IEA Heat Pumping Technologies Annex 47

Heat Pumps in District Heating and Cooling Systems

Task 1: Market and energy reduction potential

Country report Sweden

September 2018

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1 Executive summary

The Swedish heating market represents a fourth of Sweden's total energy use and today four heating technologies dominates the heating market: district heating, heat pumps, electrical heating and biofuel boilers. The heating market is worth 100 billion SEK or 100 TWh. District heating stands for over half of the total heating demand, while heat pumps and electrical heaters together represent one third of the market. District heating is dominating multi-family houses and premises, while heat pumps dominates single-family houses.

District heating is well developed in Sweden and there are district heating grids in 285 of the county's 290 municipalities. In the same time no other country has a larger amount of heat pumps installed in their district heating grids. In 2016 4,5 TWh district heating was produced with heat pumps in Sweden, representing 7% of the total energy used in the Swedish district heating grids.

District heating have had a significant growth in delivered energy since mid-20th century, with a flattening trend during the last couple of years primarily because of market saturation. The economic potential for increased district heating is therefor considered to be rather small. The market potential for adding new district heating is predicted to 8 TWh to 2030 (4 TWh to 2020) compared to 2011. 5 of the 8 TWh is calculated to be installations in already existing buildings and 3 TWh in new buildings. But in the same time the total amount of sold district heating is foreseen to decrease. District heating in Sweden is predicted to decrease with 3-4 TWh to 2030. This is due to energy savings in the building stock that will reduce the total amount of sold district heating energy. Another reason is that heat pumps are predicted to increase their market share, mainly in larger buildings.

District cooling has increased steadily since 1990 but from very low numbers, and the installation speed has decreased slightly during the latest years. In 2016 approximately 1 TWh district cooling was delivered and the estimated potential to 2030 is calculated to 3 TWh.

The amount of heat pumps in the Swedish district heating grids rapidly increased during the 80's and stabilised around 1990, but since year 2000 the share of heat pumps in the district heating mix has slowly decreased from 16% of the mix year 2000 to 7% 2016.

One reason why the share of heat pumps has decreased in the district heating grids is fuel and production prices in relation to the electricity price. The heat plants prioritise low production costs and district heating based on CHP plants using waste or biofuels have low production costs today. In the same time the total amount of delivered district heating has flattened or even decreased. Thereby the economic interest today to increase the use of heat pumps seems to be a low, but this can change fast if the energy prices changes.

2 Sweden's energy situation today and in the future

The heating market represents a fourth of Sweden's total energy use and today four heating technologies are dominating the Swedish heating market: district heating, heat pumps, electrical heating and biofuel boilers. The heating market is worth 100 billion SEK or 100 TWh. District heating stands for over the half of the total heating demand, while heat pumps and electrical heaters together have one third of the market. District heating is dominating for multi-family houses and premises, while heat pumps dominates for single-family houses. (Värmemarknad Sverige, 2014). In 2016 4,5 TWh district heating was produced with heat pumps in Sweden, representing 7% of the total heat sources to the Swedish district heating grids (Energimyndigheten, 2018).

2.1 Energy supply and use in Sweden

2.1.1 Total energy supply and use

In Figure 1 the total energy supply and energy use in Sweden is shown. The energy use has varied around 550-600 TWh from the late 80's until now, with a noticeable change at the supply side in an increase of bio-fuels of 70-80 TWh from 1985 and almost a corresponding decrease in crude oil and other petroleum products together with coal and coke. From 2001 the wind power share of the supply has increased from more or less nothing to 15 TWh 2016.

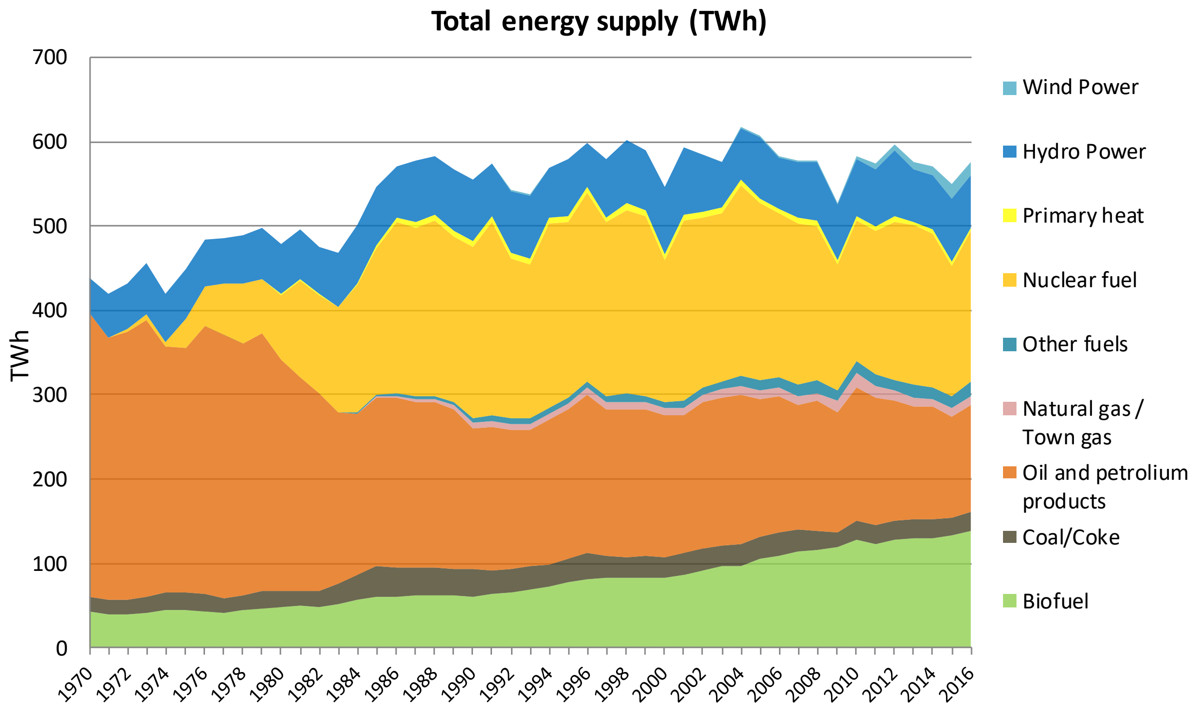

FIGURE 1. TOTAL ENERGY SUPPLY IN SWEDEN FROM 1970 TO 2016 IN TWH. SOURCE: (ENERGIMYNDIGHETEN, 2018)

On the end-user side, the residential, service etc. sectors, has decreased from 155 TWh 1988 to 140 TWh 2014 with a peak at 163 TWh 1996. The industry sector is back at 143 TWh 2014, with a strong growth 1992-2007, where it peaked at 159 TWh. Domestic transportation follows the same overall pattern as the industry sector during the period: returning at 85 TWh 2014 and peaking at 93 TWh 2007.

The GNP over the same period (1988-2014) has increased from 146 to 239 (Index, 1970 = 100) with just minor changes to the electricity and energy use during these same years (Ekonomifakta). Figure 2 shows a Sankey diagram of energy supply and use within Sweden, 2014.

