Helsinki Energy Challenge

Background material – Heating system in Helsinki

Helsinki

energychallenge.hel.fi
www.hel.fi

Contents

Glossary

Abbreviation	Definition
CAGR	Compound annual growth rate
Capex	Capital expenditure
CCGT	Combined cycle gas turbine
CHP	Combined heat and power
CO_2	Carbon dioxide
COP	Coefficients of performance
DH	District heating
DHC	District heating and cooling
DSO	Distribution system operator
EED	Energy Efficiency Directive
EPBD	Energy performance of buildings
EU	European Union
EU ETS	EU Emissions Trading System
GHG	Greenhouse gas
GSHP	Ground source heat pump
GT HP	Geothermal heat pump
GWh	Gigawatt hours
HFO	Heavy fuel oil
HOB	Heat only boiler
km	Kilometre
kWh	Kilowatt hours
LCOE	Levelised cost of energy
LFO	Light fuel oil
LULUCF	Land Use, Land-Use Change, and Forestry
mm	Millimetre
MW	Megawatt
MWh	Megawatt hours
n. a.	Not available
Opex	Operational expenditure
RED	Renewable Energy Directive
RES	Renewable energy source
TWh	Terawatt hours
VAT	Value added tax
WACC	Weighted average cost of capital

Foreword

This background report has been prepared by Pöyry Management Consulting Oy to support the Helsinki Energy Challenge organised by the City of Helsinki. Helsinki Energy Challenge is a global challenge competition that seeks to answer the question: How can we decarbonise the heating of Helsinki, using as little biomass as possible?

Executive summary

Space and domestic hot water heating in Helsinki is currently mostly based on the district heating system. The heat production for the district heat system is based on several energy sources and fuels, but coal is one of the main sources. Due to Helsinki's aim of being carbon-neutral by 2035, as well as the banning of coal for energy production purposes in Finland from 2029 onwards, new solutions are needed to supply Helsinki's heat demand.

The volume of district heat demand in Helsinki is approximately 7 TWh, which is about 20% of the total district heat demand in Finland. Helsinki is located on the south coast of Finland, and the population of the city is concentrated in the coastal area. Due to the cold climate, heat demand is strongly correlated to weather, and the capacity needed to produce heat on cold winter days is substantial. The volume, variation, and the location of the heat demand means that it has been challenging to find a replacement for fossil fuels in Helsinki. Fossil fuels are mainly used in cogeneration of heat and electricity or in trigeneration of heating, cooling, and electricity. Current district heating production by unit type and fuel use in Helsinki is presented in Figure 1.

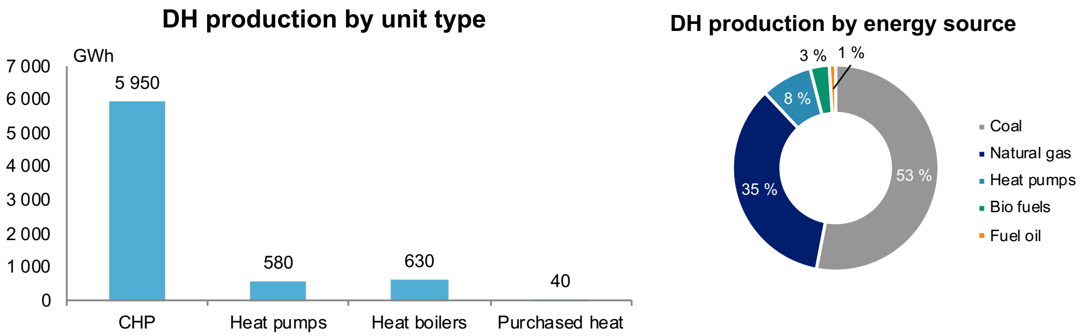
Helen, the owner and operator of the district heat system in Helsinki, needs to replace its coal plants by 2029 at the latest due to the phase-out of coal regulation. In 2018, Helen used some 6.5 TWh of coal, producing both heat and electricity from it. Helen plans on implementing the coal phase-out in two stages, where the first stage involves the closure of a coal CHP plant in Hanasaari by 2024 followed by the second stage where another coal CHP unit in Salmisaari is shut down or converted to other fuels by 2029. Coal phase-out results the loss of a total of 920 MW of heat production capacity and there is a need for a replacement of the capacity, particularly to ensure sufficient, reliable capacity during cold winter periods. In heat production terms, this amounts to some 3.5 TWh of heat.

Helen's current plan for the first stage of replacements comprises a new biomass heat-only boiler plant investment, increasing waste heat recovery and heat pump capacity, geothermal heat, locality-level heating solutions, as well as increased heat procurement from the adjacent district heating networks in Espoo and Vantaa.

In Finland, district heating business is not directly regulated and customers are free to select their own heating method and also switch away from district heating. On the other hand, the change of heating method can require investments.

In heating supply, there is an obligation to maintain high security of supply of heating during normal conditions as well as emer-

Figure 1 District heat production by unit type and energy source in Helsinki, 2018.



Source: Finnish Energy (2019), Helen website

gency conditions, which is also to be taken into account when considering new solutions. Furthermore, the time requirements of land use and permitting procedures need to be considered. All of these aspects set challenging prerequisites for new solutions for the replacement of coal in Helsinki.

1 Introduction

1.1 Background

Helsinki's goal is to be carbon-neutral by the year 2035. Currently, about 56% of Helsinki's carbon dioxide emissions originate from the production of energy used for heating. In order to reach the carbon-neutrality goal, Helsinki needs to reduce the emissions originating from the production of heat, in addition to other actions.

In the densely populated Helsinki, the main source of space heating and domestic hot water heating is district heating, with a share of around 92% of total heat demand. The total district heat demand in Helsinki is about 7 TWh, which is approximately 20% of the entire district heat demand in Finland. The location of Helsinki is presented in Figure 2.

In Helsinki, the city-owned energy company Helen is in charge of the production, distribution, and sale of district heat. In 2018, coal accounted for 53% of the district heat produced by Helen. Coal is used mainly in cogeneration of power and heat and in trigeneration, where power, heat, and cooling is produced in one process. The coal-fired power plants are located in Hanasaari and Salmisaari close the city centre. The shutdown of Hanasaari by 2024 has already been approved, and due to the Finnish government's decision to ban energy use of coal as of 2029, coal-based production in Salmisaari must also cease before 2029. The current indicative plan to replace coal indicates that a substantial part of current coal use would be replaced with biomass which could result in up to 1.5–3 TWh of biomass (incl. biomass pellets) being used in the production of heat in Helsinki in 2030. This corresponds to approximately 20% of all the biomass fractions used in the production of district heat in the whole Finland in 2018.

1.2 Heat demand and other natural circumstances in Helsinki

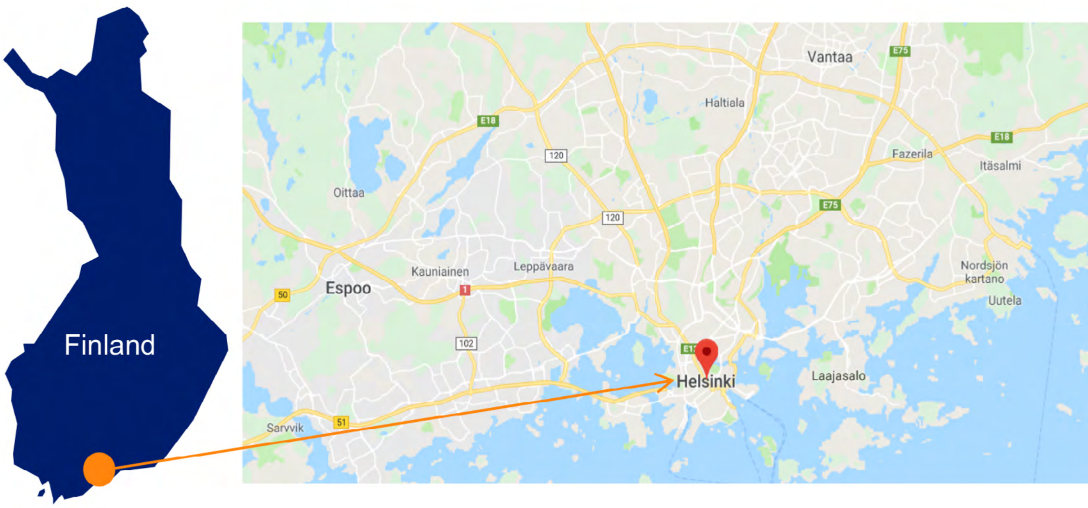
The northern location of Helsinki means that the temperature levels vary considerably and the heat demand is large in the winter months. Average temperature and precipitation information at Helsinki Kaisaniemi (central Helsinki) is presented in Figure 3.

Further temperature-related graphics can be found at the FMI webpage, with information on other factors such as typical maximum and minimum temperature range as well as typical Helsinki snow depth[1].

The heat demand can be measured in heating degree days, a measurement quantifying the demand for energy needed to heat a building. It is the number of degrees that a day's average temperature is below the temperature where buildings need to be heated (17°Celsius in Finnish measurement). On average, there were 3,878 heating degree days in Helsinki in the latest long-term reference period 1981–2010. Table 1 summarises average heating degree days in Helsinki for each month during the reference period. Annual heating degree days in the period of 2008–2018 are depicted in Figure 4. During this period, the heating degree days in the Helsinki area have been around 7% lower than the reference period average.

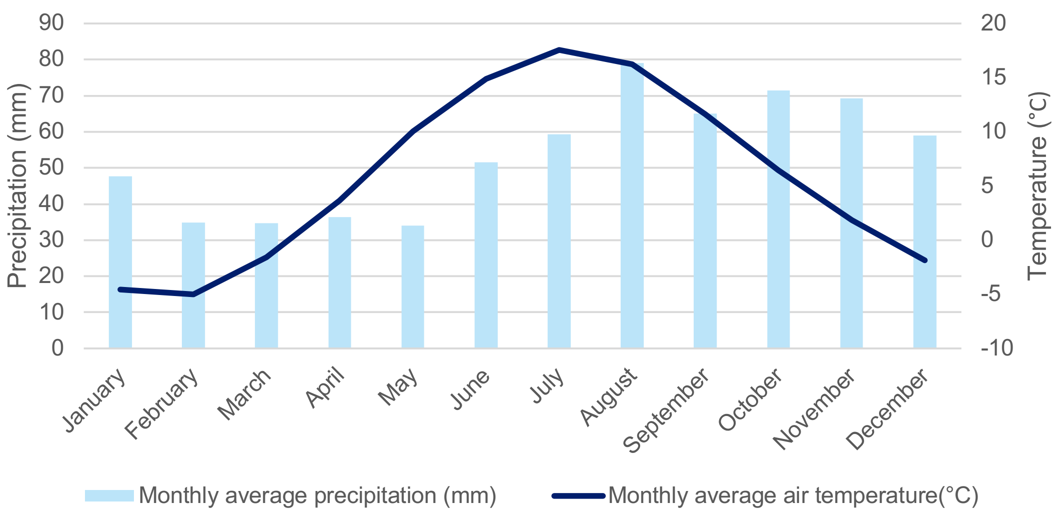
1 Finnish Meteorological Institute (FMI). Available at: https://en.ilmatieteenlaitos.fi/climate

Figure 2 Map of Finland and Helsinki.



