A Brief Introduction to District Heating and District Cooling

Sustainable heating and cooling for cities

Over the past decades, Stockholm and Sweden have reduced CO_2 emissions and increased resource efficiency, while maintaining high and sustainable economic growth. A major part of the recipe for success has been the development of the infrastructure for district heating and cooling. The district heating and cooling networks cover the Greater Stockholm Area. A set of large production plants, where waste and biomass are utilized to simultaneously produce heat and electricity, form the basis of district heating supply. In addition, sea water, chillers and a range of large heat pumps supply the district cooling network. All in all, these systems make for a virtually unmatched large scale solution to the challenge of sustainability, cost efficiency and security of supply.

Historical overview of district heating in Stockholm and Sweden

1853: The first gaslight is lit in central Stockholm, as the city improves its urban development plans.

1878: Sabbatsberg Hospital was first in Sweden to heat several different buildings with a common boiler in a local district heating system.

1950's: The rapid urbanization and increased energy demand forced the Swedish municipalities to develop their heating systems and implement district heating infrastructure on a large scale. The district heating system in Stockholm used cogeneration plants from the beginning, as the City feared a future shortage of both electricity and heating due to the high population growth.

1960's: More cogeneration plants became operational and the sales of district heating in Stockholm doubled in five years, from 5 to 10 TWh annually.

1970's: The oil crisis accelerated the development of district heating. Peat was introduced as an alternative fuel during the oil crisis, thus phasing out oil dependency. Large scale roll-out of district heating in Stockholm. The housing project in Stockholm, to construct one million homes in 10 years, was connected to district heating from start.

1990's: Many municipal energy companies were privatized. District cooling systems were developed and more widely implemented. Stockholm's system started to use sea water as cooling method.

2010: The City of Stockholm was appointed as the world's first Green Capital 2010. In part thanks to the district heating system, Stockholm is one of the cleanest capitals in the world.

2013-2014: Inauguration of new waste-based plant north of Stockholm, Brista 2 by Fortum Värme. Launch of the Open District Heating© concept in Stockholm by Fortum Värme.

2016: Fortum Värme opens the KVV8 plant, Europe's largest biomass combined heat and power production unit. 270 of 290 municipalities have a district heating system in Sweden. More than 50% of Swedish heating market is through district heating (European average 10%). More than 90% of apartment buildings in Sweden are connected to district heating. The Swedish district heating infrastructure measures 18 000 km of piping altogether.

District heating and cooling - How does it work?

District energy, both heating and cooling, tie together the energy generating sources in a city with buildings and facilities having a need of heating and/or cooling. Instead of each building having its own heating or cooling system, the energy is delivered to several buildings in a larger area from a central plant. The water based distribution system guarantees that heat and cooling arrive safely to the end users.

With district heating, energy is saved overall, as it takes advantage of resources that would otherwise not be have been used, making it an efficient and sustainable solution to satisfy the local heat and cooling demand in a city.

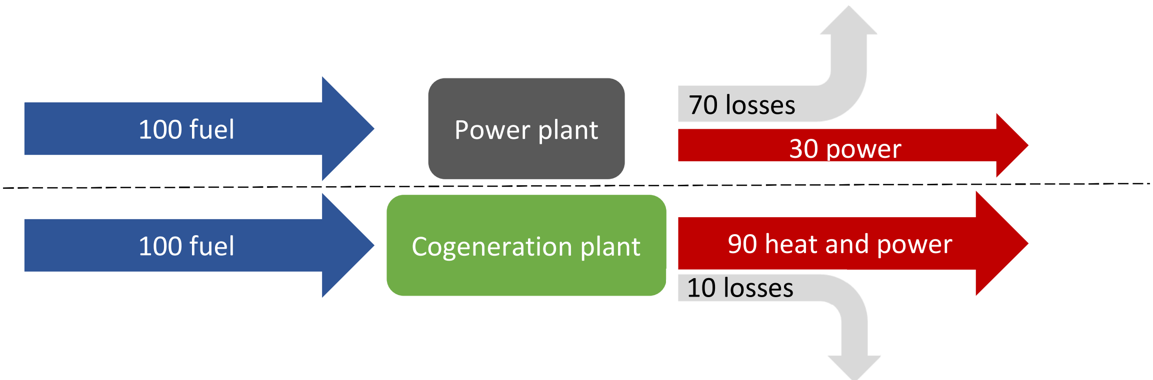
District Heating

District heating is the most widespread of the two types of district energy; heating and cooling. To transport heat efficiently, the district heating distribution infrastructure comprises a network of insulated pipes, delivering heat in the form of hot water, from the generation site to the end user. Networks can measure from a few hundred meters to covering entire large cities. End users range from residential buildings to offices and industrial facilities. The network's coverage can easily be extended by laying more pipes, often in combination of adding more points of generation.