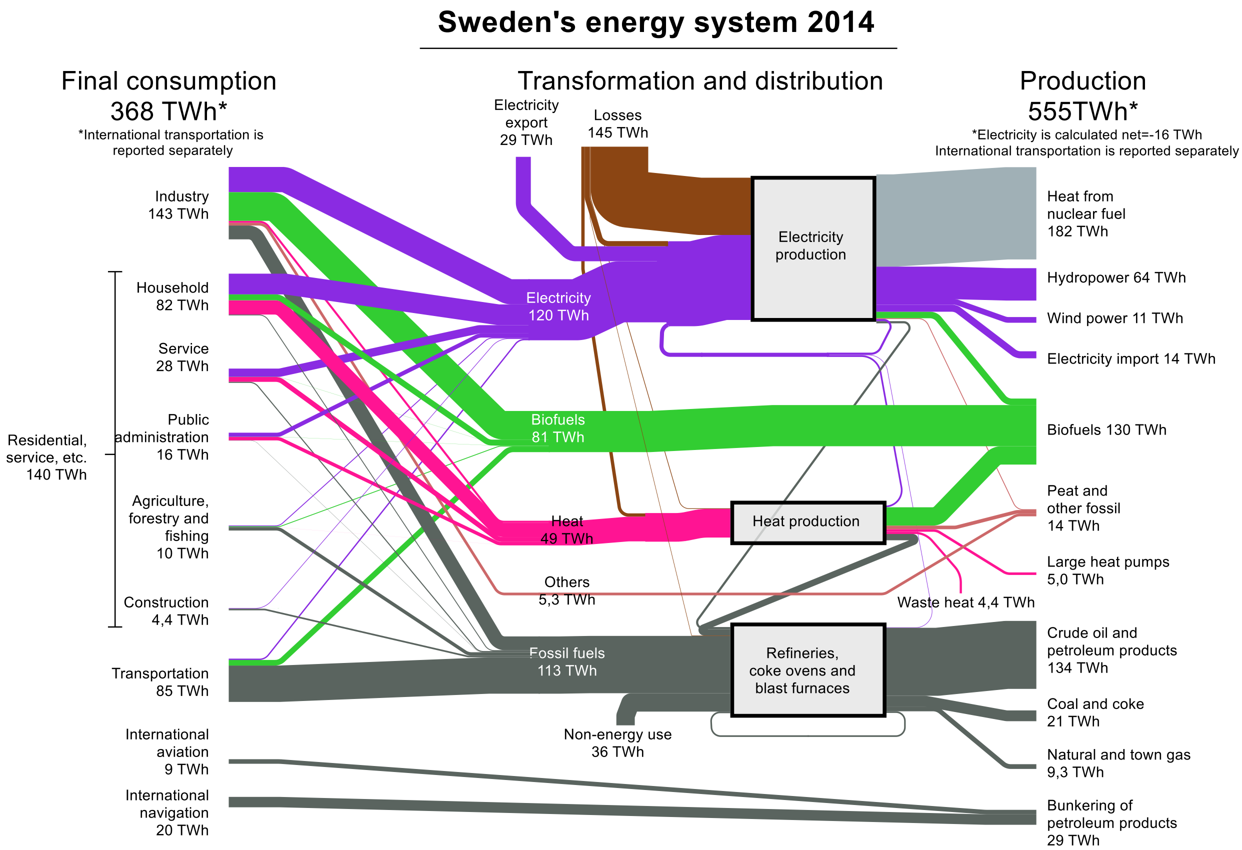

FIGURE 2. SWEDEN'S ENERGY SYSTEM, 2014. SOURCE: SWEDISH ENERGY AGENCY.

Sweden's total energy supply 2014 amounts to 555 TWh, with 145 TWh energy losses and 29 TWh electricity export, resulting in a final energy use of 368 TWh. Sweden's supply of electricity (2014) relies primarily on nuclear power (182 TWh before losses) and hydropower (64 TWh), with smaller contributions from imports (14 TWh), wind power (11 TWh) and bio-fuel power plants. Non-electricity supply (heat, industry, transportation etc.) relies primarily on biofuels (130 TWh) and crude oil and other petroleum products (134 TWh).

2.1.2 Total energy use by sector

The total energy use for industry, housing and services etc. amounts to 283 TWh in 2014 (transportation excluded). District heating stands for about 16% of that use, see Table 1.

TABLE 1. TOTAL ENERGY USE BY SECTOR, 2014 (TWH). SOURCE: SWEDISH ENERGY AGENCY – ENERGY IN SWEDEN, FACTS AND FIGURES 2016.

Energy source	Industry **(TWh)**	Transports (TWh)	Housing, services etc. (TWh)
Bio-fuels	56	11	14
Coal and coke	15		0
Petroleum fuels	9	71	12
Natural and city gas	4	1	2
Other fuels	5		0
District heating	4		45
Electricity	50	3	68
Total	**143**	**85**	**140**

2.1.3 Total electricity use

The total electricity uses for industry, transportation, district heating and housing, services etc. amounts to about 120 TWh in 2014, with the residential and services etc. sector as the single largest sector. District heating and refineries stand for about 3, 5% of that use. See Table 2.

TABLE 2. TOTAL ELECTRICITY USE BY SECTOR, 2014 (TWH). SOURCE: SWEDISH ENERGY AGENCY – ENERGY IN SWEDEN, FACTS AND FIGURES 2016

Sector	**Electricity (TWh)**
Industry	49,7
Transport	2,6
Residential and services etc.	68,0
District heating, refineries etc.	4,7
Distribution losses	10,2
Total	**135,3**

2.1.4 Energy use for space heating and DHW in buildings

The one- and two-dwelling buildings sector is the single largest market for heating and hot water use, both with respect to turn-over and energy. It stands for more than 50% of the total turn-over and for about 40% of the energy demand. Multi-dwelling buildings stand for just over 20% of the turn-over, and about 30% of the energy demand, while non-residential premises stand for about 17% of the turn-over and 25% of the energy demand. (Värmemarknad Sverige, 2014)

Today, there are four major heating techniques in Sweden for heating and hot water production boilers (Värmemarknad Sverige, 2014):

- District heating
- Electricity heating
- Heat pumps
- Bio fuel

For buildings, district heating stands for about 60% of the heating and hot water demand, and electricity heating (including heat pump electricity) stands for about 25%, see Table 3 for details. Looking at each building type separately, the district heating has a dominant role for multi-dwelling buildings, whereas electricity-based solutions are dominant in one- and two-dwelling buildings. Electricity heating and heat pumps stand for about 45% of the turnover (SEK) and district heating stands for 40% (SEK), (Värmemarknad Sverige, 2014).

TABLE 3. ENERGY USE FOR SPACE AND WATER HEATING BY TYPE OF BUILDING AND FUEL, 2014 (TWH). SOURCE: SWEDISH ENERGY AGENCY – ENERGY IN SWEDEN, FACTS AND FIGURES 2016.

	One- and two-dwelling buildings (TWh)	Multi-dwelling buildings (TWh)	Non-residential premises (TWh)	Total (TWh)
Oil	0,7	0,1	0,4	**1,3**
District heating	5,8	22,0	16,5	**44,4**
Electricity heating	14,0	1,4	2,9	**18,4**
Gas	0,2	0,2	0,3	**0,8**
Bio-fuels	10,3	0,3	0,5	**11,0**
Total:	**31,1**	**24,1**	**20,7**	**75,9**

During 1983-2014, the energy use for heating and hot water in one- and two-dwelling buildings has declined with approximately 10 TWh, with oil being almost entirely phased out, see Figure 3. The decline is partly due to better insulation and more energy efficient indoor climate equipment. District heating has been gaining ground over the period.

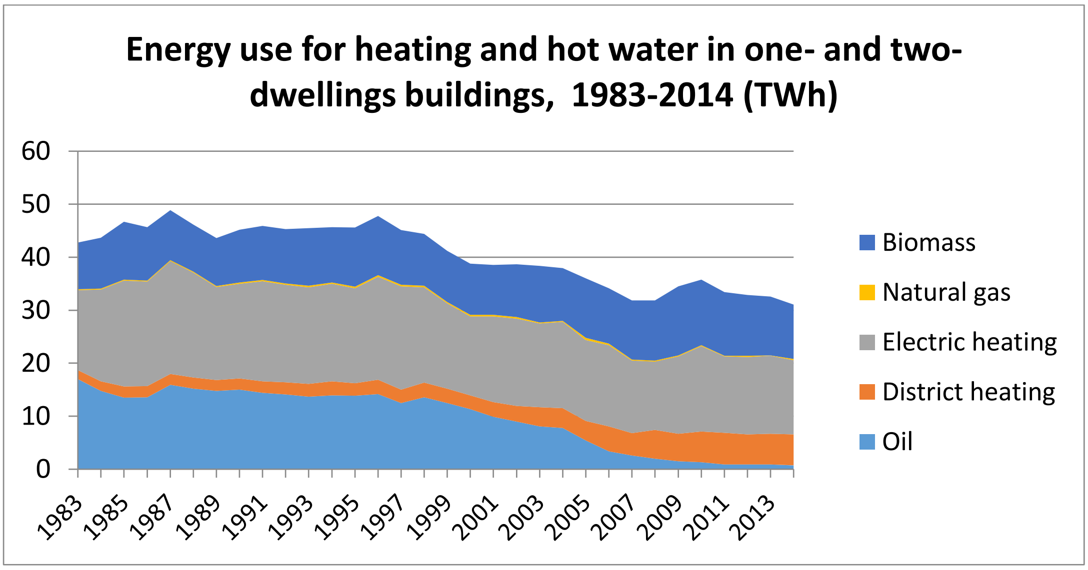

FIGURE 3. ENERGY USE FOR HEATING AND HOT WATER IN ONE- AND TWO-DWELLING BUILDINGS, 1983-2014, TWH. SOURCE: SWEDISH ENERGY AGENCY.

During the same period, energy use for multi-dwelling buildings fell with nearly the same amount (~10 TWh). District heating's share of the total supply has risen from almost 50% to approximately 90% - to a large degree at the expense of oil, see Figure 4.