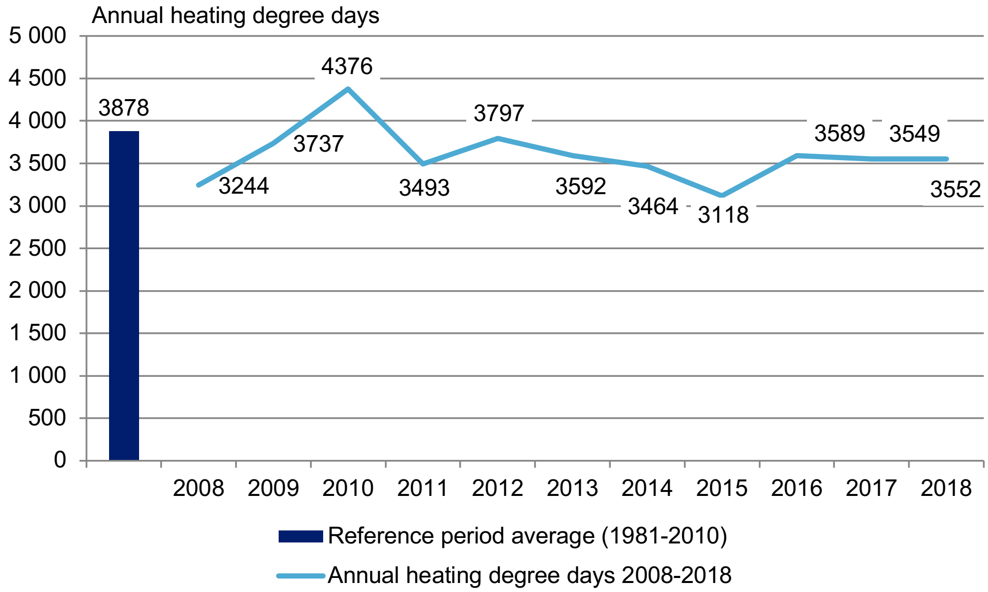
Source: Pöyry

Figure 3 Average precipitation and temperature information, 1960–2018, Helsinki Kaisaniemi measurement point.



Source: Finnish Meteorological Institute (FMI)

Figure 4 Annual heating degree days in Helsinki in the period of 2008–2018.



Source: FMI. More information and data regarding heating degree days in the 2010s can be found at: https://en.ilmatieteenlaitos.fi/heating-degree-days

Table 1 Monthly heating degree days in Helsinki, reference period 1981–2010.

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Helsinki	647	612	566	383	153	11	1	12	125	316	464	588

Source: Finnish Meteorological Institute (FMI).

2 Heat consumption characteristics

2.1 Total energy and heat consumption in Helsinki

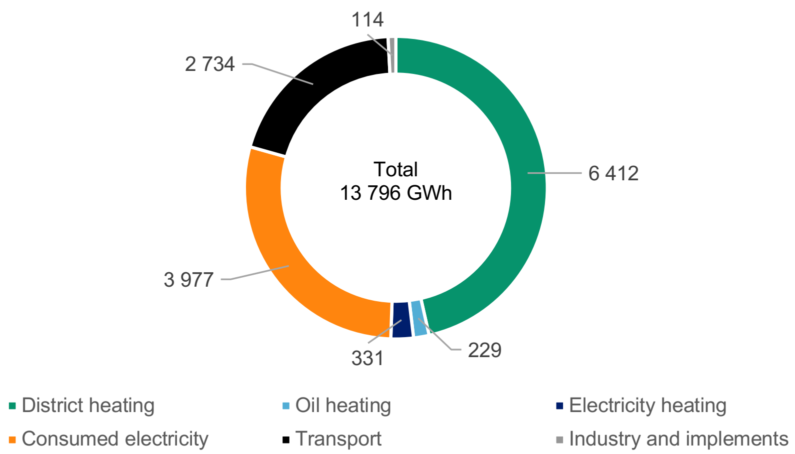
Heat consumption represents half (50.5%) of the total energy consumption in Helsinki and is in the range of ca. 7 TWh in a year. This corresponds to ca. 20% of Finland's heating demand. District heating, consumed electricity and transport represent 95% of the total energy consumption in Helsinki. The normalised energy consumption shares in Helsinki in 2017 are illustrated in more detail in Figure 5.

The annual demand of energy for heating has been normalised in the figure, as described in Section 1.2. In addition to the yearly differences, the heat consumption and need also varies significantly between months and within each day. These differences are described in more detail in Section 2.2.

The normalised total energy consumption in the city of Helsinki was ca. 13.8 TWh in 2017, where the heating consumption has been temperature-normalised by a rolling five-year average. In the same year, the actual measured energy consumption was slightly higher: ca. 14.0 TWh. The historical development of the heat demand in Helsinki is shown in Figure 6.

The share of district heating of the total heat consumption in Helsinki has been stable at around 92% during past decades. Oil and electric heating represent the remaining ca. 8% of the heat demand.

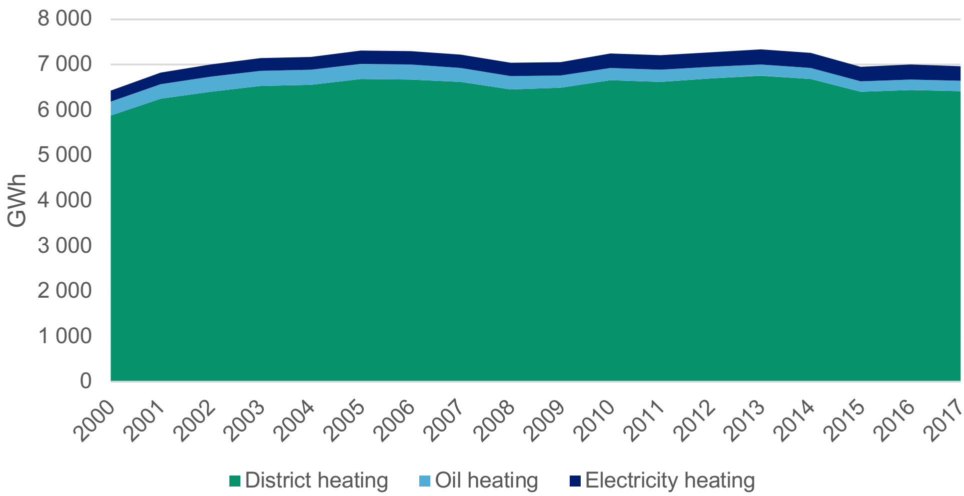
Figure 5 Total energy consumption in Helsinki, 2017, GWh.



*Normalised heat demand

Source: Helsinki Region Environmental Services Authority (HSY) at Helsinki Region Infoshare

Figure 6 Heat consumption development in Helsinki, 2000–2017, GWh.



Source: Helsinki Region Environmental Services Authority (HSY) at Helsinki Region Infoshare

Mainly due to city growth, the normalised heat demand in Helsinki has increased during 2000–2017 by a CAGR of 0.48%, which corresponds to 548 GWh. However, in the current decade (2010–2017), heat demand has started decreasing with a CAGR of −0.58% (245 GWh).

It can already be seen that the heat demand per citizen has decreased by 0.6 MWh in 17 years.

In the long term, it is expected that the total heat consumption will further decline mostly due to energy efficiency measures and the impact of climate change. The City of Helsinki has performed a study of the future of district heating in Helsinki. The study concludes that district heating demand will drop from 6,331 GWh in 2015 to 4,873–5,317 GWh in 2035[2]. The demand drivers and their impact on heat demand will be discussed in more detail in Section 2.3.

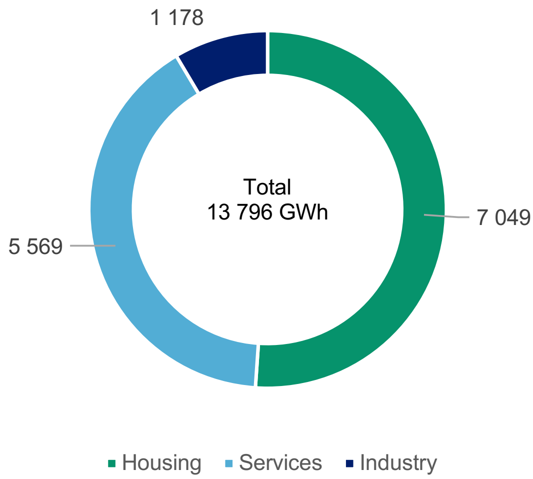
Considering the energy consumer groups in Helsinki as a whole, it is noted that housing and services covered almost 92% of the total energy consumption in 2017. The detailed numbers are presented in Figure 7.

Most of the energy consumption in Helsinki is utilised in the heating of buildings and providing electricity to housing, services, and industry. Space heating corresponds to ca. 70%, and hot water to ca. 15% of all energy use in an average building. This is the reason for looking more closely at the building sector in Helsinki in order to better understand the demand development for the heating sector. This is discussed in more detail in Section 2.3.

The consumption split of district heating by consumer type in Helsinki in 2017 is illustrated in Figure 8. It can be seen that the residential customer segment forms the largest demand, with a share of ca. 62%. Other sectors, which include different municipal buildings in e.g. health care and educational facilities, as well as other purposes such as offices and commercial buildings, represent ca. one third (34%) of the demand. Industry's share is ca. 4% of the total district heating demand.

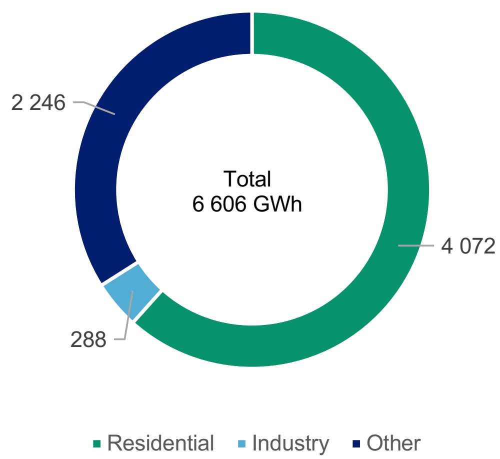
2 City of Helsinki (2018).The Carbon Neutral Action Plan. Available at: https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/julkaisut/HNH-2035/Carbon_neutral_Helsinki_Action_Plan_1503019_EN.pdf

Figure 7 Total energy consumption in Helsinki per sector, 2017, GWh.



Source: Helsinki Region Environmental Services Authority (HSY) at Helsinki Region Infoshare

Figure 8 Use of district heating by user type in 2017 in the district heating network in Helsinki.



Source: Finnish Energy (2018)

2.2 The annual profile of heat demand

Heat demand is strongly dependent on outdoor temperature and therefore demand has a systematic seasonal profile. Heat energy is primarily used for two purposes: space heating and hot water. Demand for space heating varies according to outdoor temperatures, while the demand for domestic hot water does not change appreciably due to weather variation. The heat demand during July is mostly attributable to domestic hot water. An example of the annual heat demand profile in Helsinki is depicted in Figure 9.

The typical average monthly heat load in the Helsinki network is presented in Figure 10 for each month of the year. It is evident that there is a significant variation in heat demand between seasons, thus requiring that the heat production fleet be able to maintain sufficient supply, especially during the cold winter months.

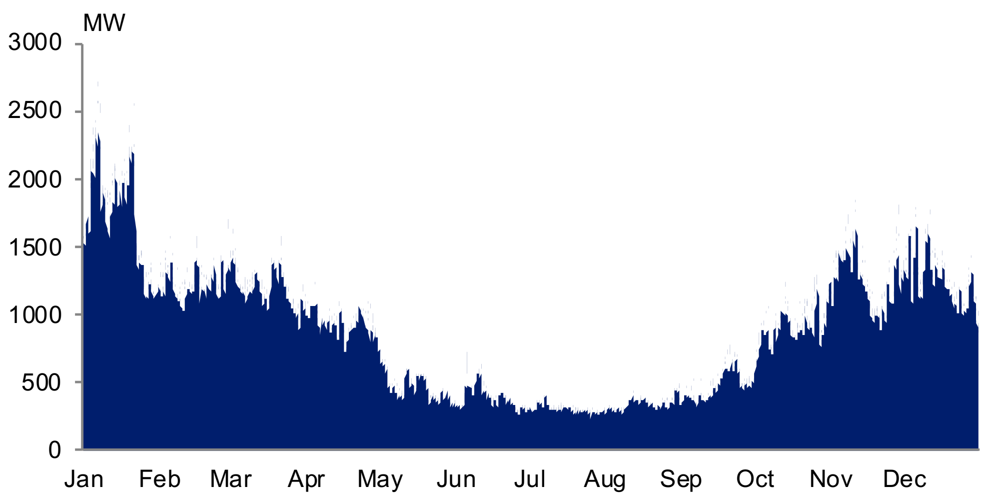
Heat demand also varies significantly within a month, due to variance in weather conditions. This is shown in Figure 11, where the typical range between the maximum and minimum heat load within each month is presented as a bar. The variance in heat demand is greater in the coldest months. This requires that the district heating production fleet be flexible enough that the production capacity is able to meet the heat load at every moment. As is typical for district heating systems, peak heat demand is currently met by separate peak load boilers in the Helsinki district heating network.