Generation and fuels

Heat is usually generated in two types of plants. The basic one is a heat generation plant with a boiler that only generates heat. The second type is a cogeneration plant, often called combined heat and power plant (CHP). As it generates both heat and electricity, it benefits from considerable economies of scale. Upon generating electricity by incineration, the steam from the boiling water that drives the turbines is lead to also heat the water in the closed circuit district heating system. It can also be used as steam in industrial processes.

Figure 1: Energy efficiency in a cogeneration plant compared to a power-only plant (condensing plant)



Source: Fortum Värme

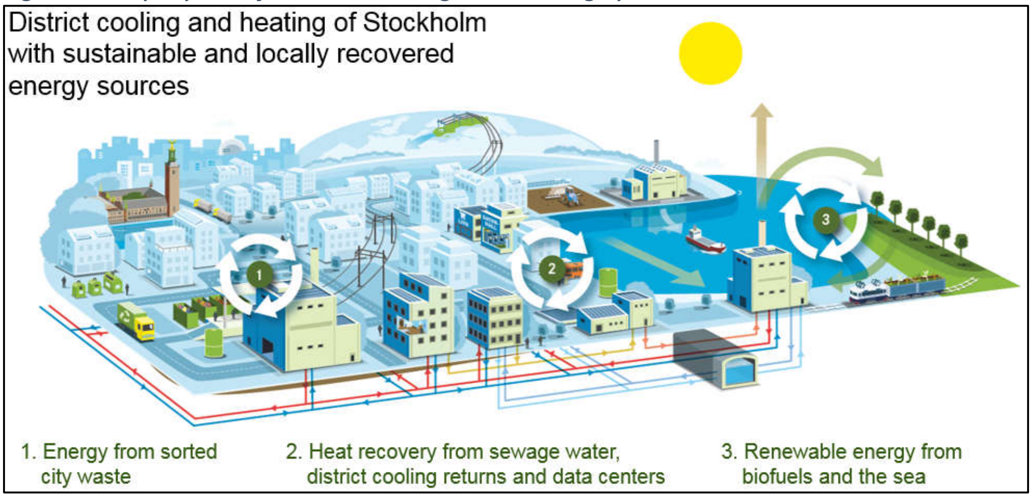
The energy generated in the Swedish district heating systems primarily comes from renewable or recycled fuels. The fuels mainly originate from residuals from the forest industry, household waste or residual heat and waste from industries. Other energy sources include: biomass and biogas, natural gas, fossil fuels, electric heat pumps or boilers, and solar or geothermal sources.

Power and heat generation companies, such as Fortum Värme, mix fuels and generation methods, depending on economic and environmental considerations. By not being dependent upon a specific fuel source, a reliable service is guaranteed and enables price competition in the supply chain.

Distribution infrastructure

After the heating process in the central plant, the hot water is transported through isolated pipes under high pressure and the water's temperature remains between 70 and 120 degrees Celsius (160-250°F), depending on the season and weather. Upon arrival, the building's heat exchanger uses the district heating system's hot water to heat its own water system for tap water and radiators in the building. Smart metering and control systems give customers the opportunity to adjust their own heat consumption.

Figure 2: City layout of district heating and cooling system



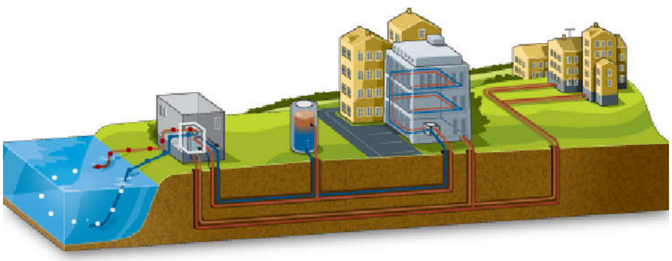
Source: Fortum Värme

Depending on local conditions and the dimensions, the costs for a distribution infrastructure, that fulfils operational security requirements, can vary between 200 and 1 300 USD per meter of piping. The industry is constantly working with quality assurance to prolong the life span as much as possible. Currently, a well-constructed district heating infrastructure can last up to 100 years.

