DISTRICT ENERGY

A peek into four decades of lessons learned in Denmark

District heating continues to be a cornerstone of the Danish green energy model. For decades, it has provided us with an efficient way to use our surplus heat. Moreover, in the future it will be a key element supporting the integration of wind energy.

Kristoffer Böttzauw, Director General, Danish Energy Agency

District heating - a cornerstone in Denmark's green transition

The very first combined heat and power plant in Denmark was built in 1903. It was a waste incineration plant, which made it possible to handle waste and provide electricity and heat to a nearby hospital, thereby delivering two services simultaneously.

During the 1920s and 1930s, a collective district heating system was developed, based on excess heat from local electricity production. From here on, district heating from combined heat and power (CHP) expanded, and by the 1970s, around 30% of all homes were heated by district heating systems.

Decreasing energy dependency and consumer costs

The energy crisis in 1973/74 made it evident that saving energy was critical both to decrease the dependency of imported fuels and to reduce consumer heating costs. Therefore, a decision was made to expand the fuel-efficient CHP systems to a number of cities in Denmark.

First heat supply law in 1979

Prior to 1979 there was no law regulating the heat supply in Denmark. Most heat consumers had small oil-fired boilers or other forms of individual heating. In order to fulfil its policy goals, Denmark passed its first heat supply law in 1979. The law contained regulations regarding the form and content of heat planning in Denmark and marked the beginning of a new era in public heat planning, which still exists today.

High energy efficiency is one of the results of long-term planning

Today, 63 per cent of all Danish residential homes are connected to district heating for space heating and domestic hot water. When producing heat and power using CHP, the overall energy efficiency is significantly higher than when producing heat and power separately. A CHP plant may have a total efficiency (combined heat and power) of 85-90 per cent resulting in an overall fuel saving of approximately 30 per cent, compared to separate production of heat and electricity. District heating and CHP have been – and continue to be – a key ingredient to Denmark's green transition.

Flexibility to develop and continuously support different policy goals

District heating ensures that Denmark has a sound and reliable heating supply. It also greatly supports Denmark in maintaining a sustainable energy sector and fulfilling its long-term energy policy targets. Looking ahead, district energy will remain a key element of the energy system in Denmark. By 2030, it is expected that wind energy will cover 100 per cent of the Danish electricity consumption. This has created heightened focus on flexible district energy systems that will support the integration of wind power into the energy system. Therefore, district energy not only contributes to achieving Denmark's climate goals but also plays a major role in balancing the future energy system.

FOCUS ON CLIMATE, RENEWABLE ENERGY AND ENERGY EFFICIENCY



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

2030. Ambitious political target of a 70 per cent reduction of CO_2 -emissions by 2030 in relation to 1990 levels. It is expected that 100 per cent of Danish district energy will be supplied by green sources by 2030.

2050. Political agreement from 2012 sets the ambition for a Denmark independent of fossil fuels by 2050.





Sources: Annual Energy Statistics 2018, Danish Energy Agency and PlansystemDK 2017, Danish Business Authority

PLANNING AND REGULATION - A PREREQUISITE

The regulatory process, responsibilities and requirements when approving district heating projects in Denmark

Clear district heating regulation, continuously improved since the Heat Supply Act of 1979, has been the determining factor in the widespread use of district heating and combined heat and power.

Kristoffer Böttzauw, Director General, Danish Energy Agency

Clear roles and responsibilities

The Danish district heating legislation is set out in the Heat Supply Act from 1979 that regulates the heating sector. It provides local authorities (i.e. municipalities) with the power to engage in local heat planning, decision-making on energy infrastructure and resource prioritisation. Local decision-makers have full authority over local heating system designs, but they do so by relying on a centralised policy and a technical framework provided at the national level. This ensures that district heating projects are in line with the overall national ambitions concerning the development of the heating sector. The Danish Energy Agency (DEA) developed the legislation and accompanying guidelines, but simultaneously, the evaluation and decision on the individual heating project are conducted by a local authority with detailed knowledge of local urban development, heat demand and any other relevant local considerations.

Main principles of the initial Danish Heat Supply Act from 1979:

- Local authorities are responsible for the approval of new heating supply projects.
- Local authorities have to make sure that the heating project with the highest socio-economic benefits is chosen.
- Where possible, heat must be produced as combined heat and power.
- The collective heat supply price must offer consumer prices based on "necessary costs", meaning that the heat price cannot be higher or lower than the actual heat production costs.

The Danish Heat Supply Act has also established specific zones of heat networks throughout the country. Within each zone a specific type of heat supply is promoted through the Danish heat legislation. The zones are as follows:

- Individual heat supply
- Natural gas
- Decentralised district heating
- Centralised district heating

Choice of heat supply based on socioeconomic cost benefit analysis

The choice of heat supply must be based on socio-economic cost-benefit analyses. To help local authorities complete relevant economic analyses, the DEA provides guidelines and methodologies with a number of socio-economic assumptions. These assumptions include, among others, fuel prices, electricity prices, externality costs of emissions and interest rates. The DEA also provides technology data, which can be used as a reference. This forms a uniform basis for assessing the heat supply possibilities for local authorities nationwide.

Regulation of consumers' heat price

The price of heat is not the same in all Danish district heating areas, but the principles of determining the heat price are the same. The method for setting the heat price is set by law. The legislation states that the heat price paid by the consumer should cover all necessary costs related to supply heat. However, heat supply companies must remain not-for-profit, under Danish law. The heat plants cannot charge more for the heat than the actual costs of producing and transporting heat to consumers. It is, however, important to emphasise that these costs also include depreciation of assets and financing costs, so that the heating companies can be financially sustainable both in the short and long term. Cost of heat to the consumer is therefore affected by the following parameters:

- Production facility investment
- District heating network investment
- Production facility operation and maintenance
- District heating network operation and maintenance
- Fuel prices
- Efficiency of the production facility
- Heat loss in the district heating network
- Taxes and VAT
- Financial support/grants
- Electricity price (relevant for district heating production facilities that either use or produce electricity)

Investment costs versus operating costs

Establishment of district heating systems requires large investments in infrastructure compared to individual heat supply options. However, the operational costs and the environmental impacts will in many cases be significantly lower. This is particularly true if the heat is produced by an energy-efficient CHP unit or if heat is produced by utilizing excess heat from an industrial plant, for example a steel or cement plant.

Levelised costs of energy

Danish experiences show that when evaluating the feasibility of district heating, it is important to consider the costs over the full lifetime of a heat supply system (typically referred to as "levelised costs of energy" or LCoE). In many cases, district heating is the most feasible solution over a full lifecycle analysis. Large infrastructure investments will be recovered after some years by lower annual costs. Of course, viability depends on a number of factors including heat demand and the heat density in the specific area.

The use of high-quality components, although initially increasing the capital cost, usually results in lower annual costs and therefore, in many cases, a lower lifetime cost due to lower maintenance costs and longer life time. This also means lower annual heating costs for heat consumers. It is important to consider that the technical lifetime of a high quality district heating network is typically 40-50 years.