Heat demand in the Helsinki network also follows a somewhat systematic daily profile, which is a result of large consumer masses having similar consumption profiles. Figure 12 presents an example of hourly demand for heat for an average day in January. The daily profile has an increasing trend in the morning and declines in the evening. Consumption begins to increase at around 6 AM and is primarily a result of increased hot water consumption in the mornings as well as due to ventilation systems in offices and commercial buildings typically turning on a couple of hours before full occupancy. Similarly to the monthly variation, this requires that the district heating system be capable of changing heat supply levels in a flexible manner.

2.3 Heat consumption drivers and their impact on demand

Heat demand in Helsinki has been increasing due to the growth of the city, while at the same time improving energy efficiency is driving demand down. The main drivers for the future demand for heating include urbanisation and population development, energy efficiency, and climate change. These factors are discussed in more detail in Table 2.

Figure 9 Helsinki district heat demand profile in 2016 (MW).



Source: Helen, https://www.helen.fi/en/company/responsibility/current-topics/open-data

Figure 10 Average monthly heat load in Helsinki network in 2016 (MW).

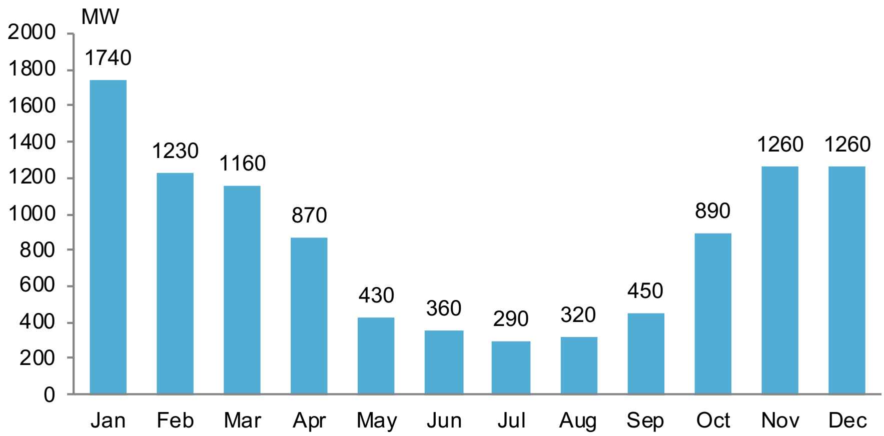


Figure 11 Range of maximum and minimum monthly heat load in 2016 (MW).

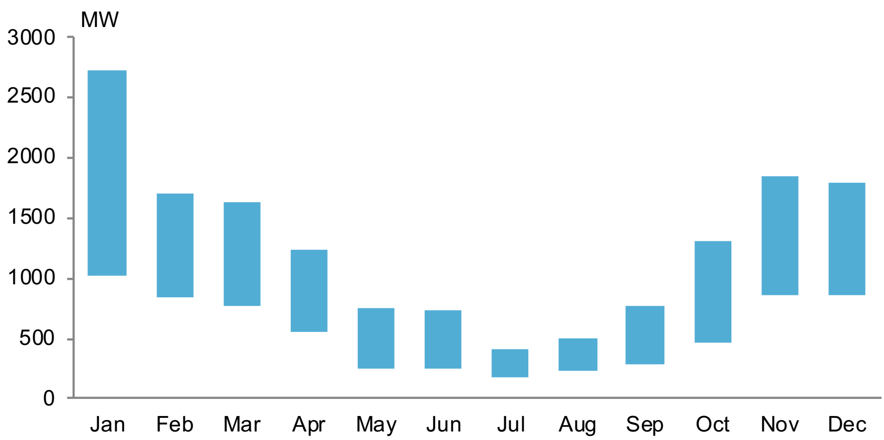
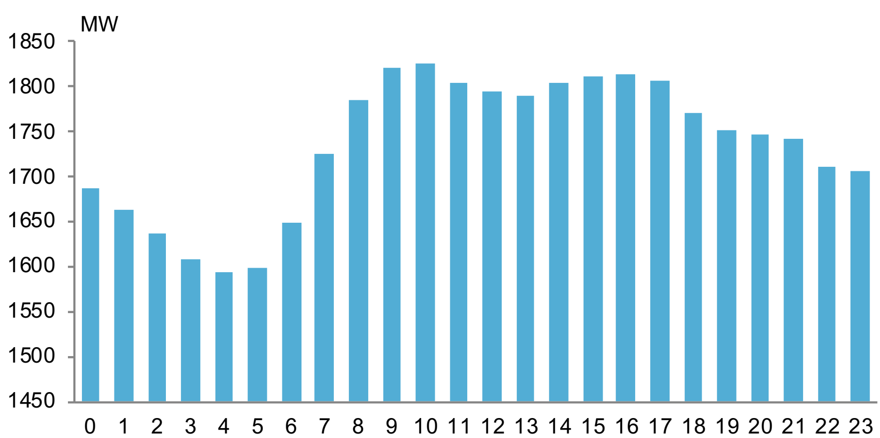


Figure 12 Average hourly heat demand in Helsinki DH network for a day in January (MW).



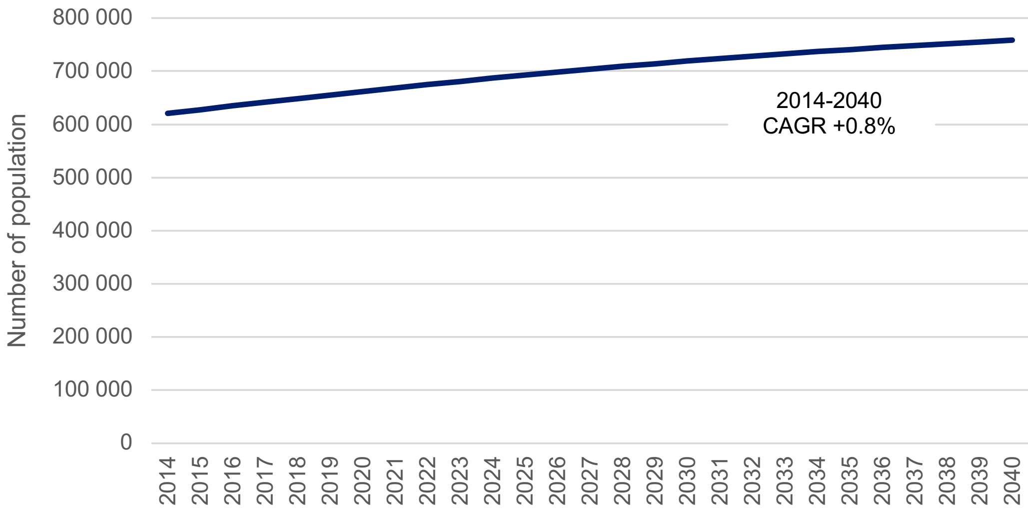
Source: Pöyry analysis, Helen, https://www.helen.fi/en/company/responsibility/current-topics/open-data

Table 2 Drivers impacting heat volume development in the long run.

Volume driver	Effect on demand	Description
Population development	↑	An increase in population will drive new building activity and heat volume demand. The capital region is expecting strong growth in the near and long term, which will impact heat demand.
Urbanisation	↑	Populations are moving from rural environments to towns and from towns to cities. It also increases the density of building stock. Helsinki and the capital region are one of the areas where urbanisation focuses.
Energy efficiency	↓	Energy efficiency is high on the agenda for the EU, and also for Finland. A number of policy measures have been integrated into the way buildings are planned, constructed, and renovated in order to meet energy efficiency targets. Although renovations are often not undertaken solely for energy efficiency reasons, gradually renovating the current building stock with more modern materials and solutions will improve energy efficiency. Building regulations also require energy efficiency improvements when major renovations are carried out. New buildings are built under more strict building codes and are more energy efficient than old buildings.
Climate change	↓	Ambient temperature is one of the main drivers of demand for heating, with cold winters increasing demand. Climate projections suggest that average temperatures will increase in the future resulting in lower heat demand.

Source: Pöyry analysis

Figure 13 Population development forecast, Helsinki.



Source: Statistics Finland

The population in Helsinki is growing, which has an increasing impact on the heat demand. The historical population development as well as the population development outlook is presented in Figure 13.

It is expected that the population of Helsinki will continue growing in the coming decades with a CAGR of 0.8% (2014–2040). In 2040, Statistics Finland estimates that the population of Helsinki will be ca. 759,000, which corresponds to ca. 22% increase in comparison to the 2014 level

Building activity especially reflects the urbanisation into city centres, where the district heating network is located. In Helsinki, the number of buildings has steadily risen during the past years. In 2017 there were 43,000 buildings in Helsinki (2013–2017 CAGR 0.84%)[3] with new buildings primarily being apartment buildings. Due to the expected population growth (Figure 13), a similar trend may be expected in the future.

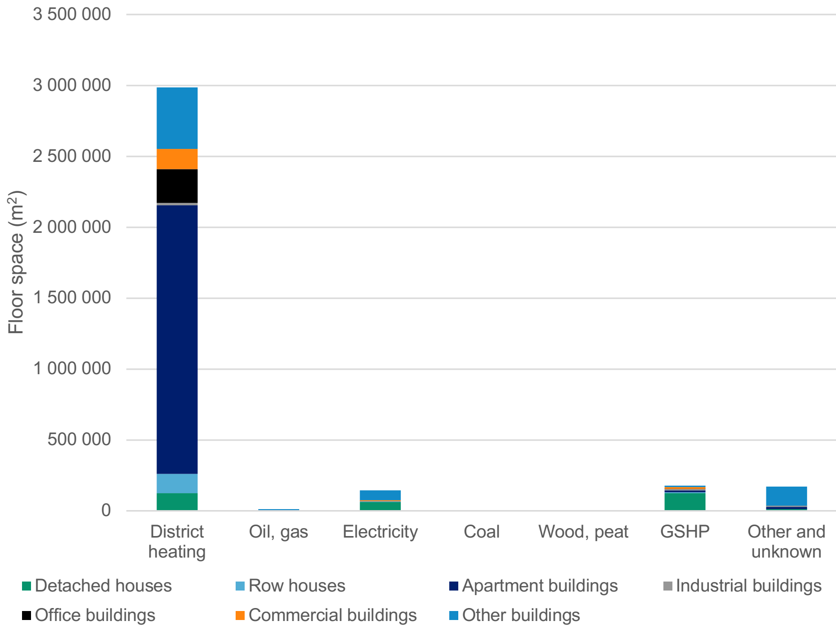
The number of new buildings built in the 2010s, by heating source and building purpose, is presented in Figure 14. It can clearly be seen that wood-, oil-, and gas-heating are almost non-existent in new buildings. Coal is not used in Finland directly in building-level boilers, but only as a fuel in district heating. Ground-source heat pumps (GSHP) are popular especially in the detached housing segment, whereas in apartment buildings district heating is the most popular heating solution.

New and existing building stock varies in its heat consumption characteristics; this is strongly driven by energy efficiency regulation, including national building codes as well as local renovation guidelines (Helsinki near-zero energy building code, HEnZEB). Energy efficiency impacts the existing building stock through renovations. New buildings are per se already more energy efficient due to better building material and techniques, for example in insulation. The age structure of buildings in Helsinki is illustrated in Figure 15. It can be seen that the older building stock is mostly located in the centre of Helsinki.

In addition, temperature is an important driver of heating volumes, and increasing outside temperatures in Finland is expected to have a negative impact on the heat demand. At the same time, demand for cooling may increase.