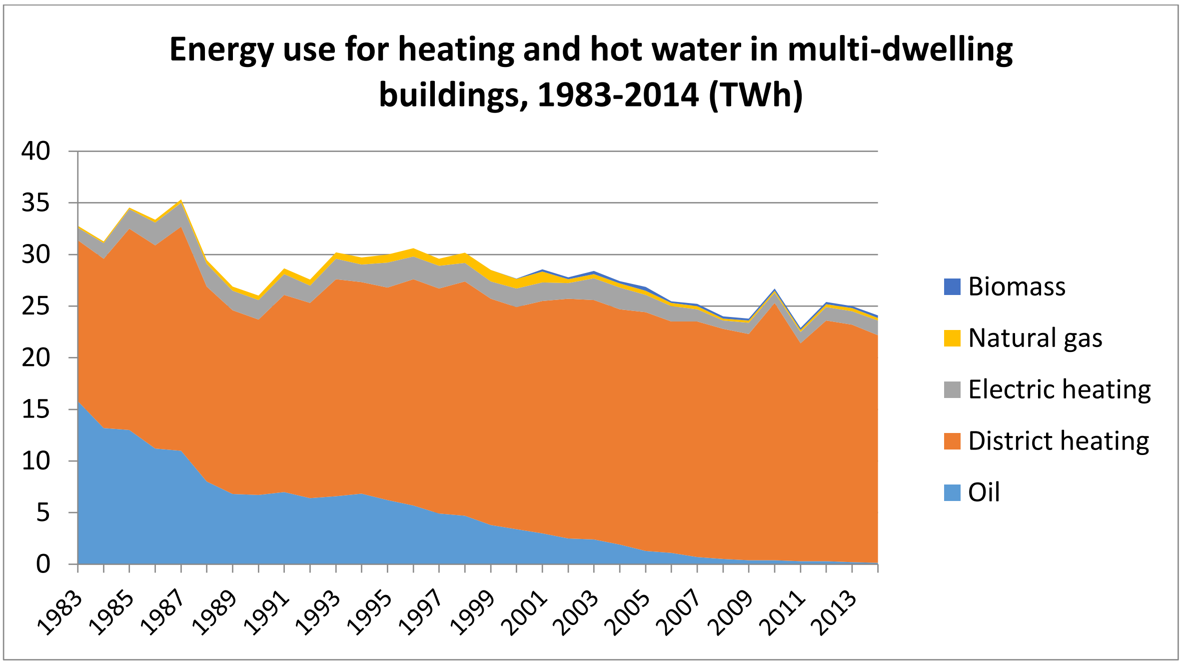

FIGURE 4. ENERGY USE FOR HEATING AND HOT WATER IN MULTI-DWELLING BUILDINGS, 1983-2014 (TWH). SOURCE: SWEDISH ENERGY AGENCY.

For non-residential premises, the same general pattern applies: district heating gains ground at the expense of oil, see Figure 5.

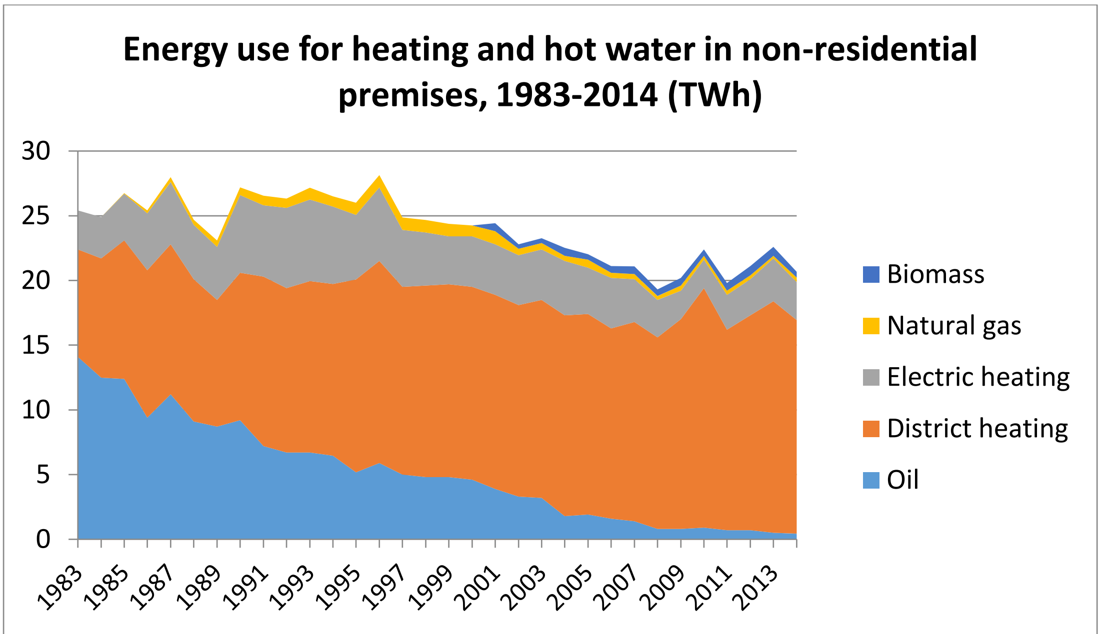

FIGURE 5. ENERGY USE FOR HEATING AND HOT WATER IN NON-RESIDENTIAL PREMISES, 1983-2014 (TWH). SOURCE: SWEDISH ENERGY AGENCY

When it comes to the supply side, combined heat and power (CHP) plants account for the single largest contribution to the district heating production with some 30 TWh heat produced 2014. Heat pumps stand for about 5 TWh, see Figure 6.

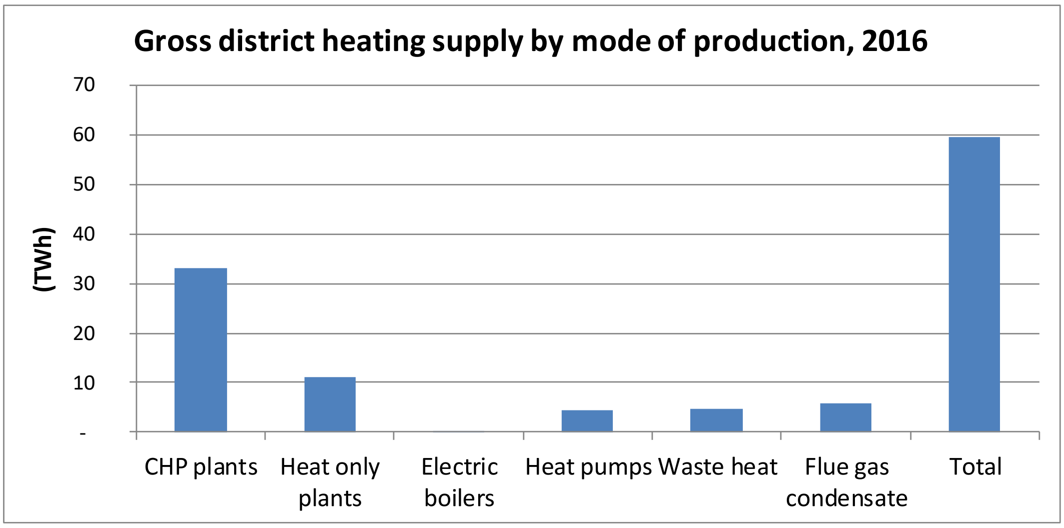

Figure 6. Gross district heating supply by mode of production, 2016. Data Source: (Statistics Sweden , 2016)

2.2 Housing stock characteristics

Roughly calculated the number of small houses is equal to the number of apartments. The Swedish house stock consists mainly of apartments (~2,5 million) and one- and two-dwelling buildings (~2 million), see Figure 7.

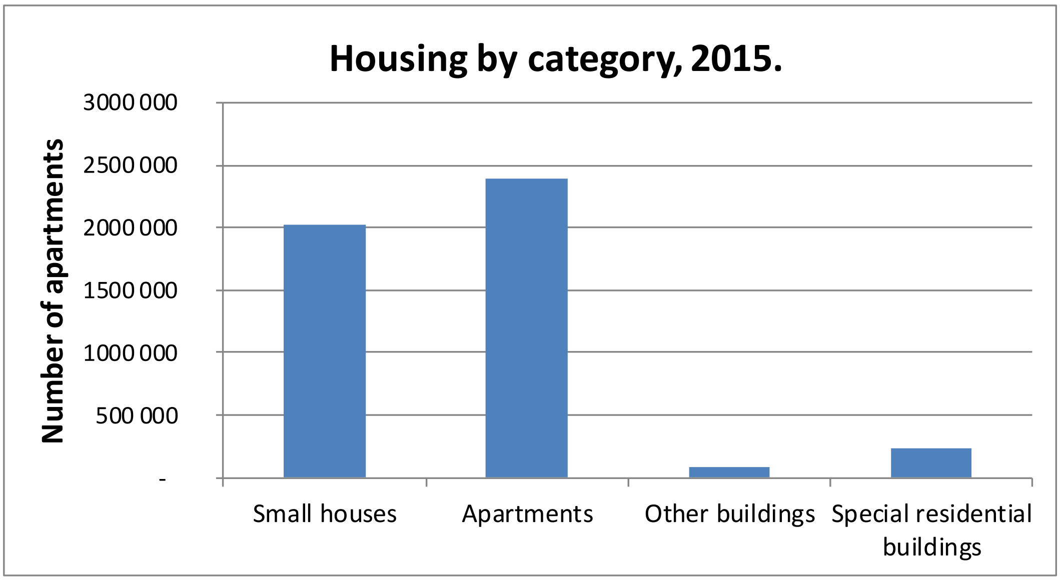

Figure 7. Number of Apartments by category, 2015. Source: (Statistics Sweden , 2016)

A large portion of the one- and two-dwelling buildings was built during 60's – 80's, and a main portion of the multi-dwelling buildings was built during the 50's – 70's. There is also a large portion of one- and two-dwelling buildings from pre-30's, see Figure 8. Many of the multi-family houses built in the so called Million Programme, built during the 60´s and 70´s are now in need for renovation.