Natural monopoly

The costs of a district heating system highly depend on economies of scale both for heat production plants and network costs. It would not be cost effective to have a parallel grid to supply heat to individual consumers. Therefore, it requires thorough and detailed planning to ensure consumer protection as well as benefits for society while creating reliable investment conditions for a technology that plays a major role in the green transition.

THE INTEGRATED DISTRICT HEATING SYSTEM IN GREATER COPENHAGEN

Cost-effective low carbon heat supply to 1 million residents in 22 municipalities

Municipal and consumer owned district heating companies have established an integrated district heating system. The heat is produced efficiently by waste incinerators (25 per cent) and power plants (70 per cent). Only 5 per cent is from boiler plants. The system is in transition towards 4th generation district heating.

Anders Dyrelund, Senior Market Manager, Ramboll

The history

From 1903 to 1979, district heating developed steadily based on surplus heat from power plants and waste incinerators, as well as heavy oil boilers, providing a good alternative to individual boilers. Since 1979 the system has increased significantly, regulated by the Heat Supply Act and in symbiosis with the power and waste sectors. Recently, many natural gas districts have changed to district heating and the heat transmission has been extended in order to meet the objectives of cost-effective heat supply taking into account the cost of CO₂ emissions.

The ownership

The heat transmission and waste management companies are owned by the municipalities they serve, and the 20 heat distribution companies are owned either by municipalities or consumers. Thus, all companies have a strong interest in working together to find the most cost-effective solutions for the consumers in Greater Copenhagen.

The district heating system

The transmission system, the heat storage tanks and the heat load dispatch unit are vital for the optimal use of the resources and competitive heat prices. The system supplies 75 million m² of heated net floor area. The annual heat sale is 8,500 GWh and the production is 10,000 GWh. The back-bone of the system is a 160 km long 25 bar transmission system (max 110 °C) and 3 x 24,000 m³ heat storage tanks. This system is connected to distribution systems via heat exchangers. A heat market unit organised by the transmission companies is responsible for optimising the heat production (hour to hour and day to day) from CHP plants, waste incinerators, more than 50 peak boiler plants and other smaller heat producers.

Future development

The system is in transition towards 4th generation district heating:

• The CHP plants will shift from coal and gas to mainly straw and wood.



- The heat storage capacity will be increased significantly with large tanks and storage pits.
- The number of district cooling systems will be increased from 5 systems to more than 20 systems, mainly with chilled water storages, co-generation of heat and cold and seasonal storages (ATES) in symbiosis with district heating.
- Consumers representing more than 1,000 GWh are expected to shift from individual gas boilers to the district heating system.
- The heat transmission will be extended further to near-by distribution companies in two more municipalities.
- More large heat pumps and electric boilers will be installed in order to integrate the fluctuating wind energy.
- The remaining parts of an original steam system will be fully replaced with hot water shortly after 2020.
- The only super-heated network (165 °C) will partly shift to low temperature network, as super-heated water from the CHP plant will only be supplied as process energy to industries.
- Consumers will renovate their heating systems to lower the return temperature and the need for supply temperature.
- Accordingly, temperatures and heat losses in the grid will be reduced.

The heat transmission system owned by CTR and VEKS interconnects the two CHP plants and the 3 largest waste incinerators with 20 distribution companies to ensure optimal production and operation. HOFOR, the largest distribution company, also operates a steam system, which is being replaced with hot water. Vestforbrænding distributes heat to own consumers and transmits surplus heat in the summer to Hillerød, which is 20 km away in northern Zealand.

SYMBIOSIS BETWEEN WORLD'S LARGEST SOLAR HEATING AND CHP PLANT

Solar heating and CHP share a large heat storage and heat pump

In symbiosis with the new solar thermal heating plant, the CHP plant becomes more efficient as a back-up for fluctuating wind energy, thanks to investments in expanding the heat storage and a heat pump.

Manager Jens Jørgensen, Silkeborg District Heating Company

First stage, efficient CHP

Silkeborg District Heating Company is a municipal owned utility. District heating supplies 21,000 buildings and meets approximately 95 per cent of Silkeborg's 45,000 citizens heating needs. Two decades ago, the utility invested in Denmark's largest decentralized gas-fuelled CHP plant (108 MW electric and 85 MW heat) in order to meet national energy policy objectives. Thanks to co-generation, fuel consumption for heating was reduced compared to indvidual gas boilers.

Second stage, solar and back-up for wind energy

Due to low electricity prices, the CHP plant has been less competitive and production has declined. Moreover, the government and the city council have decided to reduce the consumption of fossil fuels even further. Instead of closing down the plant, it will function as a back up to secure the power supply in periods with no wind and, consequently, higher electricity prices.

The first step taken was to install an electric boiler (30 MW) in 2015. The boiler uses the excess wind power and helps balance supply and demand on the electricity market.

Symbiosis between solar and CHP

The second steps taken were to upgrade the CHP plant and add a large-scale solar heating plant, a larger storage capacity, and a large heat pump. In this symbiosis, the solar heating and the CHP both benefit from the larger storage and the heat pump. The heat pump (absorption) provides a boost to the heat production from the CHP plant (+30 MW heat) by lowering the temperature from the exhaust (from 65 °C to 23 °C) and increases solar production due to low operating temperatures. The solar plant was the world's largest when it became operational in 2017. Doubling the heat storage tank capacity from $2 \times 16,000 \text{ m}^3$ to $4 \times 16,000 \text{ m}^3$ ensures production fluctuations from the solar heating are accommodated. The storage also makes it possible to increase the utilization of the CHP plant.

The 25 MW cooling capacity of the absorption heat pump increases production from the solar heating by 15 per cent and increases the total efficiency of the CHP plant via flue gas condensation, from 87 per cent to 102 per cent (based on the lower calorific value).

Heat production solar	70 GWh	
Heat pump from solar	10 GWh	
Heat production CHP	280 GWh	
Heat pump condensation	40 GWh	
Heat production boilers	3,5 GWh	
Heat production electric boilers 2,5 GWh		
Waste heat	9 GWh	
(from server cooling, supermarket etc.)		



The world's largest solar heating plant on the outskirts of Silkeborg optimises the whole DH system. The green area between the two sections has been left untouched in order to make room for the future construction of a highway.

DISTRICT HEATING IN HAFENCITY HAMBURG

Sustainable and profitable district heating in exciting new city development

HafenCity is a whole new city quarter being built in the heart of Hamburg, Germany. It is currently Europe's largest inner-city development project, setting new standards for city development.

Jonna Senger, Communication Advisor, Danfoss Heating Segment

Superlative city development

In Germany, approximately 14 per cent of all households are connected to district heating systems. The city of Hamburg stands out as a front runner in district heating. The city has a vast district heating network supplying 19 per cent of all households. Politicians in charge have declared that the district heating infrastructure will continue to be expanded. Their goal is to connect 50,000 additional households to the district heating network by year 2020.

With HafenCity, a whole new city quarter has been created in the heart of Hamburg. It covers 155 hectares of harbour area with a mix of apartments, offices, recreational facilities, retail trade and culture. City planners have chosen the most sustainable and economically advantageous long-term solution for heat supply: All buildings are supplied with district heating.