3 Statistics Finland. Paavo database based on postal code areas. Available at: https://www.stat.fi/tup/paavo/index_en.html

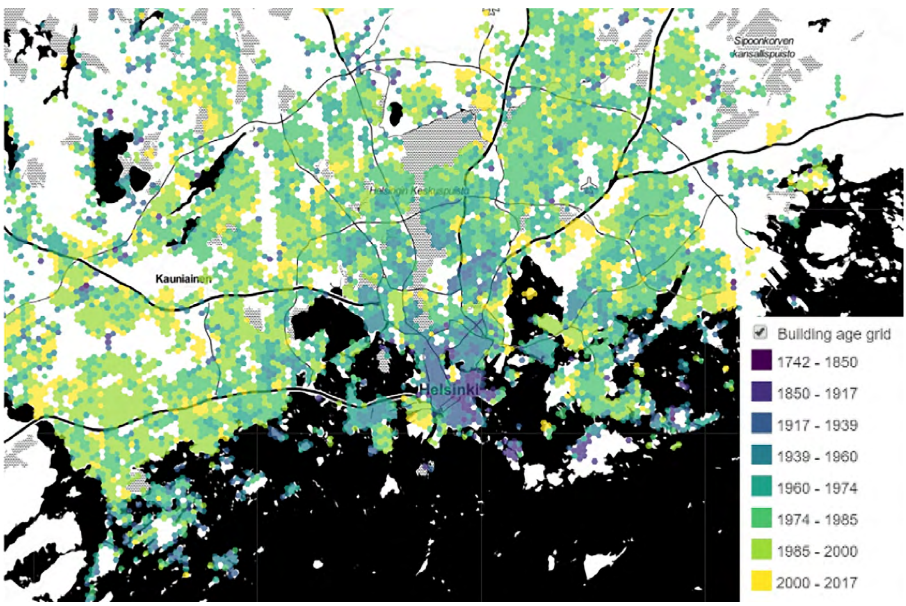
Figure 14 Floor space of new buildings in Helsinki from 2010 onwards, by heating source.



Note: other buildings include e.g. municipal buildings in education, fire department, and assembly functions, as well as other buildings such as warehouses

Source: Statistics Finland

Figure 15
Age structure of Helsinki buildings on a map.[1]



Note: the map also includes other capital region cities

Note: the map does not include very small buildings (smaller than 10 m²) or shelters, sheds, and other such building types without a building code

Source: Urban Environment Division; City Survey Services; at Helsinki Region Infoshare

1 More information about the Helsinki building stock, ownership etc. is compiled in city-maintained archives, registers and statistics available at: https://www.hel.fi/helsinki/en/housing/plots-land-buildings/building-stock

2.4 District heating customers

Customers are connected to district heating via heat exchangers which transfer heat from the network to building heating systems. Buildings typically have two heat exchangers: one for space heating i.e. serving the radiator network and one for domestic hot water.

Meters are used to measure the capacity requirement as well as heat consumption, based on district heating water flows and temperature differences. Remote metering is already the industry standard in district heating. In remote metering, the consumption information is collected centrally in a data system. New remote meters are usually hourly-based, but older meters may be based on daily or monthly consumption.

District heating customers are billed based on customer-specific heat consumption metering, but in many cases the end-users are not directly customers. For example in the case of apartment buildings, the housing company is the district heating customer instead of the individual inhabitants. Within a property, like an apartment building, heating costs are typically distributed based on the dwelling's square meters and dwelling-specific heat measurement is only rarely used in Finland.

Due to individual end-users not being directly district heating customers and lack of user-specific measurements, demand response is not yet widespread.

Private housing companies represent a large share of district heating customers, where building ownership is allocated to the dwelling owners. Changing heating solution, or other significant changes to the heating system, in such buildings requires the majority vote of shareholders.

3 Current district heating system in Helsinki

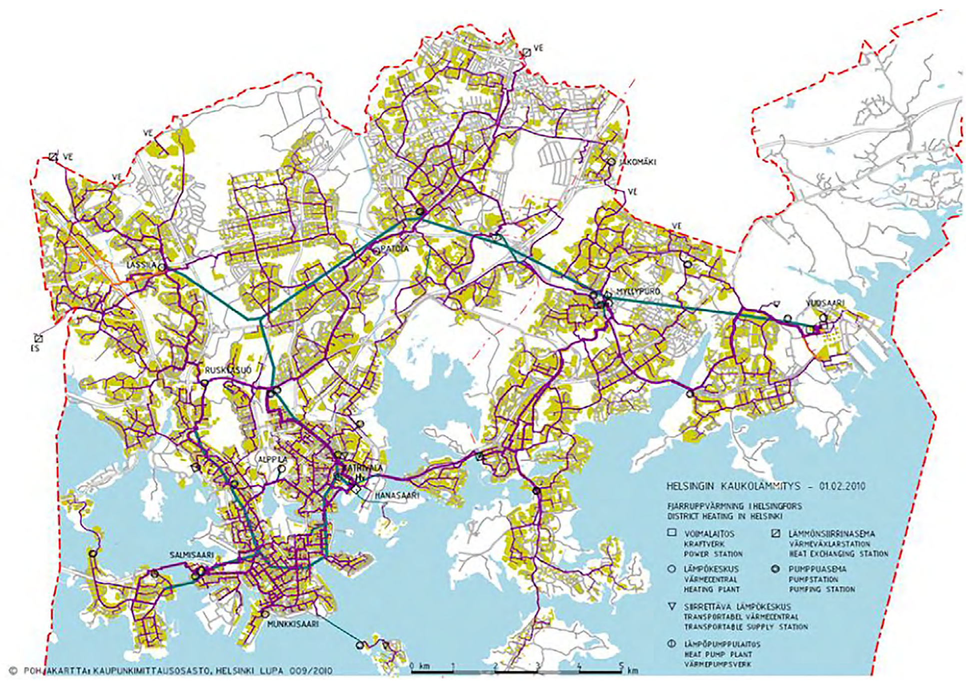
3.1 Principles of district heating system design

District heating systems are formed of the heat transfer network, heat production units, and the heat users with heat exchangers (described in the previous chapter). District heat production units are designed so that there is sufficient capacity available with reliable production to meet the heat demand all time, also during the coldest winter periods. In case of the Helsinki district heating network, the design temperature the system needs to meet is −26°C.

The current production system is designed so that each unit has its own role in the production mix and that there are no overlapping production units. In the summer time, the city-owned energy company Helen is able to produce large amount of the heat demand with heat pumps. On the other hand, during the winter period more expensive and in current situation, also more emission-intensive production is needed.

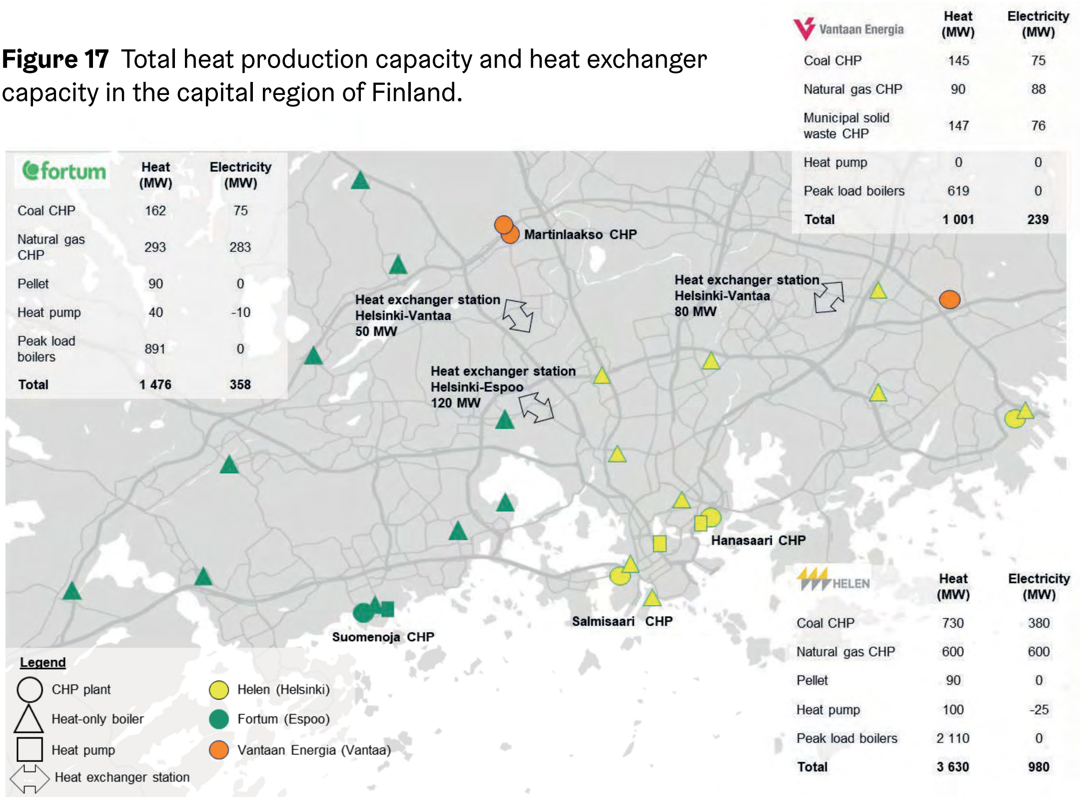
District heating company is obliged to deliver heat to its customers at all times based on their demand, and the production mix needs to ensure high security of supply.

Figure 16 Map of Helsinki district heating network.



Source: Helen

Figure 17 Total heat production capacity and heat exchanger capacity in the capital region of Finland.



Vantaan Energia	Heat (MW)	Electricity (MW)
Coal CHP	145	75
Natural gas CHP	90	88
Municipal solid waste CHP	147	76
Heat pump	0	0
Peak load boilers	619	0
Total	**1 001**	**239**

fortum	Heat (MW)	Electricity (MW)
Coal CHP	162	75
Natural gas CHP	293	283
Pellet	90	0
Heat pump	40	-10
Peak load boilers	891	0
Total	**1 476**	**358**

HELEN	Heat (MW)	Electricity (MW)
Coal CHP	730	380
Natural gas CHP	600	600
Pellet	90	0
Heat pump	100	-25
Peak load boilers	2 110	0
Total	**3 630**	**980**

Note: In Martinlaakso CHP plant (Vantaan Energia), a partial biomass conversion was performed in 2019, which is not reflected on the depicted production capacities.
Fortum's heating plant in Kirkkonummi is not depicted in the figure. Only base load production units have been illustrated from the Vantaan Energia district heating network.

Source: Pöyry analysis, based on Finnish Energy (2018) and Helen website

The district heating network is designed to ensure efficient heat distribution throughout the network and to minimise distribution bottle-necks. The location of production units within the network impacts the network construction.

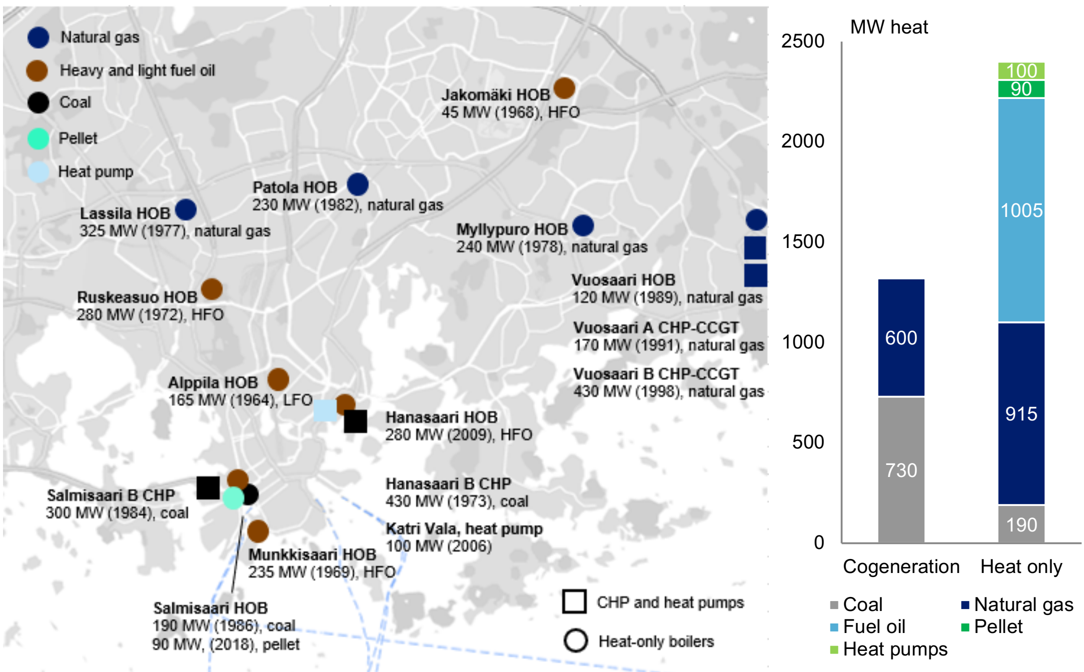
3.2 District heating network in Helsinki

The construction of the Helsinki district heating network started in the 1950s, and larger properties like housing companies and apartment buildings are connected to the district heating network.