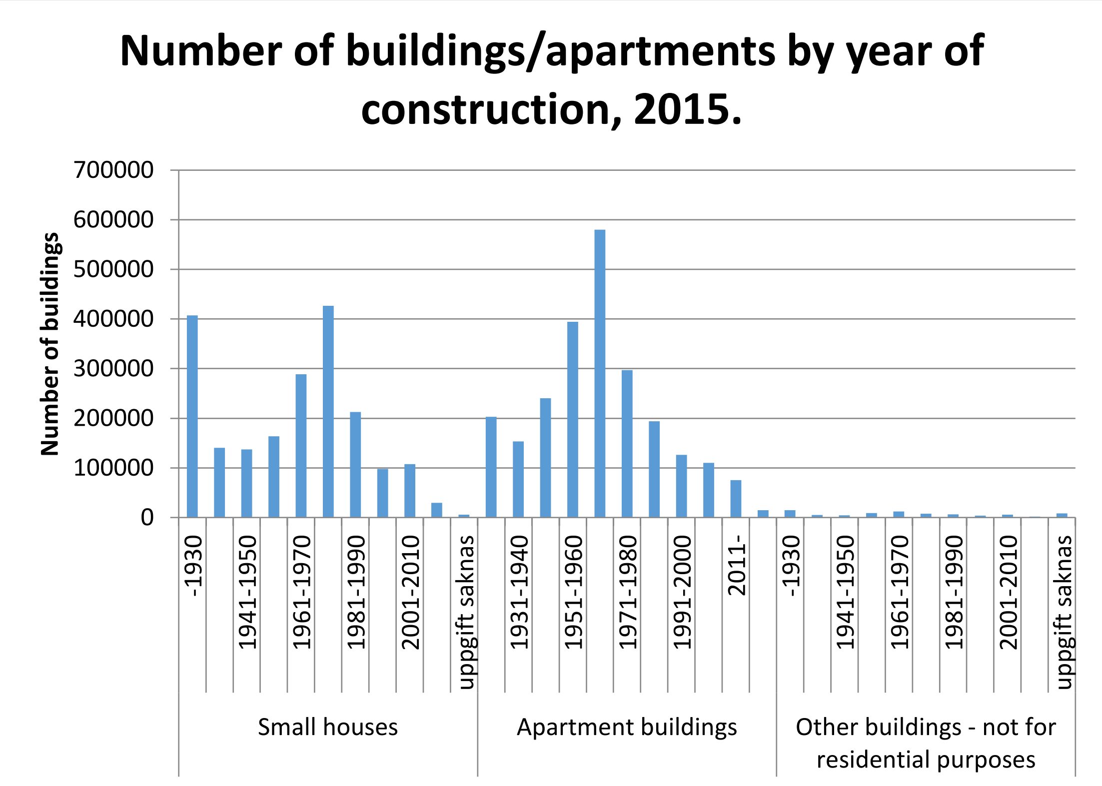

FIGURE 8 NUMBER OF BUILDINGS BY CATEGORY AND YEAR OF CONSTRUCTION. SOURCE: STATISTICS SWEDEN.

The distribution of living space in one- and two-dwelling buildings falls to a large extent into the span of 90-150 m^2, and the corresponding span for apartments is 40-90 m^2, see Figure 9.

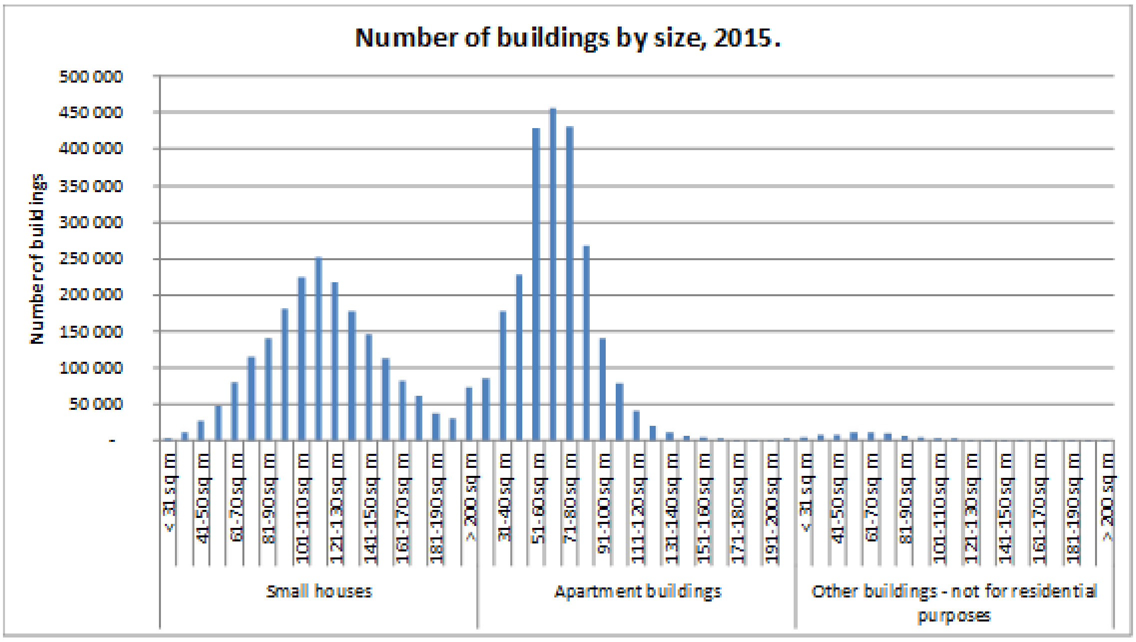

FIGURE 9. NUMBER OF BUILDINGS BY SIZE, 2015. SOURCE: (STATISTICS SWEDEN , 2016)

The specific energy use for heating and hot water in dwellings has declined during 1995 – 2014. The main contributing factors to this are installation of heat pumps and buildings with higher energy efficiency, see Figure 10.

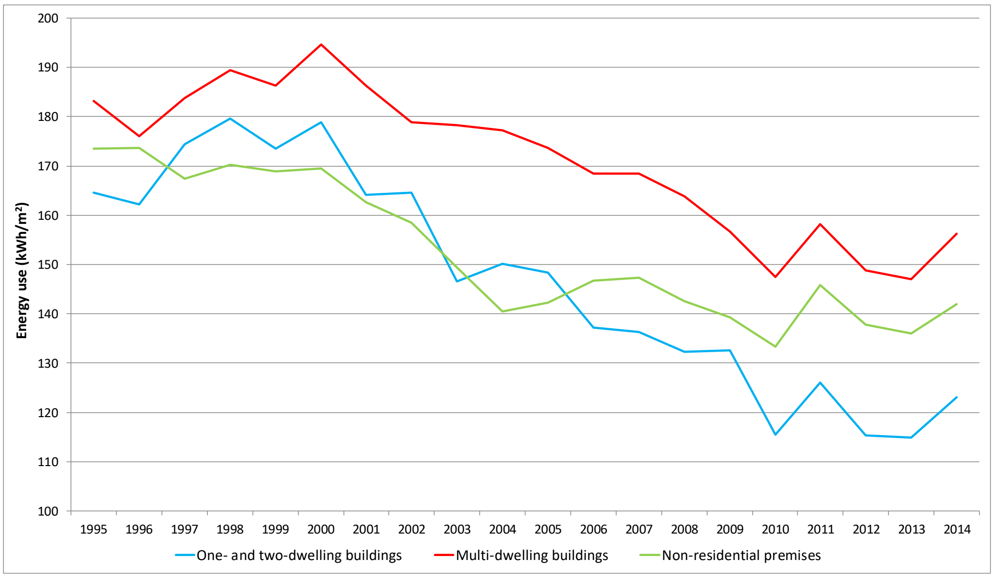

FIGURE 10. SPECIFIC ENERGY USAGE FOR HEATING AND DHW IN DWELLINGS AND NON-RESIDENTIAL PREMISES, 1995–2014. DATA SOURCE: (ENERGIMYNDIGHETEN, 2016)

2.3 Energy Infrastructure in Sweden

2.3.1 District heating

In Sweden there is district heating grids in 285 of the county's 290 municipalities. Almost 5000 people work within the business and the grid extends to approximately 24 000 km. Figure 11 shows how the district heating grid length has developed since 1996.