The aim has been to develop an energy supply concept that fulfils the strictest economic and environmental requirements. In essence, the concept is based on the combination of the existing, well-proven Hamburg district heating system with decentralised, local heating distribution units. The fuel used is mainly coal, along with household and industrial waste, natural gas, and very small quantities of light fuel oil.

To further reduce carbon dioxide emissions, the existing HafenCity heating plan is equipped as a pilot plant with a steam turbine and a fuel cell. In addition, two new combined heat and power plants are planned in the Überseequartier and at the cruise ship terminal. Buildings, which are mainly for residential use, will be equipped with thermal solar panels for the central domestic hot water supply.

HafenCity setting new standards for sustainable city development

The combination of heat and power ensures that surplus heat from the power plant is used to heat buildings in the HafenCity area instead of being wasted. This way, 90 per cent of the primary energy can be utilised – a concept which could easily be expanded to other residential areas and cities. Compared to a conventional fossil heat supply, approximately EUR 3.7 million in fuel costs and 14,000 tons of CO_2 are saved every year.



The district heating is distributed to the buildings in HafenCity via Danfoss sub-stations and domestic hot water systems, ensuring that every single kilowatt of energy is used as efficiently as possible to the benefit of house owners, tenants and the energy supplier. The buildings are also equipped with additional Danfoss technologies that control the energy consumption of the heating and cooling systems in order to deliver a comfortable indoor climate.

BUNHILL HEAT AND POWER

Utilising Innovation to Deliver Public Benefits

Islington Council is delivering a world-leading urban heat network to provide communities with low-cost, low-carbon, sustainable heat.

Stephen Mirkovic, Energy Projects & Programmes Officer, Islington Council

Islington Council has created a publicly owned heat network which has been developed in two phases. The first phase was opened in 2012. It has 1.4 km of pipework and serves 820 dwellings, two leisure centres and four office blocks. It is powered by a 1.95 MWe CHP engine and has a 115 m³ thermal store. Phase 1 has produced a saving of 2,000 tonnes CO,/year.

For the second phase, a major 1km expansion is underway which will connect 450 existing social housing units, 150 new-build homes and a primary school.

The extension includes a 50 m³ thermal store and features an energy centre built around a 1 MW heat pump, which extracts waste heat from the London Underground. The heat pump's two-stage high temperature system works in tandem with a bi-directional fan that can both draw warm air from the London Underground tunnels,

or provide air that has had heat extracted into them.

Co-located with the heat pump are two low NOx 237 kWe CHP gas engines that supply electricity to the heat pump (effectively a 'gas fired' heat pump) and export electricity to the grid.

A new smart control system will control both energy centres, allowing the network to provide demand response to the national grid by;

- Consuming electricity directly (heat pump only operation)
- Operating with no electrical load on the national grid (heat pump and CHPs both operating)
- Exporting electricity to the national grid (CHP only operation).

The extension of the district heat network piping is the largest series three insulated

pipe installation project in the UK. Phase 2 will produce a carbon saving of 500 tonnes CO₂/year.

The network provides a customer-focused approach to energy. This includes unrestricted contact hours and a four-hour response time for vulnerable customers.

The fixed heating bills are set at least 33 per cent lower than the government threshold for fuel poverty. Bunhill Heat and Power's performance has exceeded all expectations over the past year, saving the housing department EUR 98,450. This saving is passed on to tenants by reducing the impact of increases in wholesale gas prices, and reducing the service charges of leaseholders connected to the network. There has been an 18 per cent reduction in charging costs to tenants in 2016/17 compared to the previous year, and it has been frozen for 2017/18.





Ess:

Shangri-La used to be covered in a thick blanket of air pollution due to its many coal fired stoves. Today, the citizens can once again enjoy this heavenly view from the rooftop of the world due to the introduction of energy efficient district heating.

Βİ

BOOSTING ENERGY EFFICIENCY IN SHANGRI-LA

New standard for energy-efficient heat distribution in China

Shifting from inefficient individual stoves to one coherent district heating system protects the environment, spurs economic development and improves the quality of life.

Martin B. Petersen, Regional Marketing & Sales Manager, ABB Northern Europe

District heating reduces air pollution and improves the local environment

Shangri-La is plagued by air pollution from individual stoves using fossil fuels and wood as the primary heat source among its 50,000 residents. Now air pollution is substantially reduced and protection of the local ecological environment is promoted by introducing district heating. Shangri-La is located 3,300 meters above sea level in the northwest of Yunnan Province in China. There is a substantial need for heating in Shangri-La. Daily temperatures are low and can vary quite dramatically in winter, from as low as -27 °C to 1 °C.

Implementation of the entire district heating system

A new and comprehensive district heating system is set up to supply five districts of Shangri-La. ABB supplies the equipment for the system; from the steam to water heat exchanger in the boiler room to the end user installation. This includes electrical and mechanical equipment needed to supply sufficient heat to the citizens. The automation and electrical solution interconnects and monitors the new heating plants for maximum efficiency, which helps providing a safe and reliable source of heat for about 50,000 residents.

In addition, air-source heat pumps are installed, thereby changing from individual heat-only boilers and stoves to boilers based on CO₂ free electricity from hydropower. The pumps boost the system's energy efficiency and help improve quality of life substantially by reducing coal-fired emissions.

To ensure that the heating needs of the residents are met, five local automation and control systems communicate with a central control and monitoring system in order to

deliver enough heat in the most efficient way.

The shift from the use of stoves to the district heating systems will provide substantial environmental benefits by reducing CO_2 emissions by 105,000 tonnes a year and 460 tonnes of dust a year thus, among others, saving 17,000 tonnes of coal each year.

Over decades, energy-efficient and environmental friendly district heating solutions have been developed and implemented by Danish companies including ABB in the Northern part of Europe, resulting in a substantial decrease in CO₂-emssions.



Layout of a district energy system using flexible energy sources to produce centralized heating to a wide city area.

Amager Resource Center, Copenhagen, Denmark – a waste-to-energy (CHP) plant with efficiency above 90 per cent Photo: Amager Resource Center

FUEL FLEXIBILITY ALLOWS FOR SUSTAINABILITY IN DISTRICT HEATING

The key to intelligent use of energy

District energy allows for sustainability and flexibility. A vast variety of energy sources can be used, including fluctuating renewable energy and surplus heat.

Morten Jordt Duedahl, Business Development Manager, DBDH

A variety of energy sources

District heating is extremely flexible when it comes to the choice of heat source - it can accommodate all heat sources, even fluctuating ones such as wind, solar and surplus heat from industrial processes. In large district heating systems with several heat sources, district heating makes it possible to switch from one fuel source to another, dependent on local situations, price signals and green ambitions. Therefore, with a district heating system, one does not have to change all the small individual boilers in each house every time new fuel sources become viable and available. This can be done at a central location.