The Helsinki district heating network has about 1,400 km of pipeline and covers the entire Helsinki region (Figure 16). The total volume of the network is some 130,000 m³ and comprises two network areas that operate at different pressure levels. The two network areas are the main network, covering the densely populated city centre area, and the Eastern network that is located in the region of Eastern Helsinki. The pressure levels for the main and Eastern network are ca. 6 and 8 bar, respectively. The Vuosaari plant is used to maintain the pressure in the eastern network, while the Salmisaari and Hanasaari plants maintain the pressure in the main network.

The district heating network operates at temperature levels in the range of 80–115°C on the supply side and 40–60°C on the return side. Temperature levels vary between seasons and according to heat demand. High temperature levels in the supply side are needed in the winter to ensure that all heat demand is covered, while lower temperature levels are sufficient during the summer sea-

Figure 18 Heat production units and capacities in Helsinki DH network.



Source: Pöyry analysis, based on Finnish Energy (2018) and Helen website

son. The temperature level of the network is primarily defined by the requirements and dimensioning of customer heating systems. Building stock in Helsinki can be characterised as rather old where heating systems require high supply temperatures. Consequently, heating systems in new buildings are dimensioned to the prevailing network temperature levels. High supply temperature is also required due to heat losses in the large network where heat is distributed long distances. According to Helen, the company has been able to lower the network mean temperatures and is looking into further possibilities for achieving lower temperature levels.[4]

Heat demand is greater in the densely populated city centre area than the eastern part of the network. Currently a large district heat tunnel is used to deliver heat from the Vuosaari B plant to the main network.

Helsinki is located in the capital area of Finland with Espoo and Vantaa as its neighbouring cities (see Figure 17). Both Espoo and Vantaa have their own district heating networks with total heat production capacities of 1,500 MW and 1,000 MW, respectively. The district heating system in Espoo is operated by Fortum, and the Vantaa district heating system by Vantaan Energia. The district heat production capacity of Vantaa includes also a waste-to-energy plant, which utilises mixed waste from Helsinki region and the Uusimaa province as a fuel for heat and electricity production.

These heat networks are connected to the Helsinki district heat network through heat exchanger stations. The heat exchanger station between Helsinki and Espoo is located in Northwest Helsinki, and has a capacity of 120 MW. The heat exchanger stations

4 Helen website, available in Finnish: https://www.helen.fi/yritys/vastuullisuus/ajankohtaista/blogi/2018/lampomarkkinat

between Helsinki and Vantaa are located in Northwest and Northeast Helsinki, and have capacities of 50 MW and 80 MW, respectively.

The heat exchangers enable utilising heat production from another network as an additional heat source in the Helsinki district heating network, and selling excess heat to other networks.

3.3 Current production capacity in Helsinki

District heat production in the Helsinki network is primarily based on coal- and gas-fuelled cogeneration (CHP) and supported by a fleet of smaller heat-only production units. The system is founded on two coal CHP plants located in Salmisaari and Hanasaari and two gas CHP plants in Vuosaari, amounting to a total district heating capacity of 1,330 MW. These CHP plants are operated as base load units to cover the majority of the annual heat demand in the Helsinki network. In addition, the DH system includes a new pellet boiler in Salmisaari, heat pump installations in Katri Vala, and various coal-, gas-, and oil-fuelled heat boilers utilised for peak load supply and as back-up capacity. Heat-only production units amount to 2,500 MW of total district heating capacity.

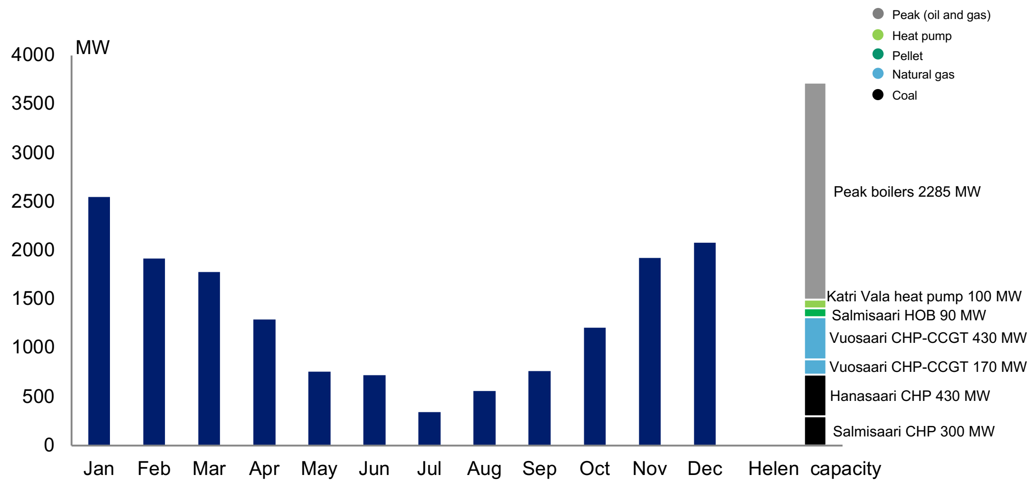
The production fleet is spread throughout the Helsinki region, with a focus on the central city area and the Vuosaari plant (Figure 18). Peak load boilers are located within a further radius of the city centre, as they are

Table 3 Summary of heat production units in Helsinki network.

Unit	Unit type	Main fuel	Commissioning year	Heat capacity (MW)
CHP units				
Salmisaari B	CHP	Coal	1984	300
Hanasaari B	CHP	Coal	1974	430
Vuosaari A	CHP – CCGT	Natural gas	1991	170
Vuosaari B	CHP – CCGT	Natural gas	1998	430
Heat boilers				
Salmisaari	HOB	Pellet	2018	90
Salmisaari	HOB	Coal	1986	190
Hanasaari	HOB	Heavy fuel oil	2009	280
Vuosaari	HOB	Natural gas	1989	120
Alppila	HOB	Light fuel oil	1964	165
Munkkisaari	HOB	Heavy fuel oil	1969	235
Ruskeasuo	HOB	Heavy fuel oil	1972	280
Lassila	HOB	Natural gas	1977	325
Patola	HOB	Natural gas	1982	230
Jakomäki	HOB	Heavy fuel oil	1968	45
Myllypuro	HOB	Natural gas	1978	240
Katri Vala	Heat pump	-	2006	100
Total heat capacity				**3,630**

Source: Pöyry analysis, based on Finnish Energy (2018) and Helen website

Figure 19 Heat production capacities and monthly peak loads in Helsinki.



Source: Pöyry analysis, based on Finnish Energy (2018) and Helen website

often required to compensate for the temperature losses in supply water distributed from the main heating sources in city centre.

A summary of the Helsinki DH network heat production units is presented in Table 3.

The total production system capacity of the Helsinki production fleet in comparison to monthly peak heat demand is presented in Figure 19. Coal-fired units Salmisaari B, Hanasaari A, and gas-fired units Vuosaari A and B cover most of the heat demand during the winter season. It is evident that the phasing out of coal-fired capacity in Hanasaari B and Salmisaari B units leaves a significant gap in heat production capacity that needs to be replaced.

CHP plants and heat-only boilers in Helsinki

Hanasaari. The Hanasaari site is located on the city centre coast and comprises the Hanasaari B CHP plant and a separate heat centre used for peak capacity. Hanasaari B is a back-pressure CHP plant that consists of two identical units, each having their own boilers and turbines. The plant was commissioned in 1974 and has 430 MW of heat capacity and 220 MW of power capacity in total. The plant uses coal as its main fuel, into which small shares of biomass pellets are blended. Helen has taken the decision to shut down the plant by 2024[5]. Currently, the plant is operated year-round with the exception of a maintenance break during the summer season. The heat centre in the Hanasaari site includes 6 fuel oil boilers which constitute a total district heating capacity of 280 MW[6].

Salmisaari. Salmisaari is located on the coastline of Helsinki city centre, and the main production asset of the site is the Salmisaari B CHP plant. Salmisaari B is a back-pressure CHP plant with 300 MW of district heating capacity and 160 MW of power production capacity. It uses coal and a small share of biomass pellets as fuel sources. The unit was

5 Helen website. Available at: https://www.helen.fi/en/company/energy/energy-production/power-plants/hanasaari-power-plant

6 Helen website. Available in Finnish at: https://www.helen.fi/globalassets/helen-oy/tietoa-yrityksesta/energiantuotanto/turvallisuustiedote-hanasaari.pdf

commissioned in 1984 and has approximately 10 years of its technical lifetime left[7].

According to company management interviews[8], Helen has made considerable investments in recent years in the modernisation of the plant in order to prolong its technical lifetime. Thus the plant would most probably have techno-economical lifetime remaining when the ban of coal use in energy production comes into effect in Finland in May 2029. The current boiler has a technical limit of a maximum share of 5–10% of pellet mixed with coal, and would require considerable investments to convert the plant to utilise other fuel sources[8].

The Salmisaari CHP unit is currently operated almost throughout the year. During the summer season when district heat demand is low, the excess heat produced in the plant is utilised in the production of district cooling via an absorption cooling unit instead of directing this heat to sea water[8]. This production process is also known as trigeneration, where heat generated in CHP production is used to generate district cooling.

The Salmisaari site also includes a 190 MW coal boiler (Salmisaari A, commissioned in 1986), and a new 90 MW pellet boiler (commissioned in 2018). Salmisaari A has seen low utilisation in the recent years due to the high cost of utilising coal in heat only production. Furthermore, the boiler will be reaching the end of its technical lifetime in the late 2020's. The new pellet boiler started operation in 2018 and is primarily used to replace the use of oil and gas in peak load demand.

Vuosaari. The Vuosaari production site is located 15 km northeast of the Helsinki city centre and includes two gas-fired CHP plants, Vuosaari A and B, as well as one heat-only plant for back-up and peak load capacity. Vuosaari A started operation in 1991 and has 170 MW of heating capacity and 150 MW of power production capacity. Vuosaari B was commissioned in 1998 and is considerably larger than the A-unit, having 430 MW of heat and 450 MW of power capacity.

Both units are CCGT (combined cycle gas turbine) plants and each comprises two gas turbine units which feed steam though one steam turbine. The main fuel of both plants is natural gas. The units are equipped with auxiliary cooling, meaning that the units can maintain electricity production, even at instances of lower DH demand, by using sea water to cool the steam. However, the units are primarily operated in combined heat and power production. The site also includes a heat-only plant, comprising three 40 MW boilers that use natural gas as main fuel source. This back-up plant was commissioned in 1989.

The merit order, i.e. the order in which the plants are operated when not all capacity is needed, is based on market conditions. In recent years the Vuosaari CHP units have often been positioned after the Salmisaari and Hanasaari coal CHP units in the merit order due to market conditions i.e. fuel and electricity wholesale prices as well as fuel taxation and CO_2 prices[9].

The CCGT units have higher power-to-heat ratios and therefore produce more electricity per one unit of heat produced compared to Salmisaari and Hanasaari coal CHP plants. Thus as the electricity market prices have been relatively low in the recent years, the Vuosaari units have been used to mainly complement Hanasaari and Salmisaari when their capacity does not cover the entire heat demand or when electricity prices are high enough.

7 Pöyry (2018). Kivihiilen kieltotyö. Available in Finnish at:https://tem.fi/documents/1410877/2132296/Selvitys_++Kivihiilen+kielt%C3%A4misen+vaikutukset/8fb510b4-cfa3-4d9f-a787-0a8a4ba23b5f/Selvitys_++Kivihiilen+kielt%C3%A4misen+vaikutukset.pdf

8 Helen website. Available in Finnish at: https://www.helen.fi/globalassets/helen-oy/tietoa-yrityksesta/energiantuotanto/salmisaari_turvallisuustiedote_2017.pdf

9 Pöyry analysis, based on operational data from Finnish Energy (2018)

Characteristic to CCGT technology is that the units have fast ramp-up times and such plants are more flexible to operate compared to coal CHP units. Flexibility in this context refers to the ability to operate the units at varying output levels. The ramp-up time for Vuosaari A when cold started is approximately 6.5 hours[10].

Other heat boiler sites. In addition to the key sites, the Helsinki district heating network includes heating plants in Alppila, Jakomäki, Lassila, Myllypuro, Munkkisaari, Patola, and Ruskeasuo. These sites are peak load and back-up boilers used in extreme weather conditions, during maintenance of base load units, and function as back-up capacity in case of malfunctions. These boilers use fuel oil and natural gas as main fuel sources.