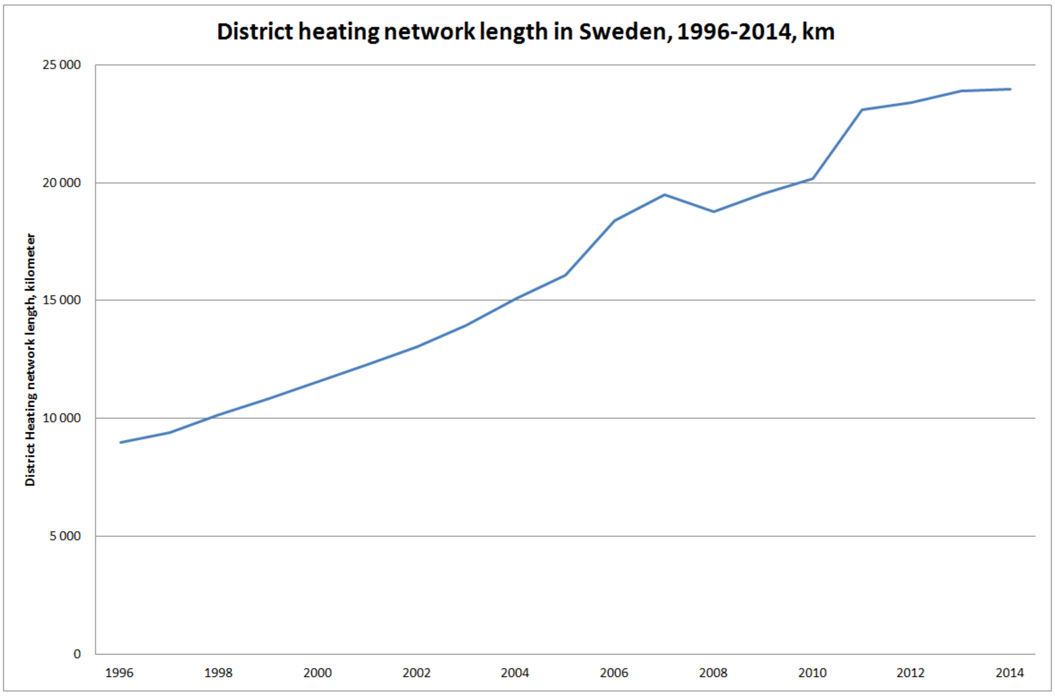

FIGURE 11. DISTRICT HEATING NETWORK LENGTH BY YEAR. SOURCE: SVENSK FJÄRRVÄRME (2015)

Energiföretagen Sverige (fusion of Svensk Fjärrvärme and Svensk Energi) organizes energy companies in Sweden. About 140 of its member companies account for 98% of the delivered district heating in the country. These companies deliver about 45-50 TWh heat annually (including heat for industrial applications). District heating accounts for about 60% of the market of DHW and space heating in Sweden. The major part of the district heating companies are publicly owned, whereas some large companies like Vattenfall, E.ON and Fortum are not.

The heat market in Sweden is built up by many local markets with individual conditions when it comes to climate, heat demand, electricity and fuel prices, building density, supply of waste heat from industries, combustible waste from forestry and so forth (Svensk Fjärrvärme, 2016).

District heating has had a significant growth in delivered energy since mid-20th century, with a flattening trend during the last couple of years primarily because of market saturation, see Figure 12. There is a positive contribution to the district heating deliveries from new building construction, which however is (partly) compensated for by more energy efficient buildings – through renovation of old buildings and construction of new energy efficient ones, (Holmström, 2016).

Maintenance is performed on older parts of the district heating grid in Sweden, but there is no easily accessible overall data about the status of the grid (Holmström, 2016).

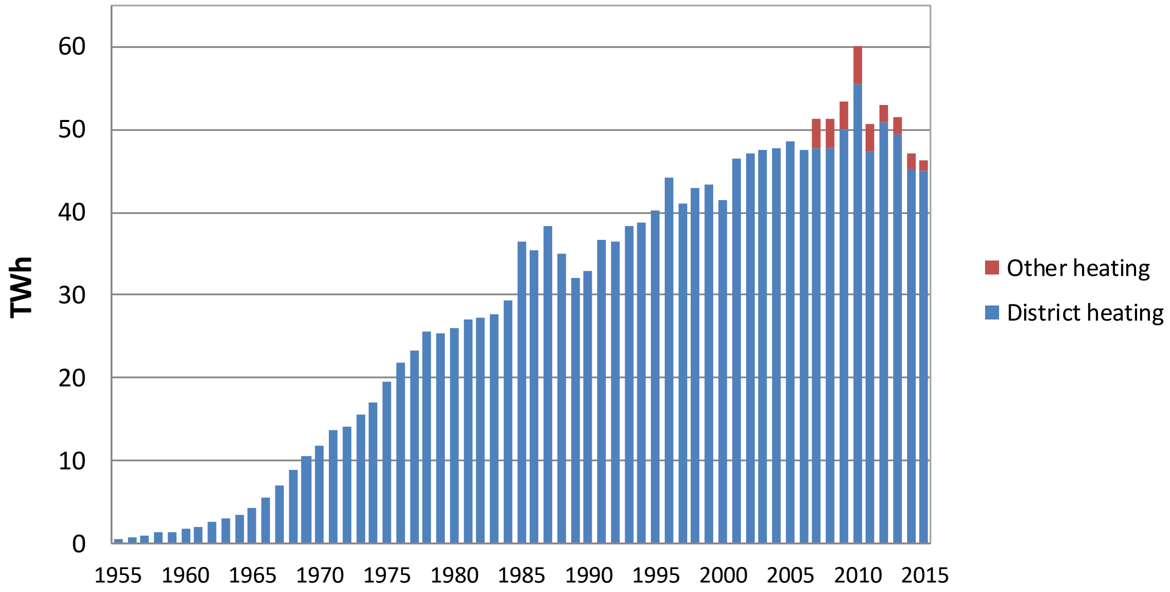

FIGURE 12. DELIVERED HEAT FROM DISTRICT HEATING 1955-2015. SOURCE: (ENERGIFÖRETAGEN, 2017)

2.3.2 District Cooling

District cooling has a small but steadily growing market share of the cooling market. It consists today of around 30 companies producing approximately 1 TWh/year to 1000 customers (Swedish Energy Markets Inspectorate, 2013). The member companies of Energiföretagen foresee increased deliveries of district cooling in the years to come. Today, Stockholm is the leader among capitals in the production of district cooling, competing with Paris and Abu Dhabi.

The customers of district cooling are mainly found among manufacturing industry, large businesses and hospitals (Svensk Fjärrvärme, 2016). Comfort cooling is still rare in Swedish residential buildings. Increasing demand for cooling may occur due to the greenhouse effect and raised standard of living (Värmemarknad Sverige, 2014).

The trend of delivered district cooling and length of the grid has been increasing over the last two decades, see Figure 13.

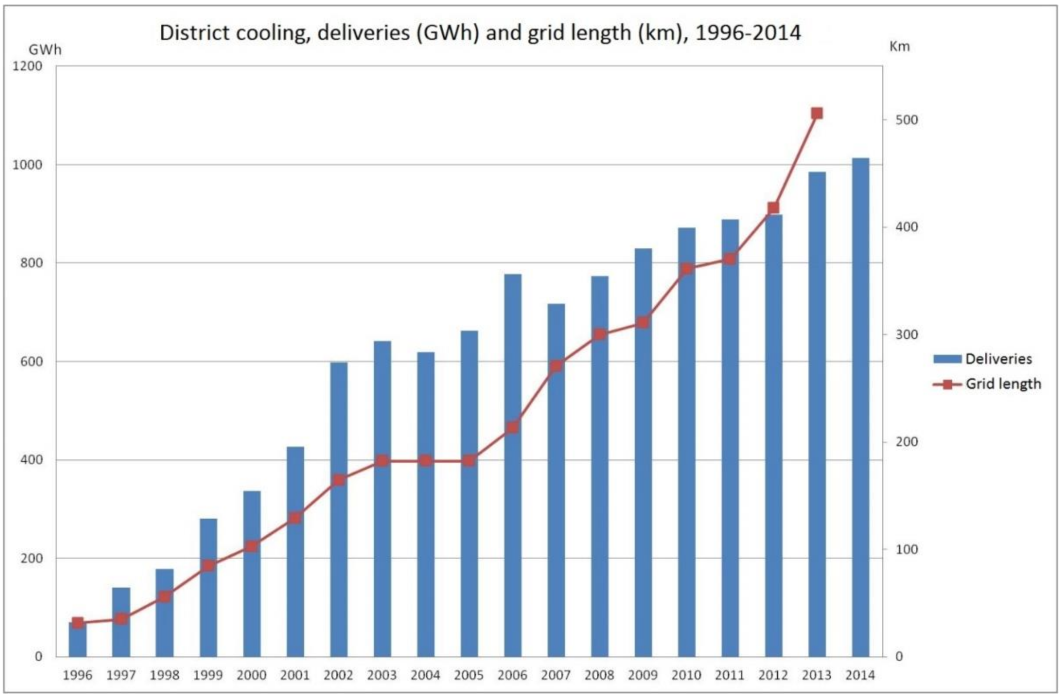

FIGURE 13. DISTRICT COOLING DELIVERIES (GWH) AND GRID LENGTH (KM), 1996-2014. SOURCE: SVENSK FJÄRRVÄRME

A handful of district energy companies accounts for the major part of district cooling, Stockholm alone stands for over 40% of the district cooling produced in Sweden.

2.3.3 Electrical grid

The Swedish electricity network can be divided into three levels - local networks, regional networks and the national network. Most electricity users are connected to the local electricity grid, which in turn is connected to the regional power grid. The regional electricity grids are connected to the national grid. There are about 160 local electricity network companies in Sweden. The size of these companies' grids varies widely. The smallest company has approximately 3 km of lines, while the largest has more than 135 000 km. The regional networks are owned largely by three companies E.ON Elnät Sverige, Vattenfall Eldistribution and Fortum Distribution. The Swedish national network is owned and operated by Svenska Kraftnät, which is a state-owned public utility. The delivery reliability in the Swedish grid is on average 99.98 percent.