Integration of electrical and thermal energy systems

An increasing share of electricity is produced from fluctuating sources such as solar and wind. Interconnectors and electrical storage can cushion some of the fluctuations in supply, but are not sufficient and often do not represent the most economic and efficient choice. Integration of the electrical and thermal energy systems can be a part of the solution. If introducing electrical boilers and large industrial heat pumps in the production of heat for district heating networks, the networks will act as large energy storages. Surplus renewable electricity can be used in heat production when the electricity price drops due to overcapacity from wind turbines and photovoltaic solar panels.

Surplus heat

Surplus heating or cooling from e.g. industry is often wasted, but is a precious resource that can easily be utilised in a district heating or cooling system. Where industrial or commercial buildings are in close proximity to a thermal grid, it can be beneficial to collaborate with the local utility company in utilising the surplus heat. Not only is there a financial benefit, but surplus heat can also replace the use of fossil fuels in heat production.

Energy from waste

Waste is a resource that contains a vast potential. The more value a society can get out of its waste the better. Waste that cannot be reduced, reused or recycled, can be used for energy recovery. Modern waste-to-energy plants handle a waste problem and produce electricity and heat to nearby cities. The best and most modern systems work with an energy efficiency close to 100 per cent through advanced technology. The impact of these plants on the local environment is minimal through advanced use of filters and other technologies to such an extent that they can even be located in the centre of large cities as is seen in Copenhagen, Denmark.

An enormous amount of surplus heat from power production is commonly wasted. This energy resource is increasingly being integrated into district heating systems and used for heating and cooling purposes in buildings.

In Denmark, more than 60 per cent of district heating was produced from renewable sources in 2018. The renewable sources cover biomass (wood, bio-degradable waste, straw and bio oil), biogas, solar, geothermal and electricity (heat pumps and electrical boilers). Source: Annual Energy Statistics 2018, Danish Energy Agency.

- Renewable energy
- Natural gas
- 🛑 Waste, not bio-degradable
- Coal
- Oil

Electricity (heat pumps, electrical boilers etc.)



In Dronninglund, an unused plot of land has been utilised for a solar thermal plant. The solar installation totals 37,537 m² collector area. The underground seasonal storage has a total capacity of 62,000 m³. The installation has an annual output of 18,000 MWh. The solar collectors are installed to follow the lines of the landscape so as not to disturb the environment. Furthermore it makes no noise and releases no odor.

PRIZE WINNING SOLAR DISTRICT HEATING

Solar thermal energy in district heating saves money and benefits the environment

In Dronninglund, Denmark a large-scale solar thermal installation combined with large-scale seasonal thermal energy storage supplies 40 per cent of the annual district heating demand.

Casper Christiansen, Chief Operations Officer, District Heating Dronninglund

Solar heating lowers consumers' heating bill

Large-scale solar heating has been installed in numerous district heating power stations since the 1980s. The sun is the cleanest of all energy sources and the most powerful source of sustainable energy, emitting zero CO_2 . The cost of the sun is always the same: zero. Even taking the cost of the facilities into account, large-scale solar thermal installations will generate the lowest possible heating costs. Furthermore, it makes no noise, does not release any smell and does not spoil the environment.

With the latest innovative development, allowing also large-scale storage of the solar energy, this technology has been taken to a new level. In Dronninglund, 1,350 district heating customers are happy and proud of their clean, renewable technology because it benefits the environment and has lowered their heating bills by about 20 per cent.

New decisions made a huge impact

It all began when the 40-year-old oil boiler needed replacement. This was a good occasion to rethink the whole setup and decide which installation would serve the district heating plant most effectively in the future. With assistance from advisers, it was concluded that a replacement of a part of the fossil fuels with solar thermal energy would make sense, both in economic and environmental terms.

The installation consists of 2,982 solar collectors equivalent to a 37,573 m² solar heating plant. A huge seasonal thermal energy storage has been established. It is a water basin formed by a welded liner with an insulated lid, which is filled with 62,000 m³

of water. It works like a thermos flask, allowing the energy to be stored from summer to winter. During summer, the plant produces 10 times the demand for heat per day, and the excess heat is stored for later use. That makes it possible to cover 40-50 per cent of the annual heat demand with solar thermal energy, using only solar power from May to October. During winter, the heat supply is supplemented with natural gas and bio oil. The plant has reduced CO_2 emissions by approximately 2 tonnes annually for each household it supplies.

Dronninglund District Heating received EUROSOLAR's European Solar Prize Award 2015. The prize recognises and promotes pioneers and leaders within solar energy, as well as providing fresh impetus to a renewable energy-based and decentralised energy turnaround.



TURNING SURPLUS HEAT INTO WARM HOMES

Optimum co-operation: How to use groundwater as a source for cooling and heat recovery

Partnership between industry and district heating company generates substantial savings for the partners and benefits the environment. Using thermal storage to eliminate energy waste in an existing district heating system brings us closer to zero impact buildings.

Anders Nielsen, Application Manager, Grundfos

In 2013, the industrial company Grundfos and the local GUES utility company inaugurated a joint system to exploit heat extracted from the cooling compressors in the factories for district heating. Operation of compressors requires a lot of energy and is thus expensive. Furthermore, a large amount of surplus heat has to be emitted into the atmosphere by means of cooling towers. Or at least that is how it used to be.

The thermal storage system

The new system is based on three elements: using surplus heat from the cooling machines, indirect storage of heat in an underground aquifer and use of a heat pump to raise the temperature of the stored energy. The surplus heat is used in the local district heating system.

During the summer months, Grundfos doesn't require heat, and therefore all the condenser heat from the cooling compressors are transferred to the storage aquifer, where the heat is put "on stock". In autumn, when the district heating system requires heat, 80-85 per cent of the heat stored during summer is still available.

In order to increase the temperature to the level needed in the district heating network, Bjerringbro District Heating increases the temperature by using a heat pump. In winter, the district heating company gets the surplus heat from the storage and directly from the compressors.

Groundwater is used for cooling at Grundfos' factory. The water is 6-12 °C when it arrives and 18 °C when returned. The temperature of the water is raised to 46-67 °C with heat pumps and supplied to the district heating network. Coefficient of performance (COP) for heat pumps for heating is 4.60. In summer, when heat demand is low, the surplus heat is stored for later use.

Sizeable cost and emission savings

From the start, it was evident that the current system capacity was unable to cover the complete cooling requirement for Grundfos' production. However, after only a few years in operation, it is now clear that the economy in this system is sufficiently attractive to be extended further. This also helps Grundfos achieve its overall goal of reducing carbon emissions by reducing power consumption from conventional chillers.

Grundfos will save up to 90 per cent of the power consumption used up until now in the cooling towers, and the district heating company will be able to cut gas consumption in its combined heat and power plant (CHP). In total, USD 6 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 are in addition to this amount.

This corresponds to a payback time of 8-10 years, which is fine for a district heating company, but a little long for an industrial company. However, at the same time, 3,700 tonnes of CO_2 are saved annually, and in light of Grundfos' policies related to energyconservation and sustainability, this result is acceptable for the company.



DATA CENTRE'S SURPLUS HEAT PROVIDES DISTRICT HEATING

Facebook's new data centre assists in phasing out coal and implementing heat pumps

In early 2020, Fjernvarme Fyn (District Heating Funen) is commissioning the world's largest district heating centre based on surplus heat from a data centre. The project was developed in close collaboration with Facebook who is recovering and donating the heat.