District Cooling

The district cooling system in Stockholm was implemented on a larger scale during the 1990's. It is based on the same distribution principle as district heating, and can be generated by different fuel sources and techniques. Free water cooling is a common technique, using sea or lake water in order to cool the water in the system. Heat pumps, generating both heating and cooling, as well as cooling machines can also be used. Another way is to use the heat energy from the district heating in cooling sorption machines.

Figure 3: Layout of district cooling using free cooling with sea water



Source: Fortum Värme

The common denominator for the different techniques to generate district cooling are the minimal levels of energy consumption and the low impact on the environment, compared to cooling through building specific facilities. A central district cooling generation plant is run more efficiently, mainly based on sustainable energy sources, such as free cooling.

Fortum Värme and the Stockholm market

Fortum Värme generates more than 7 TWh of heat every year. The total production in the wider Stockholm area is around 12 TWh. The largest customer segment is residential buildings, constituting 35% of the revenues, followed by public buildings, industries and enterprises in the construction sector. Fortum Värme runs the largest district cooling network in Europe with a distributed cooling capacity of close to 350 MW. District cooling customers are mainly real estate stakeholders in need of comfort and process cooling to their hospitals, commercial malls, supermarkets and data centers. The district cooling business is growing as the need for process cooling is increasing. Lately, the main surge in demand has been from data centers and similar establishments.

Table 1: Fortum Värme generation data, 2015

	GWh	Renewable and sustainable energy (%)	Number of customers	Number of delivery contracts
District Heating	7 357	84%	>10 000	15 500
District Cooling	361	100%	300	650
Electricity from cogeneration plants and wind power	1 333	61%	NA	NA

Source: Fortum Värme

In Stockholm, the piping infrastructure measures 2 800 km for the district heating network and 250 km for the district cooling network. More than 80% of the buildings in Stockholm are heated with district heating. Fortum Värme's production system in Stockholm consists of 30 facilities with a total capacity of 3 900 MW for heating and 580 MW for electricity production. The electricity is sold over the public market Nordpool.

Figure 4: Fortum Värme in short

Fortum Värme in short

- Fortum is the largest supplier of district heating and cooling in the Nordic countries.
- Ownership structure of Fortum Värme in Stockholm: 50% City of Stockholm / 50% Fortum Power and Heat AB
- > 30 production facilities
- World's first offering combing cooling and heat recovery for data centers

To the right: Map of Stockholm area with Fortum Värme's district energy infrastructure.

Open District Heating©

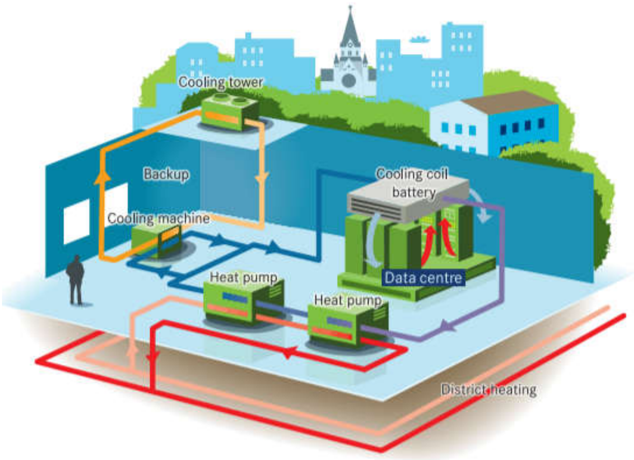
In 2014, Fortum Värme developed an initiative called Open District Heating© as a pioneering way to make the district heating system in Stockholm even more efficient and flexible. It enables the excess heat generated in third party facilities to be incorporated into Fortum Värme's district heating network. The aim is to achieve profitability, sustainability and efficiency for both suppliers and Fortum Värme, through long-term, transparent and competitive terms for trade in surplus heat and surplus capacity in heating and cooling systems.

In 2016, the Open District Heating© initiative enabled heating corresponding to 20 000 modern apartments (55 kWh/m^2, year).

The new business model for recovered energy was developed together with pilot suppliers such as Bahnhof, an Internet service provider with data centers. With Open District Heating©, the excess heat from data centers can be recovered using a heat pump that cools the data center and simultaneously supplies heat to the district heating network, offering a reliable cooling and efficient heat recovery at the same time.

The initiative Stockholm Data Parks is the next step, aiming to increase the presence of data centers in the Stockholm market, with a view to enabling even more excess heat to be recovered and used for residential heating.