In Sweden there is an ongoing transformation from an electrical system where electricity was produced in a few large plants to a system where the traditional electricity production is complemented with production in many, small and scattered plants - for example, on individual roofs for residential dwellings. This is also a transition from a system of almost only hydro and nuclear power – which both can be controlled and planned, to increasingly weather-dependent power from sun and wind. This development places new demands on the electrical grid. The networks need to be more flexible and tailored to both new ways to produce and use electricity. (Energiföretagen, 2018), (Svenska Kraftnät, 2018)

2.3.4 Gas grid

The Swedish natural gas system is small compared to most other grids for natural gas in Europe and the grid only covers a smaller part of the country and is located in the south and west of Sweden. The system consists of a national network owned by Swedegas, which stretches from Trelleborg in the south and up to Stenungsund, 50 km north of Gothenburg. The grid is approximately 600 km long. From this main pipe, other pipes branch out to regulator stations. From these stations, the gas is distributed out to regional and local distribution systems, only 30 of Sweden’s 290 municipalities has access to the grid. The Swedish natural gas network was originally built for natural gas, but now biogas is also being fed into several of the local distribution systems and is distributed along with the natural gas. (Swedegas, 2018) (Swedish Energy Markets Inspectorate, 2016)

Swedegas has sole ownership of the national network for natural gas in Sweden and is responsible for balancing the natural gas transmission network. This means that Swedegas handles both operation and maintenance of the national network and ensures that the consumption and supply of gas is balanced.

There is also a grid for town gas and CNG in the Stockholm area owned by Gasnätet Stockholm AB, responsible for development and maintenance of the grid. The town and CNG grid include approximately 500 and 40 km of pipes respectively.

Sweden is not producing any natural gas, the supply of gas comes from Denmark via a pipeline. The natural gas consumed in Sweden mainly origins from the Danish gas fields in the North Sea, however an increasing proportion of biogas is being upgraded to natural gas and added to the network system. Due to the structure of the Swedish gas grid the natural gas market in Sweden is closely connected to the Danish market. The natural gas suppliers sell gas to their clients on the free market, in competition with other natural gas suppliers. Actors on this market are free to set their own prices and it is up to the consumer to choose the natural gas supplier offering the best deal.

The national gas grid is made of steel pipes coated with a corrosion protection. The pipes are assumed to have a lifetime of at least 40 years while equipment for monitoring, steering and regulation is expected a life time of 5-20 years.

2.4 Energy policy

The development of energy policies in Sweden rests with the central government, supported by several national and local authorities. Since 1995 Sweden is a member state of EU and thereby follows EU´s framework regarding legal requirements related to the energy policies. (International Energy Agency, 2013)

In the government bill *En sammanhållen klimat- och energipolitik – Energi (2008/09:163)* Sweden has defined the following climate and energy goals to 2020 (Energimyndigheten, 2017):

1. 50% renewable energy
2. 20% increased energy efficiency compared to 2008
3. 10% renewables in the transport sector
4. 40% reduction of greenhouse gases for sectors not included in EU´s emission trading system compared to 1990, of which two thirds in Sweden

There is also a political energy agreement, including five of the eight parties in the Swedish parliament, that 100% of the electricity production should come from renewable sources 2040. Thereby electricity from nuclear power, today representing around 40% of the Swedish electricity mix, should be replaced by 2040. Finally, there is a goal that the energy use in Sweden should be 50% more efficient to 2030, measured as supplied energy per GDP.

Already 2012 the goal related to 50% renewable energy was fulfilled, 2015 54% of the energy used in Sweden came from renewable sources. (Naturvårdsverket, 2018). The goal related to reduction of greenhouse gases is still not fulfilled, but according to Naturvårdsverket's assessment the goal will be reached within time (Energimyndigheten, 2017). In Figure 14 and Figure 15 below the trends for reduction of Swedish emissions of greenhouse gases are shown.

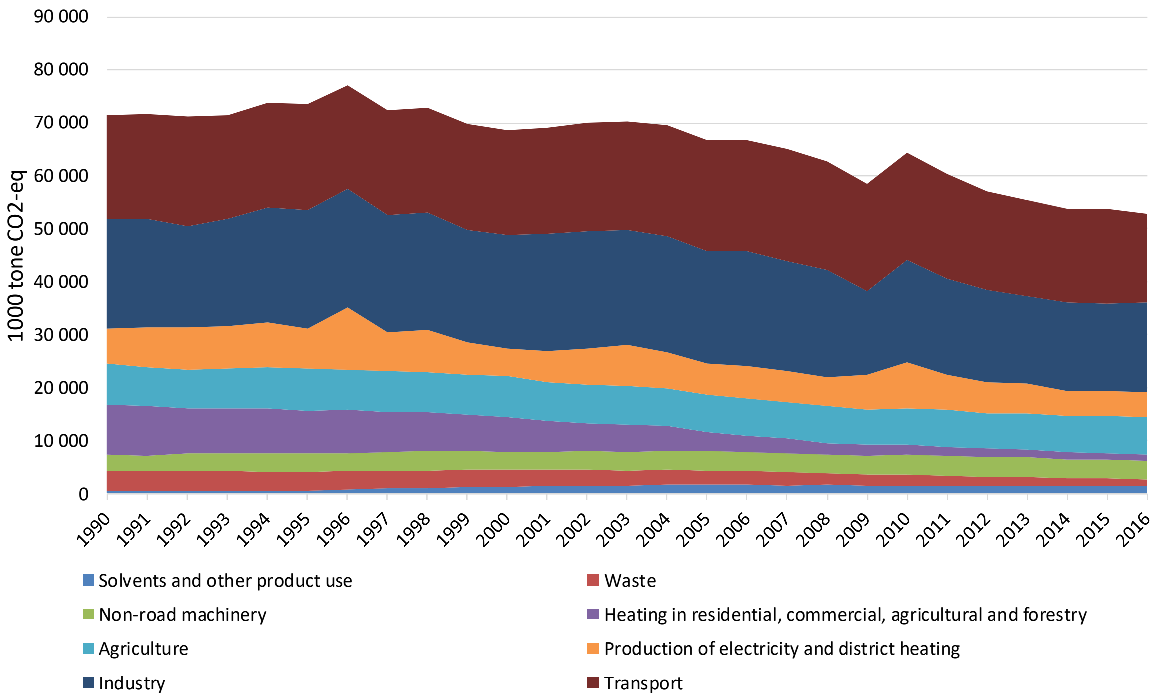

FIGURE 14. TOTAL GREENHOUSE GAS EMISSIONS PER SECTOR IN SWEDEN 1990-2016, SOURCE: (ENERGIMYNDIGHETEN, 2018)

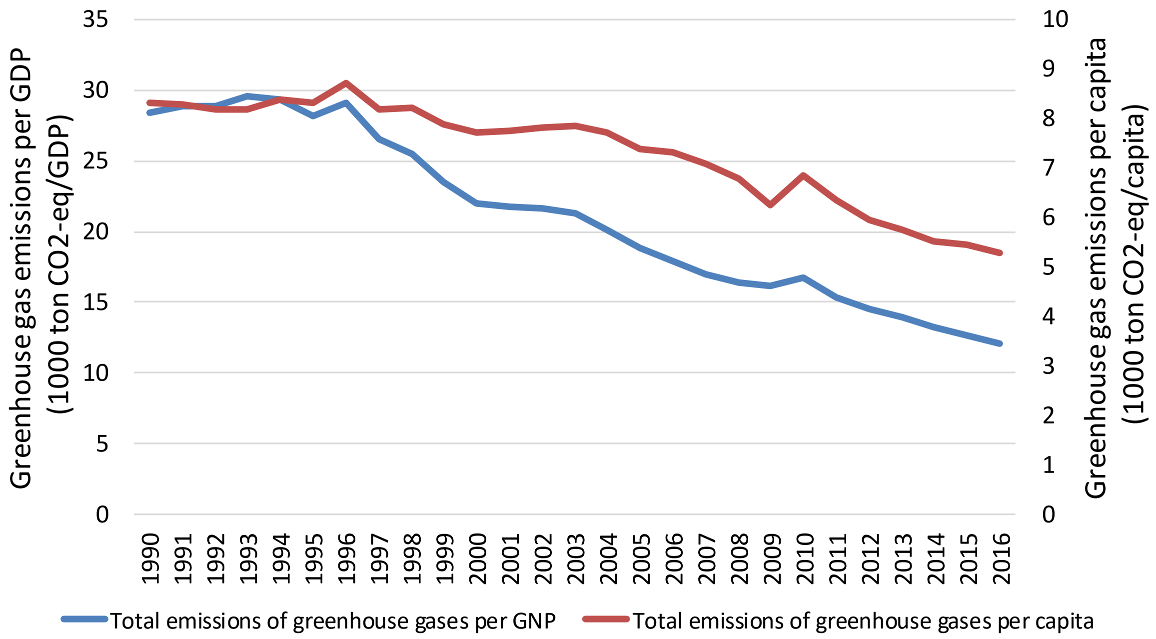

FIGURE 15. EMISSIONS OF GREENHOUSE GASES PER GDP AND PER CAPITA IN SWEDEN 1990-2015, SOURCE: (ENERGIMYNDIGHETEN, 2018)

2.4.1 Energy taxes

A large part of the total Swedish energy prices is related to taxes. In Figure 16 below the development of general energy- and CO_2 taxes for fossil fuels and electricity is shown.