Kim Winther, Head of Business Development, Fjernvarme Fyn

In 2014, Fjernvarme Fyn was contacted by Facebook and the result of a new collaboration is now ready for commissioning. The district heating centre named Tietgenbyens Varmecentral (TBV) is developed, owned and operated by Fjernvarme Fyn and will upgrade heat recovered by Facebook's hyperscale data centre on a site adjacent to TBV in the Danish city of Odense.

The TBV project

The plant is expected to deliver 125,000 MWh of heat, which is equivalent to the consumption of almost 7,000 local households. A visitor centre at the TBV plant will facilitate the sharing of information about this innovative project and the potential for heat recovery to the rest of the world.

Fjernvarme Fyn has decided to expand the capacity at TBV with additional heat pumps that will be in operation by end of 2020. The additional capacity can either be deployed

to reuse surplus heat or to extract energy from air.

Surplus heat for a green transformation

Surplus heat projects face some regulatory uncertainty and concerns over the reliability of the heat supply. However, for Fjernvarme Fyn, the implementation of surplus heating is part of a larger plan to phase out fossil fuels, and the TBV project accelerated the plan, as heat pumps will provide a substitute for coal.

The surplus heat from Facebook is far from enough to replace the production from a coal-fired plant, but it is part of the solution. When combining the surplus heat from Facebook's data centre, industries, and sewage treatment facilities with a substantial amount of natural heat sources such as air and sea and a limited amount of biomass, Fjernvarme Fyn is able to create a green transformation. With the expansion at TBV, Fjernvarme Fyn is expecting to have heat pumps with more than 100 MW heat capacity operational by end of 2020. This heat pump capacity enables Fjernvarme Fyn to base about 25 per cent of the district heating production on electric heat pumps.

Good dialogue has paved the way

A number of factors has made the collaboration between Fjernvarme Fyn and Facebook possible. Firstly, the location of the data centre has minimised the need for new infrastructure and boosted efficiency. Secondly, the Danish regulatory framework, such as the Energy Saving Scheme, has supported the collaboration. Thirdly, the parties have had a good and productive dialogue and aligned objectives: to utilise resources efficiently and support the green transition.

Tietgenbyens Varmecentral makes use of surplus heating from Facebook's data centre to heat almost 7,000 local households in the Danish city of Odense.

Photo: Peter Kiærbye, Fjernvarme Fyn

Two large day-to-day storage tanks at the Avedøre Plant near Copenhagen. These storage facilities are mainly used to make it possible for the owner of the plant to produce electricity when the prices are right and store the surplus heat for later use when electricity prices are lower. Thereby, the storage system assists in optimising the plant's economy.

THE NECESSITY OF HEAT STORAGE

Saving money and securing supply

A heat storage provides many advantages. It is possible to improve the economy in a district heating system, consumption can be decoupled from production and more sustainable heat sources can be implemented.

Morten Jordt Duedahl, Business Development Manager, DBDH

The value of heat storage

A unique characteristic of district heating is that hot water can be stored - both from day-to-day and from season to season. Heat storage does not differ from the storage of any other product, as it decouples the time of production and the time of consumption. For district heating, this means that you can store heat when it is available from e.g. CHP plants, solar collectors, surplus wind electricity and industrial surplus heat, and use the stored heat when it is needed. In Denmark, both central and decentral district heating combined heat and power (CHP) areas have heat storages.

The day-to-day solutions mainly allow the CHP plants to optimise their cogeneration of electricity and heat according to the demand of electricity, and still be able to supply heat when needed.

With large-scale heat storage, it is possible to utilise much more energy that would otherwise have been wasted. The large scale heat storages allow for storing heat from warmer to cooler seasons. The heat can be collected from many sources, e.g. solar collectors, CHP and industrial processes that do not necessarily have a steady production.

Day-to-day storage

One very important element of all Danish district heating networks is short-term heat storage. The main purpose of the short-term storage is to decouple the power production at CHPs. Thereby, the CHP plants can optimise their cogeneration according to the fluctuating electricity market price without compromising the heating supply. The CHP plant will then only produce electricity (and heat) when the electricity prices are high (normally in the morning and in the afternoon) and simply store the hot district heating water until it is needed during the day. In Denmark, both large and smaller district heating systems utilise short term heat storages. The short-term heat storage introduces flexibility to the energy system, which is crucial for optimising the total system, both economically and environmentally.

Day-to-day storage is also used when external heat production, which cannot be controlled by the district heating company, is introduced into the district heating system. These heat sources can be industrial surplus heat, where production at the plant varies throughout the day or week, e.g. fish industries that only produce when fishing boats unload fish. If there is surplus heat during these periods, it can be stored in smaller day-to-day storages.

Seasonal storage

Today, seasonal storage in Denmark is used mainly for large-scale sun-collectors that produce much more heat during the summer than needed immediately.

Seasonal heat storages are typically a pit, i.e. a very large hole in the ground, with a liner in the bottom, filled with water, and covered by a floating layer of insulation. Other solutions are groundwater storage systems, where surplus heat can be stored at a lower temperature and then utilized later at higher temperatures by using heat pumps. Groundwater systems could well become relevant in cities with no room for large pit storages. For both systems, the heat is stored for weeks or months until the heat demand rises and will be consumed during autumn and winter.

For many Danish district heating systems, seasonal heat storage will become more and more important in the future, as utilising energy that would otherwise have been wasted is an important element in the green transition.

Surplus wind energy for district heating

In 2019, 46.9 per cent of the total Danish electricity consumption was covered by wind energy. Due to the fluctuating production from renewable energy sources, Denmark sometimes experience surplus electricity, which is sold at very low or even negative prices. There is currently no full-scale technology available for storing renewable energy directly.

In combination with both short and long term storage, the surplus electricity can be used to make district heating. When prices are right, the district heating companies will use electricity to produce hot water, either directly through a boiler or through heat pumps.

Seasonal storages are very large – the size of several swimming pools. After using months to fill up the storage with water, the next step is to cover the surface with a floating layer of insulation. Subsequent heating of both the water and the walls of the storage also takes months. When it is all warmed up, the storage is ready for use.

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DISCOVERING THE OPPORTUNITIES IN LARGE-SCALE STORAGE

Seasonal heat storage - where size matters

The world's largest pit heat storage of 205,000 m³ combined with a 70,000 m² solar heating plant is an efficient and cost-effective way to reduce CO₂ emissions.

Flemming Ulbjerg, Senior consultant, Ramboll Energy

Reducing fossil fuel and consumer prices

The district heating company in Vojens, Denmark, supplies the majority of the town with heat from its new production facilities - the solar panels. Until recently, the main fuel was natural gas. The production was partly combined heat and power and partlyheat only boilers.

Due to lower electricity prices, heat production has become increasingly important for profitability. This change has spurred a search for alternative ways of producing heat. Today, the solar heating plant, including the pit heat storage, delivers 45 per cent of the annual heat demand for the consumers in Vojens.