Figure 5: Open District Heating© implemented as a cooling solution in a data center. The existing cooling system is used for redundancy



Source: Fortum Värme

Figure 6: Fortum Värme's bio cogeneration plant, KVV8

Europe's largest bio cogeneration plant is in Stockholm, Sweden

In May 2016, the new bio cogeneration plant in Stockholm was inaugurated by Fortum Värme, named KVV8. The plant is the biggest investment in the company history, 4.5 billion SEK (500 million USD). The plant plays a vital part in the effort to reach the objective to exclusively use 100% renewable and recycled energy by 2030. With KVV8, close to 90% of the district heating in Stockholm will be produced with renewable and reused energy.

In the cogeneration plant, the bio fuels will be transformed annually to 750 GWh of electricity and 1 700 GWh of heat. The fuel used in this plant is forest waste from Sweden, Norway, the Baltic countries and Russia.

With the plant fully operational, the CO_2 emissions in Stockholm are expected to decrease with 126 000 tonnes annually, equivalent to the amount that the road traffic in Stockholm emits in a month and a half. It is estimated that the CO_2 emissions in Europe will decrease with a total of 650 000 tonnes thanks to the plant, as the electricity produced in Stockholm, will replace electricity produced with fossil fuel in other parts in the Nordic countries and Europe.