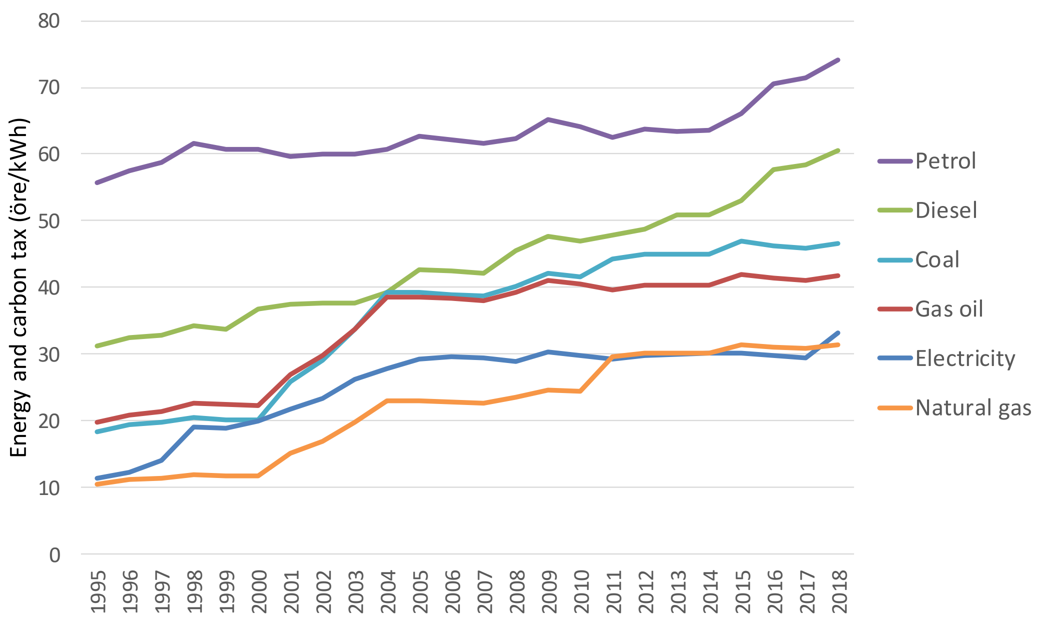

FIGURE 16. GENERAL ENERGY AND CO2 TAXES ON FUELS AND ELECTRICITY 1ST OF JANUARY 1995-2018, CALCULATED IN 2017 PRICE LEVEL, DATA SOURCE: (ENERGIMYNDIGHETEN, 2018)*

* 10 öre is approximately 0,01 €.

Note that not all energy users are paying full taxes. Households pays the general taxes while the industry has reduced taxes for energy, see Figure 17. In 2008 started a stepwise reduction of CO_2 taxes for fuels consumed in industry and CHP-plants included in EU: s emissions trading system (EU ETS). From 2011 the industry included in EU ETS don't pay any taxes on CO_2, only energy taxes.

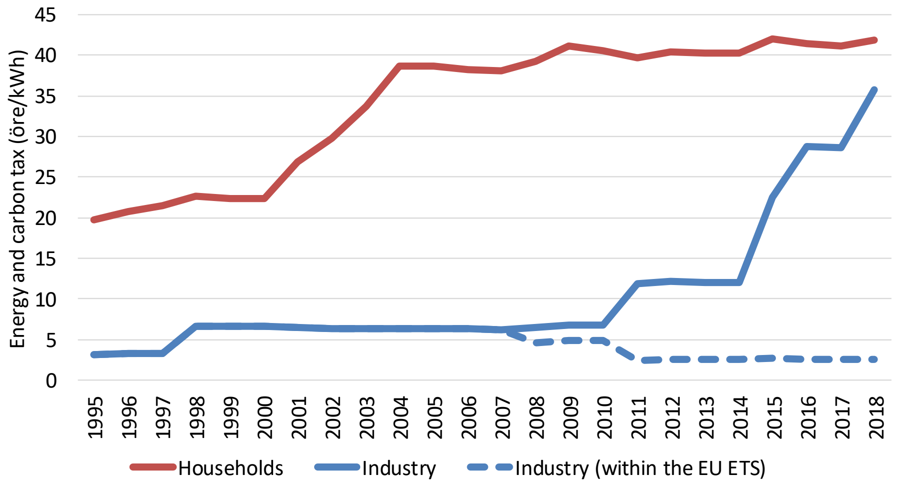

FIGURE 17. ENERGY AND CO2 TAXES FOR FUEL OIL FOR DIFFERENT CONSUMERS 1995-2017, CALCULATED IN 2017 PRICE LEVEL, DATA SOURCE: (ENERGIMYNDIGHETEN, 2018)

2.4.2 Electricity certificates

Electricity certificates is an instrument to increase the production and use of renewable electrify, mainly from wind, water, biofuels and sun. The producer of renewable energy gets ”electricity certificates”, that can be sold to power suppliers and other that need certificates representing a certain quota of sold or used electricity. Sweden and Norway have a common electricity certificates market and the aim is to increase the yearly production of electricity from renewable sources with 28,4 TWh to 2020 compared to 2012. The use of electricity certificates increases the possibilities for renewable sources to compete with non-renewables. (Naturvårdsverket, 2018)

2.4.3 Tax exemptions for biofuel

There are no taxes related to energy and CO_2 on biofuels. The combination of energy and CO2 taxes on fossil fuels and no taxes on biofuels expects to be an important reason to the low greenhouse gas emissions from the district heating sector in Sweden. Also, biofuels for transports has lower taxes compared to fossil fuels. (Naturvårdsverket, 2018)

2.5 Energy prices, tariffs and structure

Both the electricity- and the district heating sector shows large differences in price structure from one energy supplier to another.

2.5.1 Electricity

The Swedish electricity grid is divided in four “elspot areas”. I general most of the electricity is produced in the north of Sweden, while the demand is largest in the south. The Sweden’s electricity market is a part of Nord Pool, which includes the Nordic and Baltic countries (Nord Pool, 2018) and is owned by the Nordic and Baltic transmission system operators. At Nord Pool the electricity spot price is set ones an hour. In Figure 18 below the daily average spot prices for electricity in "elspot area 3 – Stockholm" for 2015, is shown.

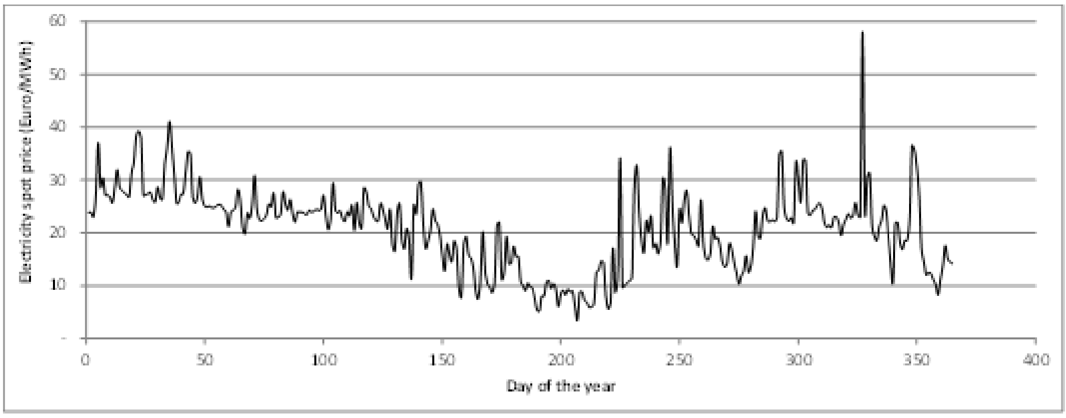

FIGURE 18. VARIATION OF THE ELECTRICITY SPOT PRICE FOR "ELSPOT AREA SE3 -STOCKHOLM" DURING 2015, BASED ON DATA FROM NORD POOL (NORD POOL, 2018)

Approximately one hundred Swedish electricity suppliers purchase electricity from Nord Pool and sell it to their customers. The suppliers sell electricity on the free market, in competition with other electricity suppliers. Actors on the market are free to set their own prices.

An electricity supplier can also have a balance responsibility, meaning that the electricity supplier has a financial responsibility to ensure that there is always a balance in the amount of electricity added and withdrawn at the infeed and outtake points that fall under the balance responsibility. (Swedish Energy Markets Inspectorate)

2.5.1.1 Electricity tariffs and price structure

In addition to the electricity price from Nord Pool there is a number of other costs for the final user. Some of the costs are fixed and some are variable. There are large differences in prices structure from one energy supplier to another and the share of fixed costs in relation to variable costs variates. Figure 19 below shows an example of the price structure based on data for a multi-family house in Linköping, Sweden.