District heating plants in Denmark are governed by a number of laws and regulations. It is not allowed for plants such as Vojens to switch fuel sources from natural gas, so economic savings from changing to e.g. biomass are not feasible.

However, energy saving measures such as solar heat, heat pumps and surplus heat are allowed. Therefore, after careful consideration, solar heat was chosen as a new heat source to reduce the demand for natural gas. The total investment in solar and heat storage was EUR 16 million. The price for the heat from this facility is 40 EUR/MWh, which in Denmark is below the average price of heat from a natural gas installation of 60 EUR/MWh.

Seasonal storage increases flexibility

During the summer period (mid-April until end of September), the solar plant supplies 100 per cent of heat demand, mainly for hot domestic water. In addition, during the summer, the solar plant has tremendous excess production capacity and delivers heat to the large pit storage. From October, the supply comes partly from the solar heating plant and partly from the heat storage. By the end of the year, the storage will normally be completely offloaded. The heat loss from the storage is calculated to only 6 - 8 per cent of the total demand.

The storage makes it possible to store heat from both the CHP unit and the electric boiler, in case it is feasible to operate these units in the summer period. This feature increases the flexibility of the plant and increases income from the sale of electricity.

Due to the high benefit both in terms of flexibility and lower consumer prices, it is expected that many solar and large storage plants, such as in Vojens, will be built in the future – even without subsidies.



The storage in Vojens is heated up by thermal solar energy in summer and provides heat for the town during winter.



Historical development of district heating networks. 4th generation district heating focuses on energy efficiency, flexibility and integration of all available renewable and surplus energy sources. Source: Aalborg University and Danfoss District Energy

THE FUTURE OF DISTRICT ENERGY

Realising a strong global potential

District energy systems are expected to grow in years to come due to increased urbanisation, technological advancements, stronger focus on resource efficiency and consumers' increasing demand for comfort.

Hans Peter Slente, Senior Advisor, Danish Energy Industries Federation

Growing demand ahead

The use of district energy varies widely across countries. This is only in part due to the given circumstances such as the climate, urban density and energy resources available. Differences in regulatory frameworks, building traditions and energy policies also explain the strong variation in the uptake of district heating. In Europe, according to Euroheat & Power, there are approximately 6,000 district heating systems which meet 12 per cent of Europe's heat demand.

The share of district heating in total heat delivery in EU can increase for several reasons. The level of urbanisation in EU is expected to grow to 75 per cent in 2020 and almost 84 per cent in 2050, expanding the market for district heating which operates most efficiently in densely populated areas. Even in Denmark, where currently more than 60 per cent of households get their heat supply through district heating, analyses show that it is economically feasible to increase the market share. The potential lies both in increased urban densification and wider use of district heating in existing supply areas.

EU's Energy Efficiency Directive obligates Member States to carry out a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling. The European Commission argues that the share of heat produced from high-efficiency combined heat and power (CHP), as well as high-efficiency district heating and cooling, needs to be further promoted by member states. Thus, EU's drive towards decarbonizing the economy is spurring a focus on district heating. Member states are currently drawing up more national heat maps and action plans for district heating.

4th generation district heating

Technological advancements favour the use of district heating. The temperature of the water required in a district heating system is becoming even lower, thereby increasing energy efficiency. This provides economic rationale for more use of surplus heat from industry and for the use of thermal energy storage. Buildings are expected to become still more energy-efficient in the future, thus having a smaller demand for heat per square meter. However, the demand for space and comfort is increasing, which increases the demand for heat. Therefore, efficient low-temperature district heating solutions will play an increasing role in the future. 4th generation district heating builds on the long experience with district heating focusing on integrating all the available energy sources. It integrates still more renewable energy and surplus heat from various sources. Energy storage and

dynamic interaction with producers and consumers ensures further flexibility and efficiency in the system. By using water at lower temperatures and still better pipe systems, heat losses are minimised and district heating becomes feasible in still more places. The modern principles of 4th generation district heating are applied today both in new-built district heating systems and when retrofitting and expanding existing ones.

District cooling

The demand for cooling is far higher than for heating on a global scale. Current practices of applying individual cooling solutions to each building, or each room, is expected to be replaced by district cooling solutions. District cooling works according to the same principles as district heating. It provides better energy efficiency, frees up much-needed space in urban areas and provides easier operations of cooling systems for users. The market for district cooling is currently smaller than for district heating and it is mainly used in commercial buildings. It is already growing rapidly and is expected to keep growing in the future - both in temperate countries and even faster in warmer countries where the strongest growth inpopulation, building mass, income levels and thereby cooling demand is expected.



Share of citizens served by district heating in percent

Source: Euroheat & Power "2017 Country by Country"

GLOBAL RENEWABLE ENERGY AND ENERGY SECURITY FOCUS IN THE HEATING SECTOR

Research helps unlock energy savings in buildings and district heating

Climate change, competitiveness, energy security and dependency on imports of, for example, natural gas increase the attention on buildings and heating in Europe and globally.

Dr. Brian Vad Mathiesen, Professor, Aalborg University, Denmark, www.brianvad.eu

The UNFCCC COP21 Paris Agreement, energy security and major health effects arising from the burning of fossil fuels or bioenergy has meant that many countries are turning their focus to district heating and energy efficiency in buildings. Traditionally, renewable energy in the electricity sector or energy efficiency at the building level has attracted most attention. However, heating and cooling in buildings actually account for 40-50 per cent of the final energy consumption in Europe and globally. Thus, cities and countries around the world are now investigating how to improve building standards and utilize district heating to address these challenges. Cities are expected to house two thirds of the global population in 2050, which will increase population density in urban areas. The solutions of tomorrow require joint local and national efforts at policy level.

Understanding the roles of the individual technologies is crucial: What is the role of savings, flexible demand or storage at the building level? To what extent do we need on site renewable energy supply? Do we need district heating in the future? What is the role of bioenergy and heat pumps? How can we use low-value heat? What policies and planning methods can facilitate change?

These questions and more are at the heart of research being conducted at the Strategic Research Centre for 4th Generation District Heating Technologies and Systems (4DH). The research has served as inspiration for e.g. European Commission initiatives on heating and cooling as well as globally in the UNEP-led Global District Energy in Cities Initiative (DES Initiative).

The research reveals that savings in buildings and district heating are essential in cost-effective renewable energy systems. A drastic change of direction in the European and global heating sector is needed in the near future if a cost-effective transition is to be achieved. Currently the heat wasted in Europe can supply the heat demand of almost all buildings. Energy sectors need to be integrated (Smart Energy System) to utilize these potentials. Heat Roadmap Europe is a series of studies initiated by 4DH in collaboration with key industrial and university partners. They combine energy system analyses with geographical information systems (GIS). They provide strategies and methods that can be replicated globally together with a pan European Thermal Atlas (Peta4). The studies suggest that 30-50 per cent heat savings and 50 per cent district heating are feasible by 2050 in Europe. In rural areas, high levels of refurbishment are also needed in combination with individual heating technologies such as heat pumps.

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Suggested changes in Danish buildings towards 2050.