Heat storage capacity

Heat accumulators in district heating networks are typically large storage tanks for hot water, which are charged when there is excess supply compared to demand and similarly dispatched when the heat production capacity that is online does not cover the entire demand. Therefore heat accumulators provide flexibility to the district heating system and allow more economical and environmentally-friendly district heating production, as storage units are typically dispatched to avoid the start-up of peak load boilers.

There are currently two heat accumulators installed in the Helsinki district heating system, which are located at the Salmisaari and Vuosaari production sites. The two accumulators are approximately of the same size and have a combined storage capacity of ca. 2,250 MWh of heat, and each have 100 MW of heat dispatch capacity.

In addition to existing storage capacity, Helen has ongoing projects for two additional heat storage units to be placed in Mustikkamaa and Kruunuvuorenranta. A summary of existing and planned heat storage capacity in Helsinki DH network is outlined in Table 4.

Current utilisation of waste and surplus heat sources

Waste and surplus heat is utilised in the Helsinki district heating system via heat

10 Nurmi, K. (2014). Flexible operation of CCGT plant in cogeneration. Available in Finnish at:http://urn.fi/URN:NBN:fi:aalto-201412233301

Table 4 Existing and planned heat storage capacity in Helsinki DH network.

Storage unit	Storage volume (m^3)	Storage capacity (MWh)	Dispatch capacity (MW)	Charging temperature (°C)	Commissioning year
Vuosaari	25,000	1,250	100	90	1998
Salmisaari	20,000	1,000	100	90	1987
Mustikkamaa	320,000	11,600	120	90	2021
Kruunuvuorenranta	300,000	4,500	1,5	18	n. a.

Source: Helen website. Available in Finnish at:https://www.helen.fi/yritys/vastuullisuus/ajankohtaista/blogi/2019/postkivihiili pumps and leveraging the combined heating and cooling network infrastructure. Currently approximately 10% of all DH supply in Helsinki network is based on waste heat utilisation. Sources of waste heat include excess heat from buildings, businesses such as data centres, and sewage water; this waste heat is then re-used in the production of district heating.

The most notable sites for waste heat utilisation are Katri Vala heat pump station and Esplanadi cooling plant.

Katri Vala heat pump station. Katri Vala heating and cooling plant was commissioned in 2006 and is the world's largest heat pump station with 100 MW of heating and 60 MW of cooling capacity[11]. The plant is located under the Katri Vala park in Sörnäinen, which is adjacent to the Hanasaari power plant site.

Katri Vala plant utilises heat recovered from the return water from the district cooling network and wastewater. As the district cooling water returns to the heat pump station, it recovers the heat acquired from cooling customers and transfers it to the district heating network by using the plant's heat pumps. This combined with the waste heat from sewage water is used for district heating.

Currently the plant is used for base load but it potentially also adds flexibility to the Helsinki district heating system. The plant currently comprises 5 heat pumps which can be operated independently. During the coldest ambient temperatures, the district heating produced in Katri Vala is primed with heat from Hanasaari site to reach the required supply temperature of 115°C.[12]

Esplanadi cooling plant. The Esplanadi cooling plant has two heat pumps that produce both heating and cooling. The plant is located 50 meters below the Esplanadi Park in the centre of Helsinki. The plant also includes 25,000 m^3 cold water storage. Esplanadi station uses heat pumps to recover heat from district cooling return water and has 20 MW of heating capacity, and a total of 50 MW of cooling capacity when including the discharge capacity of cold storage. The heat pumps started operation in 2018[13].

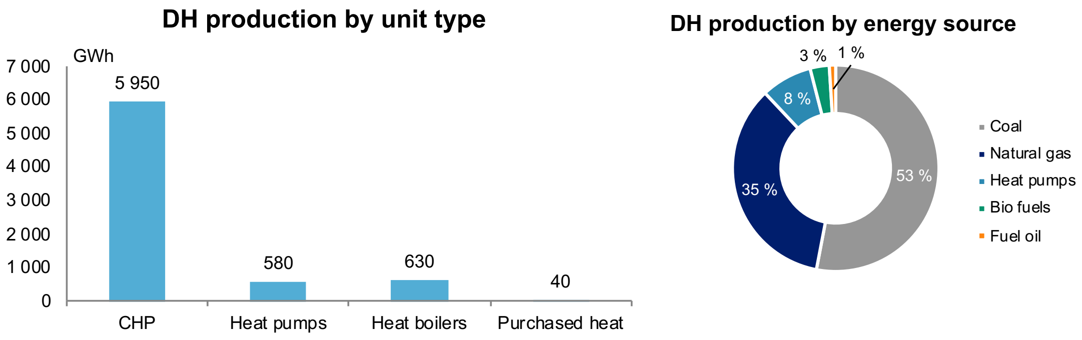
Open district heating. Helen has recently launched a new pricing model for purchasing waste and surplus heat from its district heating customers. This model is based on a voluntary agreement, where Helen commits to purchasing all excess heat but does not obligate the customer to sell. The producer is compensated for the supplied heat by a seasonal tariff structure, which is based on Helen's production costs and total demand for district heating, thus valuing excess heat during heating season over the cooling season.

11 Helen website. Available at: https://www.helen.fi/en/company/energy/energy-production/power-plants/katri-vala-heating-and-cooling-plant

12 Valor Partners (2016). Large Heat Pumps in District Heating Systems. Available in Finnish at: https://energia.fi/files/993/Suuret_lampopumput_kaukolampojarjestelmassa_Loppuraportti_290816_paivitetty.pdf

13 Helen website. Available at: https://www.helen.fi/en/news/2018/underground-heating-and-cooling-plant-utilises-waste-heat

Figure 20 District heat production by unit type and energy source in Helsinki, 2018.



Source: Finnish Energy (2019), Helen website

Heat generation in Helsinki with current production units

Heat generation is mostly based on cogeneration in Salmisaari, Hanasaari, and Vuosaari. The share of CHP generation was 85% of all heat production in 2018 (Figure 20). The Hanasaari and Salmisaari coal CHP units are operated the most. Heat pumps accounted for approximately 580 GWh of heat generation and heat procurement from adjacent district heating networks (Espoo and/or Vantaa) accounted for 40 GWh. The remainder of the heat was produced with heat-only boilers.

Coal and natural gas are the main fuels of the CHP units and therefore compose the majority of the total fuel consumption. In 2017 the Helsinki district heating system fuel usage comprised: coal approximately 7,500 GWh (60%), natural gas 4,500 GWh (36%), and pellet, fuel oil, and electricity 550 GWh (4%).

The Katri Vala heat pump plant produced approximately 8% of all district heating in Helsinki and 70–75% of district cooling in 2017. According to Helen[14], Katri Vala station can produce the majority of the heat demand of the city centre during the summer season, when the district cooling demand is the highest. During the period of peak cooling demand, about 50% of Helsinki district heat demand is produced with heat pumps. However, during cold winter weather this share is 5%, which is mostly recovered from wastewater[15].

Current investment plans to replace coal in Helsinki

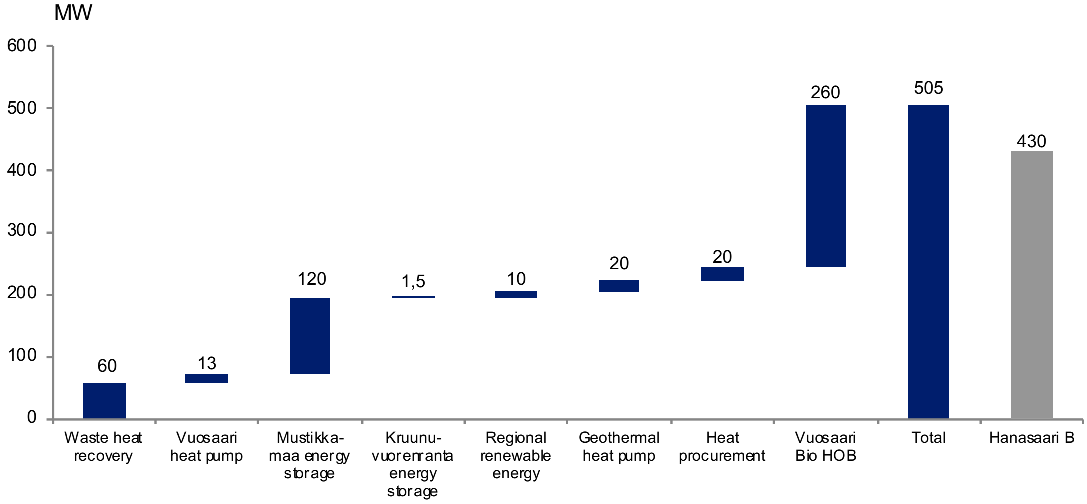
Helen plans on implementing the coal phase-out in two stages, where the first stage involves the closure of the Hanasaari coal CHP by 2024, followed by the second stage where the Salmisaari coal CHP unit is shut down or converted to other fuels by 2029. Helen has been evaluating options for replacement and it is likely that the replacement solution will be a combination of different technologies and heat sources.

Helen's current plan for the first stage of replacements consists of a new biomass heat-only boiler (HOB) plant investment, increasing waste heat recovery and heat pump capacity, geothermal heat, locality-level heating solutions, as well as increased heat procurement from the adjacent district heating networks in Espoo and Vantaa. In addition, the Mustikkamaa heat storage unit adds flexibility to the system. A summary of Helen's replacement plan for Hanasaari coal

14 Helen website. Available at: https://www.helen.fi/en/news/2018/newheatpump

15 Yle. Available in Finnish at: https://yle.fi/uutiset/3-9843548

Figure 21 Helen's indicative plan to replace Hanasaari B by 2024 in capacity terms.



Source: Pöyry analysis, based on Helen website

CHP is presented in Figure 21, presenting the estimated capacity impact of each solution.

Heat production plants in Helen's indicative investment plan. Helen is preparing for future production unit investments with area reservations. According to the current plans, the most likely locations for potential future production assets are in Vuosaari, Tattarisuo, and Patola. Biomass (or pellet) HOBs have been in the discussion as a potential production technology but the final investment decision is ultimately based on selecting most technologically and economically suitable alternative for the sites at the time of the decision.[16]

Helen has proceeded with initial investment plan by announcing the construction of a new biomass HOB in the premises of the current Vuosaari power plant. Vuosaari biomass HOB will have 260 MW of district heating capacity and is planned to become operational during the 2022–2023 heating season. Construction works are set to begin in spring 2020.[17]

Helen has been preparing also an investment at the Patola site next to the existing heat plant. According to the current indicative plan, the production unit would be a new pellet boiler with a fuel capacity of 120 MW equipped with a flue gas condenser. No investment decision has been made, but the plant has been granted environmental permits.[18]

An investment at Tattarisuo site with a production capacity of 130 MW boiler has also been planned. According to the current indicative plan, the production unit would be a biomass boiler or a co-firing biomass and waste plant. The zoning process of the plant has not yet started.[19]

16 Helen website. Available at: https://www.helen.fi/en/news/2018/bioenergy-heating-plants

17 Helen website. Available in Finnish at: https://www.helen.fi/yritys/energia/kehityshankkeet/biolampolaitokset/vuosaari

18 Helen website. Available at: https://www.helen.fi/en/news/2018/patola

19 Helen website. Available at: https://www.helen.fi/en/news/2018/environmental-impact-assessment-of-the-tattarisuo-bioenergy-heating-plant

Heat pumps in Helen's indicative investment plan. In addition to new thermal plant capacity, Helen is planning on increasing its waste water heat recovery capacity by 40–60 MW in the next few years. The Katri Vala heat centre will be expanded with a sixth heat pump and the new unit will recover heat that has already been utilised once in the heat recovery process of waste water, thus improving the recovery efficiency of the process. This also enables the heat centre to operate more during winter as it relies less on heat recovery from the cooling network, which has a strong seasonal demand profile. The Katri Vala expansion adds 20 MW of heating capacity and should start operation in 2021. Helen is also planning on another 20–40 MW of new heat pump capacity that should be online in 2022.[20][21]