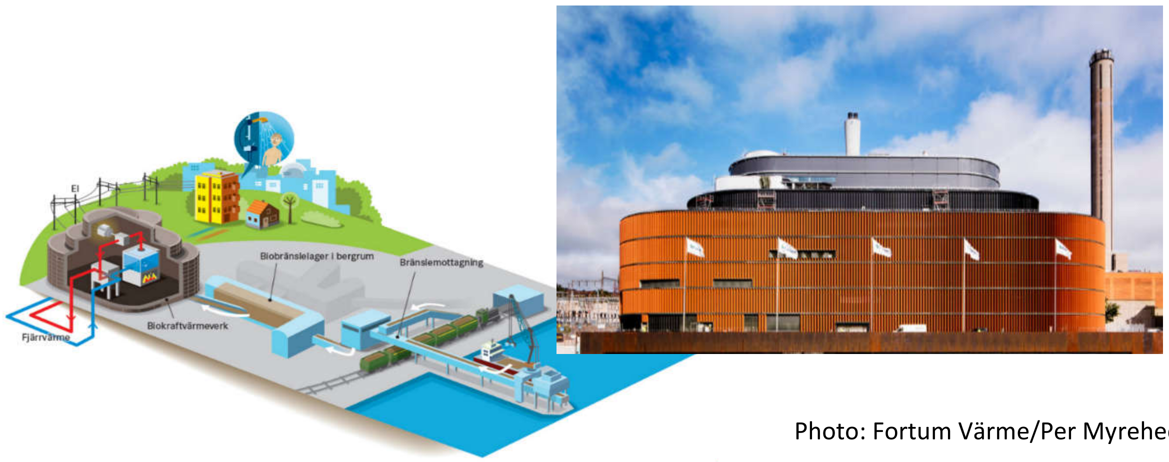


Photo: Fortum Värme/Per Myrehed

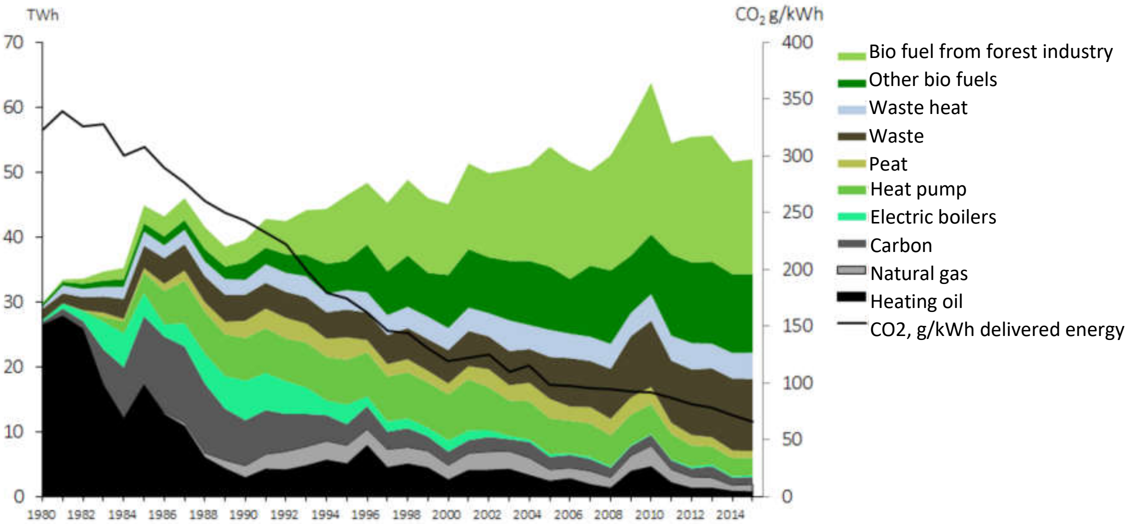
Environmental impact

The high level of sustainable solutions that Stockholm and Sweden generally keep in the heating sector is explained by the transition from oil based heating to a system based on renewable and recycled fuels and by use of combined heat and power plants. Almost 80% of the heat supplied to the Swedish district heating systems is generated from energy sources/fuels which would not otherwise have been used.

Overall, district energy is a very efficient solution to capture energy which would otherwise be wasted, and instead supply the energy to an end user. Compared to decentralized heating systems, a central plant benefits of scale and has better access to advanced technology to treat residuals, thus enabling a lower level of pollution and a better air quality in a city. The combined heat and power generation provided by Fortum Värme, contributes to lowering emissions with 25-40% in Stockholm.

In Sweden, only a very low amount of household waste ends up in landfills, thanks to elaborate policies and regulations, and to efficient recycling systems. The cogeneration plants are the most efficient way to use society's left overs and residues, that cannot be recycled in another way and which would otherwise be placed in a landfill.

Figure 7: Fuel use for district heating in Sweden, 1980-2015

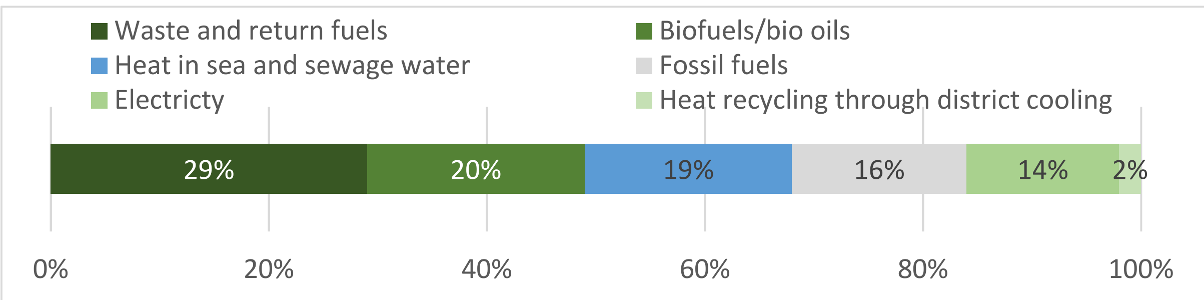


Source: Svensk Fjärrvärme

In the process to generate heat and electric energy, Fortum Värme often use bio fuels, such as wood chips, pellets, bio oils, olive pits and others. To ensure a sustainable purchase process, one of the requirements in the bidding process is that the material has been produced legally, thus having a known, traceable and sustainable origin. To have a sustainable origin implies the fulfillment and compliance with the EU directives on timber, the sustainable directive for biofuels, the Fortum Code of Conduct for suppliers, and the criteria of standard for RSPO, RTRS and/or Controlled Wood.

In Figure 8 below, Fortum Värme's fuel mix for the district heating production is shown for 2015. Half of the entire production comes from waste, residues and biofuels. The current share of fossil fuels at 16% is being phased out, increasingly so with the new plant KVV8, and at the latest by 2030 Fortum Värme's production will be entirely free from fossil fuels.

Figure 8: Fuels used in the production of district heating by Fortum Värme, Stockholm area, 2015



Source: Fortum Värme

Conclusion

District heating and cooling is an efficient way to heat and cool buildings and industrial facilities, and is an essential part of Stockholm's environmental ambitions to be a sustainable city, free of fossil fuels by 2040.

The Stockholm Data Parks initiative is about enabling data centers to reach the next level of efficiency and sustainability by providing data center cooling as a service and heat recovery, creating a win-win situation for the data centers, the residents of Stockholm and the environment. The collaboration between data centers and Stockholm's district energy system has the potential to play a key role in the transformation of the city's energy system, while making data centers truly green, even net climate positive.

Published in January, 2017.