Total heated floor space ~470M m² Total average heat demand ~72 kWh/m² Total heating demand ~34 TWh

COPENHAGEN MARKETS

The nordics' largest refrigerator offers reduced district energy bills

Flowers, fruit and vegetables are kept fresh in the Nordic countries' largest and most advanced refrigerator in Høje Taastrup, while simultaneously providing green, inexpensive district heating to its neighbours.

Uffe Schleiss, Technical director, District Heating Høje Taastrup

At the old market square, each business owner had their own cooling systems, with varying levels of efficiency. In the new 67,000 m² Copenhagen Markets, which opened in Høje Taastrup in April 2016, a 15,000 m² cooling area has been established, which is supplied by a large, joint district cooling plant. This system is the most comprehensive of its kind in the Nordic countries and has a number of positive impacts on energy consumption, the climate and the working environment.

Although the name of the company providing energy to Copenhagen Markets is Høje Taastrup District Heating, it actually provides district cooling as well. The cooling is delivered from a newly installed electricity and ammonia powered cooling compressor. A heat pump utilises the energy from the cooling process to create green, inexpensive district energy. It is necessary to deliver water at a temperature of between 2 and 5 °C to the customers at Copenhagen Markets. This requires that the water is chilled to a temperature of minus 8 °C. District Cooling is normally delivered with a flow of 6 °C and a return flow of 16 °C. To meet Copenhagen Markets' requirements, an extra chiller has been installed.

Production of the cooling means that considerable amounts of heat are also generated in the process. An electricitypowered heat pump upgrades the heat and sends water to the nearby district heating system with a temperature of 73 °C, which is a satisfactory flow temperature. The system is a co-production of chill and heat, where the one product cannot be produced without the other.

There is a cooling capacity of 2 MW. Heat

corresponding to 2.3 MW is produced at a water temperature at 73 °C. This constitutes approximately 2.5% of the overall heating consumption to Høje Taastrup District Heating's 6,700 customers and is yet another example that systems thinking and utilisation of resources are of the utmost priority.

The cooling system at Copenhagen Markets is designed so that the cooling can be used at different levels according to need. The markets are divided into 80 tenancies under the one roof, whereof 55 use cooling. Each tenant has the option of using cooling and deciding exactly where in their area the cooling should be delivered is needed. Consumption is calculated individually via an innovative meter solution.

The capacity for cooling can be increased as the need develops over time.



In Albertslund, a 4th generation district heating system provides comfort and clean energy to customers with maximum efficiency and minimum heat loss.

MUNICIPALITY IN TRANSITION TO LOW TEMPERATURE DISTRICT HEATING

From 2nd to 4th generation district heating in an existing supply area

Use of low temperature district heating is realistic and makes it possible to both save energy and reduce dependency on fossil fuels.

Theodor Møller Moos, Chief Project Manager, COWI

Albertslund District Heating Company

Albertslund District Heating Company was established in 1964, and the district heating supply area increased in line with the development of the city. Initially, the district heating network was established for operation with a supply temperature of 110 °C. Over the years, the temperature has been lowered, and today the system operates with a flow temperature of approx. 90 °C.

4th generation

As part of Albertslund municipality's vision for the heat and electricity supply to be CO_2 neutral by 2020, a new low-temperature 4th generation district heating system, where the supply temperature is lowered from 90 to 55 °C, is being established. This allows for more efficient use of the existing heat generation plant and lowers heat losses from pipework, thus helping Albertslund achieve its goal of a CO_2 -neutral heat supply. Based on the success of the first phase, Albertslund have recently taken the bold decision to convert the entire town, approximately 30,000 inhabitants, to low temperature district heating before 2026.

Challenges

While it is relatively easy to supply new apartments with low-temperature district heating, older apartments are generally poorly insulated and require a high flow temperature to give an adequate comfort level. Albertslund Municipality is therefore instituting a renovation program which switches apartments to low-temperature district heating and thereby increases their energy efficiency.

The distribution system

Apartments are connected in phases in line with the renovation plan and the termination of the high temperature distribution system. The low temperature circuit is supplied via the return from the 'old' district heating system, which is mixed to 55 °C through a shunt valve.

The apartment system

New low temperature instantaneous water heaters are installed in the apartments, which supply domestic hot water at 45 °C on the consumer side. Legionella is controlled by design according to the German rule DVGW W55, which requires that only a very small amount of water is held in the heat exchanger and hot water system at any time. After refurbishment, the apartments are supplied with space heating via underfloor heating and radiators. The overall supply temperature from the district heating system is 55 °C and the return temperature from the user will be around 30 °C.



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HOFOR

Facts about district cooling

- Up to 70 per cent reduction of CO₂ emissions and 40 per cent reduction in total costs when using district cooling compared to local compressor cooling.
- Lower operating costs, lower costs of maintenance combined with lower energy costs and lower cost of capital.
- High reliability of supply.
- District cooling creates a comfortable indoor environment, without noise and vibrations.
- District cooling takes up less space than traditional cooling methods. A cooling system with an estimated usage of 1 MW will free up 115 m² on the roof, since all cooling towers are removed. In addition, the basement will only need a heat exchanger, which is about 10 m², compared to the traditional cooling system taking up 90 m² in the basement.

2 63

The district cooling system is under constant expansion in order to supply new urban areas and more customers. In 2019, HOFOR built a new, architecturally designed, cooling plant in the urban development area of Copenhagen known as Ørestad in order to supply the many office buildings with climate friendly district cooling.

DISTRICT COOLING REDUCES CO₂ EMISSIONS IN COPENHAGEN

A sustainable and cost-efficient alternative to conventional cooling

In the capital of Denmark, district cooling results in up to 70 per cent reduction in CO_2 emissions and up to 40 per cent reduction in total costs compared to conventional cooling.

Jakob Thanning, Head of District Cooling, HOFOR

Increasing demand for cooling in cities Temperatures are rising in cities throughout the world. In Copenhagen, several warm summers have increased the demand for air conditioning and cooling. That calls for sustainable, city-friendly and cost-efficient solutions to meet the demand.

The Greater Copenhagen Utility Company, HOFOR, has built a district cooling system, inspired by the well-functioning district heating system in Copenhagen. The district cooling system consists of a distribution net of pipes in the ground and several cooling plants, that primarily uses seawater to chill the water supplied to the customers. The system supplies commercial buildings such as banks, hotels, department stores and offices as well as cooling for servers and other processes all year round.

The cooling system supplies different parts of Copenhagen with cold water, and the pipe system is expanded all the time in order to supply more customers in the future. HOFOR's district cooling activities are the biggest of their kind in Denmark. The first cooling plant was opened in 2010, the second in 2013. In 2019, HOFOR built a new cooling plant in the part of Copenhagen known as Ørestad, so the many office buildings in the new urban area can get climate friendly cooling. In 2021, HOFOR will open yet another cooling plant in Nordhavn, Copenhagen's newest and most sustainable living area.

The district cooling system is under constant expansion, so HOFOR can supply the increased demand for cooling and help reduce CO_2 emissions. It is the ambition to continuously increase the amount of customers and thereby contribute further to Copenhagen's target to become CO_2 -neutral in 2025.