A heat pump investment at the Vuosaari production site is also under planning. The heat pump would utilise excess heat from the plant cooling processes and is planned to produce heat at 13 MW capacity. The heat pump would also utilise heat from the sea water, thus adding the operational span of the unit to the full year. Construction of the heat pump is expected to start in 2020 and the unit would be in production use in 2022.[22]

The reasonable minimum heat source temperature for sea water heat pumps is between 2–3°C. Due to the gently sloping seabed in the Gulf of Finland, the availability of sufficiently warm sea water during winter months is challenging. To secure availability and heat production throughout the year, a tunnel with length of up to 12–20 km could be required to supply sea water for the heat pump.[23]

Heat storage units in Helen's indicative investment plan. The storage facilities add flexibility to the district heating system and are primarily discharged during peak demand. Construction of the Mustikkamaa heat storage began in early 2019 and is expected to be in use in 2021. The Mustikkamaa heat storage is to be built in old underground fuel oil caverns and the facility will be filled with hot water and connected to the district heating network via heat exchangers. The heat storage will be Finland's largest, with some 12,000 MWh of heat storage capacity and a dispatch capacity of 120 MW.[24]

Seasonal heat storage is also planned for rock caverns located beneath Kruunuvuori, where warm surface sea water is collected during summer and used as a heat source for heat pumps during summer. Although the storage capacity in terms of volume and heat is rather large, the total dispatch capacity of the configuration is only 1.5 MW.[25]

20 Helen website. Available at: https://www.helen.fi/en/news/2018/newheatpump

21 Yle. Available in Finnish at: https://yle.fi/uutiset/3-10766814

22 Helen website. Available at: https://www.helen.fi/en/news/2019/heat-pump-sea-water-heat-vuosaari

23 Helen website. Available in Finnish at: https://www.helen.fi/yritys/vastuullisuus/ajankohtaista/blogi/2019/merivesilampopumput

24 Helen website. Available at: https://www.helen.fi/en/news/2018/gigantic-cavern-heat-storage-facility-to-be-implemented-in-mustikkamaa

25 Helen website. Available in Finnish at: https://www.helen.fi/yritys/vastuullisuus/ajankohtaista/blogi/2019/postkivihiili

4 Cost of district heat production

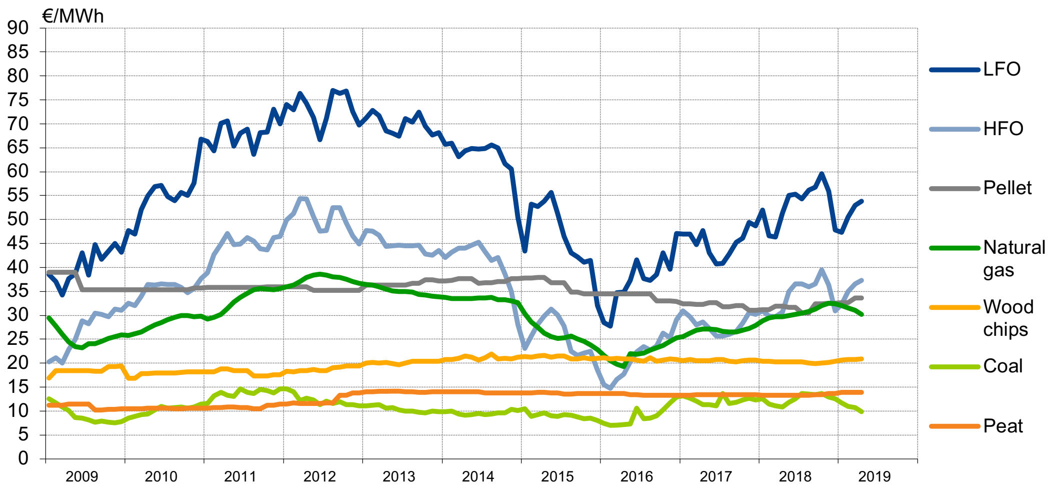
4.1 Cost components of district heating production

The cost of district heat production depends on the type of capacity used for heat production, the price of fuels used, as well as CO_2 cost and fuel taxes for fossil fuels and peat. In the case of CHP production or production based on electricity, such as heat pumps, electricity prices also impact the cost of heat production. The recent development of these cost components in Finland is depicted through Figures 22–25.

During the most recent years, the fossil fuel prices as well as emission allowance costs and fuel taxes have increased notably. The 12-month average electricity price has mostly varied between 35 and 45 EUR/MWh.

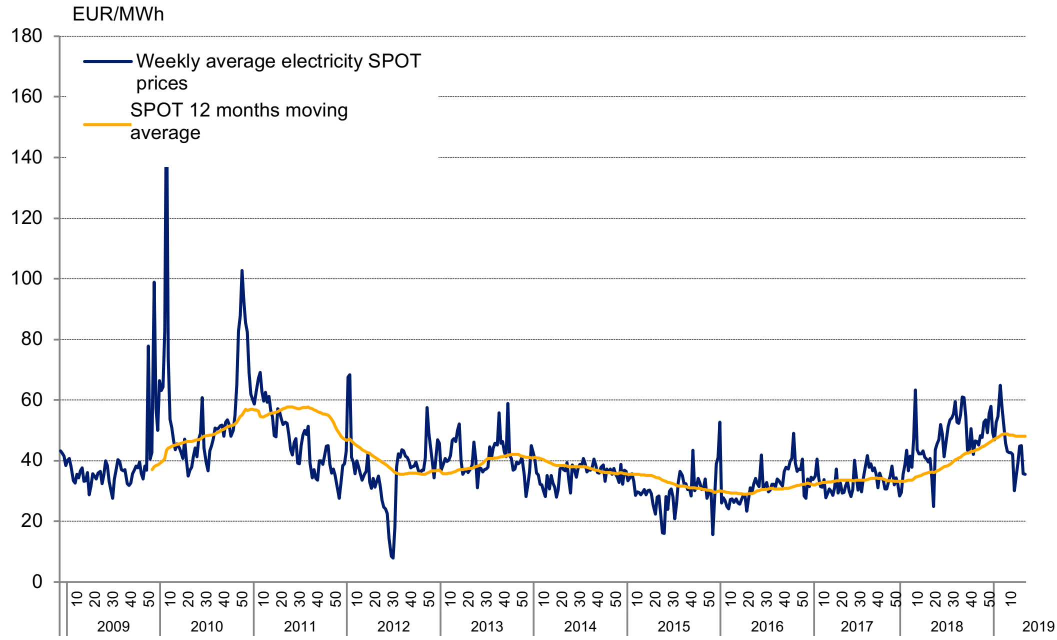
The marginal cost of district heating varies throughout the year based on the capacity utilised in the production. The average cost of heat production also varies greatly both within a year and between years.

Figure 22 Tax-free fuel prices in Finland in the period of 2010–2019.



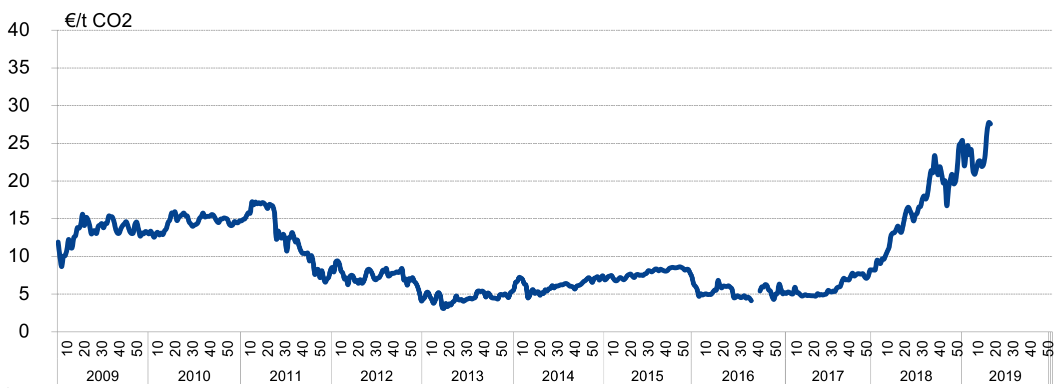
Note: Does not include fuel taxes, emission allowances, or strategic stockpile fees
Source: Pöyry

Figure 23 Weekly average electricity SPOT price in Finland in the period of 2009–2019.



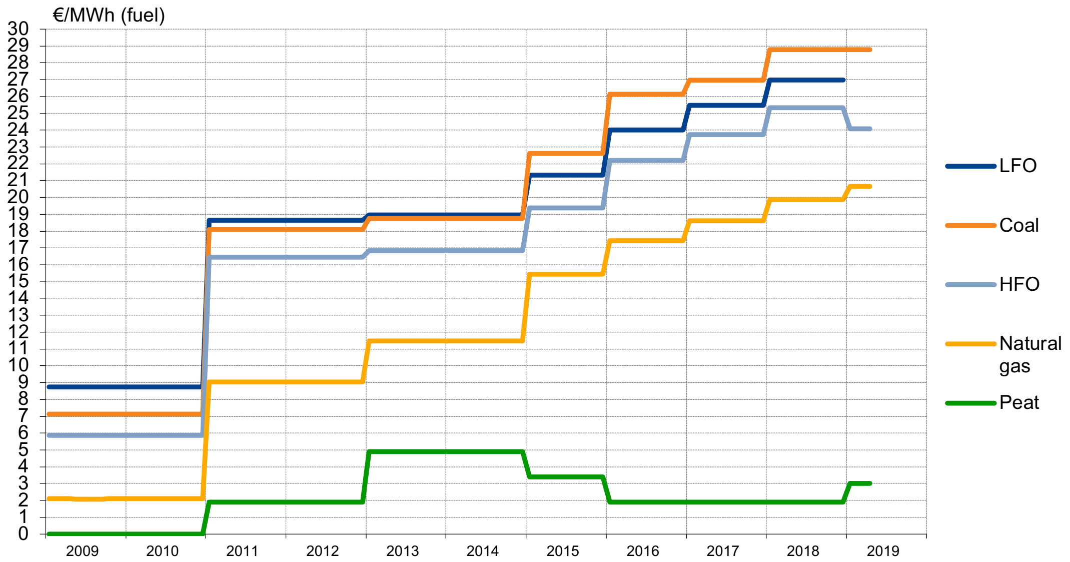
Source: Nordpool

Figure 24 Weekly average emission allowance price in the period of 2009–2019.



Source: Nordpool

Figure 25 Fuel taxes in heat production in the period of 2009–2019.



Source: Pöyry

4.2 Comparison of district heating and some alternative heating methods

District heating has a high market share in heating in the cities, but there are also many alternative heating methods. In locations where it can be utilised the main alternative to district heating especially in new buildings is currently ground source heat pumps (GSHP). Pellets and direct electricity heating can be utilised for building-level heating, as well as oil heating and natural gas heating in locations where the gas distribution network is available. District heat users are free to switch their heating methods from district heat to other heat methods and disconnect from district heating, but this typically requires investments in the buildings.

District heat users would typically mainly consider disconnecting from district heating at the time of district heat exchanger renewals which require some investments. For new buildings, the choice of heating methods is more open. However, in the densely populated city area, there are limitations, for example, for ground source heat pumps.

Ground source heat pumps have higher initial investment compared to other heating methods, but those are compensated with lower operational costs. Taking into account both investment and operation costs, the levelised cost of heat produced with ground source heat pumps is typically in the same range as district heat prices. The costs of different heating methods vary a lot from building to building depending on specific heat demand patterns and other specific conditions.

5 Regulation impacting the district heating sector

5.1 Regulation of district heating in Finland

There is no separate district heating act in Finland. The Competition Authority has interpreted that district heating operators have been in a dominant market position relative to their current district heating customers. The abuse of a dominant market position is prohibited, which sets certain requirements for the district heating operators, concerning their pricing but also their cost elements, such as investments into new capacity.

The requirements are typically related to prohibitive prices and terms, and price discrimination. District heating prices are not regulated, but the dominant market position requires pricing to be on equal terms for all similar customer groups. The Competition Authority can initiate investigations if they suspect an abuse of pricing when considering the dominant market position of district heating by charging unreasonably high prices.[26]

There is in general no obligation to connect to a district heating network. However, in some cases connection has been required locally as municipalities have been imposing district heat connection in the city plans. Hybrid heating solutions are also possible, where heating is produced with the combination of district heating and customers own heating installation such as heat pumps. The district heating customers in Finland have a right to disconnect from district heating without any extra fees.