Cooling is produced centrally with help from seawater

In winter months, the chilled water supplied to customers is produced by using seawater.

The seawater is pumped into the cooling plant through a pipe from the harbour. The seawater temperature is a maximum of 6° C, when it is used directly to cool down the water for the customers. This is known as zero-carbon cooling. In summer months, when the seawater is not sufficiently cold, energy must be used to cool the water. Seawater is used to increase the efficiency of the other installations. Using seawater to remove the heat from the machines reduces electricity consumption by up to 70 per cent compared to a local compressor.

District cooling is also an asset to life in the city

With a district cooling solution, customers do not have responsibility for the maintenance of local air-condition devices, and since the pipes run under ground it also makes room for green roof terraces, solar cells and recreational space instead. Thus making Copenhagen an even greener and more livable city for inhabitants and visitors.



Illustration of district cooling system in the city of Copenhagen

INTELLIGENT ENERGY SOLUTIONS FOR NEW URBAN AREAS

In the new urban area of Copenhagen, Nordhavn, HOFOR is creating the energy solutions of the future

The cities of the future are equipped with sustainable, intelligent, and flexible energy solutions. In Svanemølleholmen, the newest part of the sustainable urban area of Nordhavn in Copenhagen, HOFOR is planning a combined district heating and cooling plant. The plant will also house a sewage pump station.

Jakob Thanning, Head of District Cooling, HOFOR

New urban areas, new possibilities

Nordhavn is Copenhagen's newest and most sustainable urban neighbourhood. In 2021, HOFOR, the Greater Copenhagen Utility, plans to commission yet another district cooling plant in this part of town in order for the many office buildings in the area to have the opportunity to connect to climate friendly district cooling. However, instead of planning for a regular district cooling plant, HOFOR is aiming for making use of the possibility to combine a cooling plant with a modern heat pump using seawater to also produce heating for the area.

A house of energy - with cooling and heating

The district cooling system in Copenhagen primarily makes use of seawater to chill the water supplied as air-conditioning to commercial buildings such as hotels and banks as well as cooling for servers all year round. HOFOR has also installed several heat pumps in Copenhagen, which can extract energy from sources such as groundwater, sewage water and seawater. These are some of the major energy sources which have the potential to supply the capital with even greener district heating in the future.

The newest district of the Nordhavn area, Svanemølleholmen, is currently under transformation from an industrial area to an area with offices. The many buildings will be supplied with district heating as well as district cooling, and as a result, HOFOR will make use of the opportunity to test and demonstrate how to work efficiently with the integration of district heating and cooling. This will be done by installing both a modern heat pump using seawater and a district cooling plant in one location, which will also house a sewage

pump, ensuring that the area can discharge its wastewater.

Integration of heating and cooling

When HOFOR cools office buildings with district cooling, the excess heat from the buildings can be used to create district heating. Similarly, the district cooling water can be used to cool the heat pump. As a result, the project in Nordhavn can be used as a test and demonstration case for new green technologies in the local area. The integration project in Nordhavn can also serve as a feasibility study of the business case to be used elsewhere.

The solutions implemented by HOFOR in Nordhavn help the citizens of Copenhagen reduce their carbon emissions and contribute to achieving the Danish capital's ambitious goal of becoming CO_2 -neutral by 2025. When tested and demonstrated in Nordhavn, these solutions can, over time, be scaled to new urban areas in major cities all over the world.

An old industrial area of Copenhagen has undergone a massive transformation and is an example of sustainable urban development. It is expected that Nordhavn, an area of 200 ha, will house 40,000 inhabitants and 40,000 jobs by 2050. The new urban area will be equipped with intelligent energy solutions by HOFOR. Photo: By & Havn





State of Green

Denmark is transitioning to an economy based on green growth and aims to become independent of fossil fuels by 2050. Therefore, State of Green seeks to foster relations with international stakeholders interested in discussing their challenges and brings into play relevant Danish solutions that enable the green transition.

As your one-point entry to more than 600 Danish businesses, governmental and research institutions, experts and civil society organisations, State of Green connects you with relevant Danish actors working to drive the global transition to a sustainable, low-carbon, resource-efficient society.

State of Green is a not-for-profit, public-private partnership between the Danish Government and Denmark's four leading business associations: the Confederation of Danish Industry, Danish Energy, the Danish Agriculture & Food Council and Wind Denmark. His Royal Highness, Crown Prince Frederik of Denmark, is the patron of State of Green.

Learn more at www.stateofgreen.com



The Danish Energy Agency is responsible for handling all national and international agreements and tasks linked to the production, supply and consumption of energy in Denmark. The Agency also deals with efforts to reduce greenhouse gas emissions, and oversees the legal and political frameworks governing the reliable, affordable and clean supply of energy in Denmark.

The Danish Energy Agency's Global Cooperation department collaborates with partner countries to combine sustainable future energy supplies with economic growth. The initiative is based on four decades of Danish experience with renewable energy, energy efficiency and transforming the energy sector to deploy a growing amount of low-carbon technologies. The Agency is part of the Danish Ministry Climate, Energy and Utilities.

Learn more at www.ens.dk



The Danish Board of District Heating (DBDH)

DBDH is a member organisation. Its mission is to promote district energy for a sustainable city transformation. Our purpose is to identify, inform and facilitate partnerships between our members and partners across more than 50 countries.

DBDH represents the leading actors within the Danish district heating sector. This includes heat and combined heat and power production companies and waste incineration companies, heat transmission and distribution companies, private consulting companies, R&D institutions and training institutes, manufacturing companies of plants, systems, components and products for the sector.

DBDH organises conferences, seminars and exhibitions. Furthermore, DBDH develops and maintains cooperative agreements with district heating organisations abroad for the purpose of exchanging information related to all aspects of district heating.

Learn more at www.dbdh.dk



DI Energy organises the Danish energy industry across all energy technologies and the entire value chain; from exploration and production of energy, to development and manufacturing of modern energy technologies and solutions and engineering of whole solutions and systems. Denmark is home to a strong cluster of innovation, manufacturing and the export of sustainable, durable and cost-efficient energy solutions. DI Energy works to further develop Denmark as a base for a strong energy industry with significant international outreach and impact.

Danish Energy Industries Federation

DI Energy supports an energy policy at the Danish, European and Global level that enables the transition towards higher energy efficiency and the use of more renewable energy. Through strong co-operation with companies and authorities at home and abroad, we contribute to meeting the ever-increasing global demand for energy. DI Energy is a part of the Confederation of Danish Industries (DI) - the voice of corporate Denmark.

Learn more at www.di.dk

Learn more about Danish solutions in heating and cooling, find more cases from around the world and connect with Danish expertise at:

www.stateofgreen.com/district-energy

State of Green is a non-profit, public-private partnership founded by



Confederation of Danish Industry

MINISTRY OF INDUSTRY, BUSINESS AND FINANCIAL AFFAIRS



Danish Ministry of Climate, Energy and Utilities



Ministry of Environment and Food of Denmark



MINISTRY OF FOREIGN AFFAIRS OF DENMARK