There is no regulation for third party access of heat production to district heating network. If a third party wishes to utilise the heat network to deliver heat to end customer, or sell the heat to the district heat network operator, it needs to negotiate with the heat network operator. Some district heating companies have published terms and pricing structure for purchasing heat from third party producers.

In some cases, investments in renewable heat sources can be supported through investment support. Energy aid can be granted to new small heating plants utilising renewable energy, when invested by companies, municipalities, and other organisations.[27]

26 Finnish Competition and Consumer Authority (2017)

27 Ministry of Economy and Employment (2017)

5.2 Energy taxation

Fossil fuels (coal, natural gas, oil) used in heat production are taxed in Finland based on their energy content and CO_2 emission. Fuels used for electricity generation are not taxed in order to avoid double taxation. The level of energy taxation is clearly higher than the minimum tax levels set by the EU.

Finland also uses energy taxation as a way to promote renewable energy and therefore fossil heating fuels are subject to both energy tax and CO_2 tax, whereas renewable fuels are generally tax-free.

An overview of the relevant tax components and fees in Finland are listed in Table 5.

When electricity is used to produce district heat, the electricity taxes and network fees also impact the production cost. According to the government program of Prime Minister Rinne, there is a plan to decrease the electricity tax of heat pumps utilized in district heating systems. Currently the tax level is 22,53 €/MWh[28].

5.3 Policy impacting heat demand

The Energy Authority is the authority responsible for promoting energy efficiency improvements. The measures include voluntary energy efficiency agreements, energy audits, energy information for consumers, and the ecolabelling and ecodesign of products. A separate state-owned energy information company, Motiva, was established in 1993. It offers services to the public administration, businesses, communities, and consumers.

In Finland, energy efficiency has been improved through voluntary agreements since the 1990s. The voluntary approach has been chosen by the government and participating sectors to avoid the need to introduce new legislation to achieve the national energy efficiency targets.

In the building sector, energy efficiency is improved with building codes, which are based on the EU directives. The legislation on building codes was introduced in 2013.[29]

5.4 Land use and permitting procedures

Relevant permitting procedures required for any new energy production installation depend highly on the planned installation type. EU directives outline the permitting framework for permitting procedures. In addition, there are several national decrees in Finland that regulate which permit procedure is applicable to different types of installation. Some of the permitting processes are participatory processes, especially in the case of operations that have environmental and social impacts.

In addition to the permitting process, the land use procedures need to be taken into account when assessing the options for heat production in the Helsinki region. Any installation may only be constructed in an area where the land use is designated for

28 More information on current energy tax levels can be found from Finnish Tax Administration: https://www.vero.fi/en/businesses-and-corporations/about-corporate-taxes/excise_taxes/sahko_ja_eraat_polttoaineet/s%C3%A4hk%C3%B6n-ja-er%C3%A4iden-polttoaineiden-verotaulukot/

29 Ministry of Environment (2017)

Table 5 Energy taxation and other charges for heat production in Finland.

Policy	Description
Energy tax component	Fossil fuels used for heat production are subject to an energy tax which is based on the calorific value of the fuel. Peat has a lower tax. Gaseous and solid biofuels are tax-free. Fuels subject to energy tax which are used for CHP production have a lower energy tax component.
CO_2 tax	Fossil fuels used for heat production are subject to a CO_2 tax which is based on carbon dioxide emissions from combustion. Gaseous and solid biofuels as well as peat are CO_2 tax-free. Energy-intensive industrial companies can receive sizeable tax refunds.
Security of supply tax	Fossil fuels as well as electricity are subject to security of supply tax. Security of supply tax is not applied for gaseous or solid biofuels or peat.
Electricity tax	The level of tax on electricity depends on the end-use sector. In addition, electricity is also subject to security of supply tax. Industry, data centres, and professional greenhouses have lower tax compared to other end-use sectors.

Source: Finnish Energy; Finnish Tax Authority

the use of the installation (e.g. industrial use, energy production, or other relevant use). If the current land use does not allow such operation, the plan needs to be changed. The change process is led by the municipality; it is a participatory process and typically takes 1 year if there are no appeals. However, in the densely populated Helsinki region it can be assumed that these processes can take several years, and there will typically be appeals. The lengthiness of the process depends on the type of production installation and its proposed location.

Construction and other developments in Finland are controlled by the Land Use and Building Act (132/1999). More specific requirements are defined in decrees. The National Building Code of Finland incorporates comprehensive technical standards and guidelines. Building permits are issued by the Municipal Building Inspection Authority.

An Environmental Impact Assessment (EIA) may be required for installations which have significant environmental and / or social impacts (specifications are outlined in the Act on Environmental Impact Assessment Procedure 252/2017). The responsible authority for EIAs is the Centre for Economic Development, Transport and the Environment (ELY Centre). The EIA is performed before the environmental permitting phase. Typically, the EIA process lasts for 1–2 years.

The Environmental Protection Act (527/2014) and Environmental Protection decree (713/2014) are the two main regulations for environmental protection and permitting in Finland. An environmental permit is required for activities that pose a threat of environmental pollution. There is a specific list of activities that require an environmental permit or environmental registration. Environmental permit applications are submitted to the Regional State Administrative Agencies (AVI Agency). Typically the permit process from application submittal to permit decision takes about one year. If there are appeals, the process will take longer. Registrations are submitted to municipal authorities and the process is simpler and faster than environmental permitting.

Generally the main conventional permits, such as environmental permit for operating the installation and building permits, are issued for the owner/operator. However, certain permits are often issued directly to the party responsible for performing a specific task, such as concrete batching or underground construction works.

If the installation includes the storage or handling of hazardous chemicals, chemical permitting may be required. Storage and handling of dangerous chemicals is regulated by the Act on the Safety of the Handling of Dangerous Chemicals and Explosives (390/2005) and by the Decree on Monitoring Handling and Storage of Dangerous Chemicals (decree 685/2015). National legislation is based on the SEVESO III directive. Responsibilities according to regulation are determined by the extent of operational activity. Operations are divided into two groups, large scale and small scale. Large-scale activities are supervised by the Finnish Safety and Chemicals Agency (Tukes). For minor industrial handling and the storage of dangerous chemicals, an application must be submitted to the municipal rescue authority. Typically the large-scale permit process lasts 8–12 months.

Operators must notify the municipal environmental protection committees in writing of measures or events causing temporary noise or vibration, such as construction work if there is a reason to expect that such noise or vibration will be especially disturbing.

Use of water resources requires a permit under the Water Act (587/2011). Such activities include, for example, water abstraction, regulation, hydropower, and water construction such as water intake and discharge structures. If the same activity poses a risk of water pollution, the permit is usually considered together with the environmental permit application and resolved through one decision.

6 Further studies and data sources

Open data: Hourly district heating power 2016
https://www.helen.fi/en/company/responsibility/current-topics/open-data

The following studies contain further background information about different energy sources and their potential in Helsinki.

- **Waste heat sources in Helsinki.** The report describes the different sources of waste heat, such as swimming halls, hotels, restaurants, hospitals, laundries etc., and their potential in Helsinki area. The study is available in Finnish at: https://www.stadinilmasto.fi/2018/02/15/helsingissa-kartoitettiin-suuria-hukkalampokohteita/

- **Nuclear district heating in Finland.** The report examines the suitability of small-scale reactors for district heat production in Finland. The study focuses on small nuclear reactors with thermal capacity between 24 and 900 MW and both heat only and combined heat and power production. The study is available in English at: https://energia.fi/files/3740/Nuclear_district_heating_in_Finland_1-2_web.pdf

- **Waste to Energy in Finland.** The report describes the current state and operating environment of waste utilisation in energy production and assesses the impacts that potential policy instruments may have on industry. The operating environment is analysed with a focus on existing waste to energy utilities as well as under construction and planning. The report is available in Finnish at: https://energia.fi/files/405/ET_Jatteiden_energiakaytto_Loppuraportti_161015.pdf

- **Seawater temperature in the coast of Helsinki.** A study on the temperature levels of seawater in the coast of Helsinki, taking into account sea water depth variations. The report provides background information for evaluating the use of seawater as a heat source. The study is available in Finnish at: https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/julkaisut/julkaisu-25-18.pdf

- **Geothermal heat in Helsinki.** The report describes the geothermal characteristics and heating potential in Helsinki as well as technical feasibility and permitting practises related to geothermal heating solutions. The report is available in Finnish at: https://www.hel.fi/static/liitteet/kaupunkiymparisto/julkaisut/julkaisut//Maalampotyoryhman_raportti_keskustelua-varten.pdf

- **Heat recovery from Kilpilahti industrial site.** The manufacturing facilities of Neste Oyj and Borealis Polymers Oy in Kilpilahti produce a significant amount of low-temperature excess heat that could potentially cover one-fourth of district heat demand in Helsinki metropolitan region. Kilpilahti is located some 30 km East from Vuosaari. The study focuses on the techno-economic feasibility of heat recovery and recirculation into district heating systems. The study not published – news in English at: https://www.helen.fi/en/news/2019/kilpilahti

Information about energy sources, Helsinki building stock and other topics can be found in the following data sources:

- **Finnish wind atlas.** An online tool for estimation of the regional and local wind energy potential in Finland. The database contains average monthly and annual wind speeds (m/s) and estimates for potential power production (MWh) for different turbine types and hub heights. Available at: http://www.tuuliatlas.fi/en/index.html

- **Solar energy potential in Helsinki metropolitan area.** The online map tool provides estimates on the annular solar energy yields in the rooftops in Helsinki, Espoo and Vantaa areas at a building level granularity. Available at: https://aurinkosahkoakotiin.fi/hsyn-karttapalvelu-kertoo-aurinkosahkon-potentiaalin-katollasi/

- **Helsinki region atlas.** A database and mapping tool for data related to energy and building stock in Helsinki. Includes data on building construction year, purpose of use, number of stories, heat source as well as feasible locations for solar panels. Available at: http://www.seutuatlas.fi/index.jsp

- **Helsinki Energy and Climate Atlas.** A 3D information model of Helsinki building stock with information related to energy consumption. The data in also available from Helsinki Region Infoshare. Energy and Climate atlas is available at: https://kartta.hel.fi/3d/atlas/#/

- **Heat losses from rooftops in Helsinki.** An online map service showing heat losses through the roofs of buildings in Helsinki. The service is based on thermal imaging of heat radiation from Helsinki’s buildings. Available at: https://www.kattohukka.fi/?etusivu

- **HSY map service.** An online map tool that includes all public spatial data sets of Helsinki Region Environment Services Authority (HSY). HSY is the provider of waste management and water services in the Helsinki metropolitan area. Available at: https://kartta.hsy.fi/

- **Helsinki statistics and research.** The Urban Research and Statistics Unit at Helsinki City Executive Offices conducts urban research, maintains official statistical and registered data, and produces statistical publications and information services. Available at: https://www.hel.fi/helsinki/en/administration/information/statistics/

February 2020

Inquiries
laura.uuttu-deschryvere@hel.fi

Publisher
City of Helsinki, City Executive Office

This report has been prepared by Pöyry Management Consulting Oy ("Pöyry") for the City of Helsinki (the "Recipient"), in accordance with the Agreement between Pöyry and the Recipient. This report has been prepared based on the instructions by the Recipient and for the specific purpose of providing background information for the Helsinki Energy Challenge (the "Purpose"). There is no certainty that the report addresses or reflects the specific requirements, interests or circumstances of other parties for any other purpose than the Purpose for which this report was prepared. Pöyry has prepared this report based on information available to it at the time of its preparation and has no duty to update this report.

Pöyry accepts no responsibility, financially, legally or otherwise, for decisions made or actions taken based on the contents of this report.

Pöyry bases its analyses on publicly available data and information, its own data and data or information provided to us in connection with specific assignments. We always assess whether the quality of these data is sufficient for use in our analyses. We can, however, not guarantee for the quality and accuracy of data that we do not own the rights to. Uncertainty is an element of any analysis. As part of the documentation of the methodical approach used in our individual analyses, we always endeavour to point out and discuss factors of uncertainty.

Helsinki

City of Helsinki
City Executive Office

Pohjoisesplanadi 11–13
00170 Helsinki
P.O. Box 1
00099 City of Helsinki, Finland
Exchange +358 (0)9 310 1641

energychallenge.hel.fi
www.hel.fi