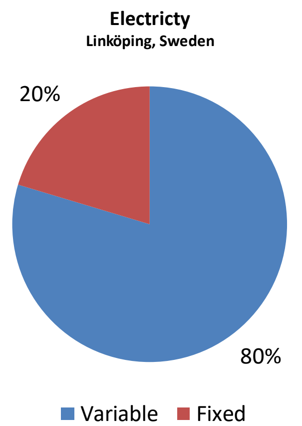

FIGURE 19. EXAMPLE OF DISTRIBUTION OF ELECTRICITY PRICE BETWEEN VARIABLE AND FIXED, BASED ON DATA FOR A MULTI-FAMILY HOUSE IN LINKÖPING, SWEDEN

Even though the electricity price from Nord Pool variated every hour very few Swedish consumers has an electricity contract giving price variations per hour. More normal is to have a variable price based on the monthly average or a fixed electricity price for 1-3 years (both shorter and longer periods exist).

In addition to the electricity price set on Nord Pool additional costs are added, like Electricity certificates (approximately 0.05 SEK/kWh) and costs for the grid transmission and peak outtake. The energy tax on electricity is 0.331 SEK/kWh and finally VAT is added. In Figure 20 the brake down of the electricity prices is shown. The figures should be seen as an example and is based on data for a multi-family house in Linköping, located in the south east of Sweden.

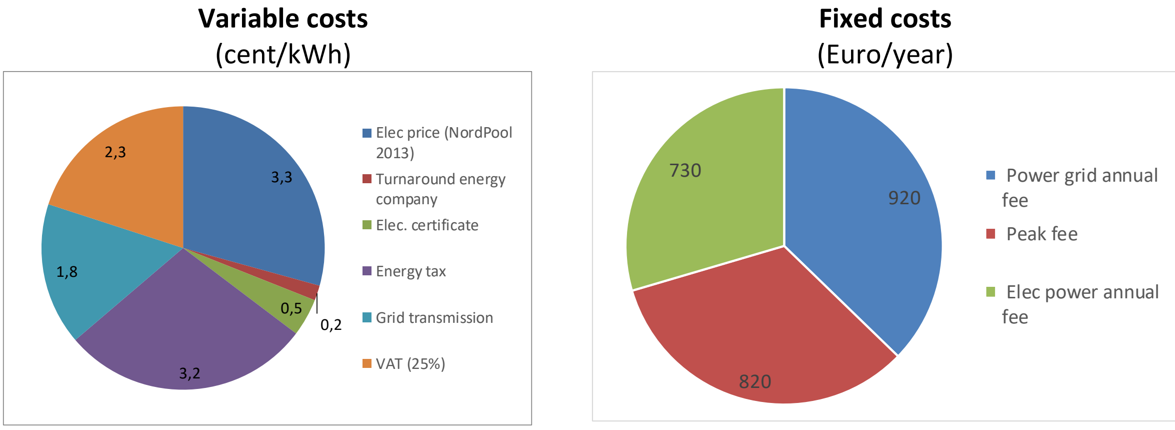

FIGURE 20. EXAMPLE BRAKE DOWN ELECTRICITY PRICE, BASED ON DATA FOR A MULTI-FAMILY HOUSE IN LINKÖPING, SWEDEN

2.5.2 District heating

The cost for district heating in Sweden varies from one municipality to another, the Swedish district heating association has published prices for different Swedish grids for three model houses (Svensk fjärrvärme, 2016). In Figure 21 below the district heating prices for a lager multifamily house in approximately 230 grids are shown. As one can see the yearly cost for district heating varies from 40 to 80 Euro/MWh depending on where your building is located. There is also a large variation between different grids in how the tariff is built up, which makes it difficult to compare the prices easily.

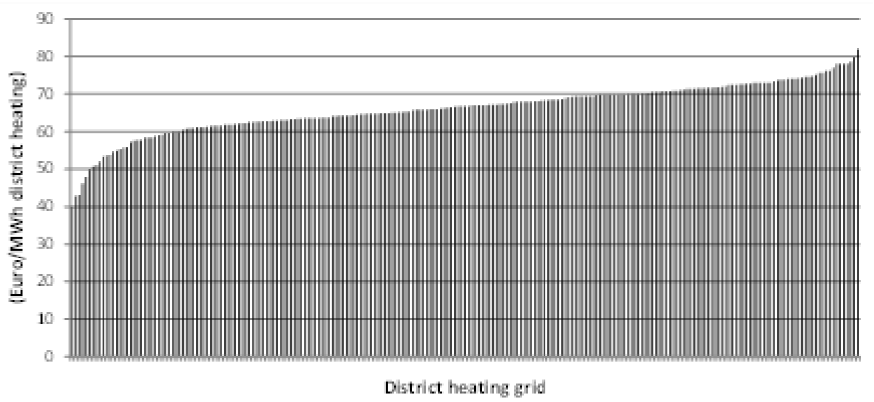

FIGURE 21. VARIATION IN DISTRICT HEATING PRICES 2016 FOR A BUILDING WITH A HEATING DEMAND OF 1000 MWH/YEAR, BASED ON AT WHICH DISTRICT HEATING GRID IN SWEDEN THE BUILDING IS LOCATED, PRICES IN EURO, VAT EXCL. (SVENSK FJÄRRVÄRME, 2016)

If the building in Linköping, used as an example for electricity in chapter 2.5.1.1 above, used district heating the distribution between variable and fixed costs for the district heating would be as shown in Figure 22.

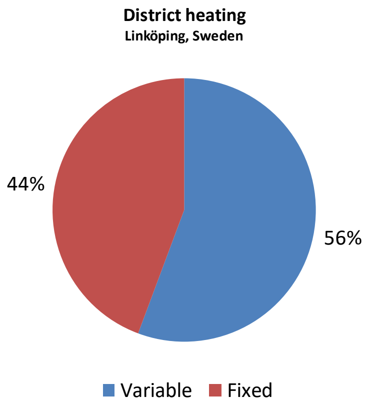

FIGURE 22. EXAMPLE OF DISTRIBUTION OF DISTRICT HEATING PRICE BETWEEN VARIABLE AND FIXED, BASED ON DATA FOR A MULTI-FAMILY HOUSE IN LINKÖPING, SWEDEN

An ongoing trend is that more district heating companies changes their prices structure from a fixed energy prices per kWh, independent of the season, to a price that variates depending of the month of the year. Typically, with low summer prices and higher prices during the winter. One reason is that district heating companies with waste incineration or industrial excess heat has a base of available energy all year with low production costs. In the same time the heating demand is low during summer. During winter time additional fuels and incineration plants are needed for heat production giving higher costs. Linköping is one city with low summer prices, see Figure 23 below.

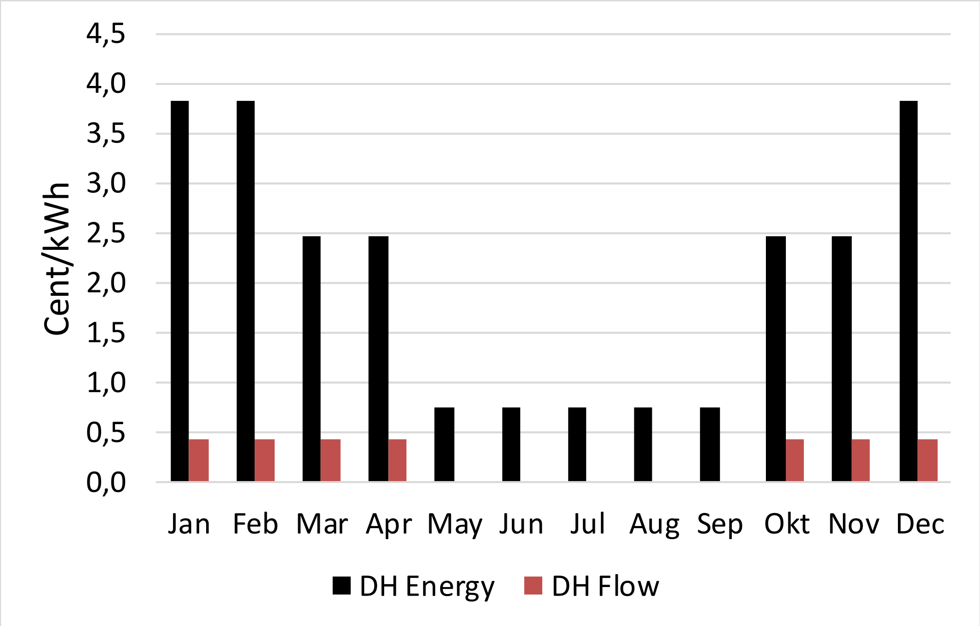

FIGURE 23. PRICE STRUCTURE DISTRICT HEATING IN LINKÖPING, DATA SOURCE (TEKNISKA VERKEN, 2015)*
* Cost for DH flow recalculated from cent/m³ to cent/kWh based on assumptions regarding the relation between energy and district heating flow.

The fixed price in Linköping is related to the maximum district heating power needed by the costumer over the year. This so called "power signature" is calculated based on the district heating power demand at the dimensioning outdoor temperature in Linköping (defined as -17,6°C).

2.6 Overview of prospects and challenges in Sweden's energy market

Värmemarknad Sverige is an interdisciplinary Swedish research project. In the project report from stage 1 (Värmemarknad Sverige, 2014) authors from Profu, SP Sveriges Tekniska Forskningsinstitut, Lunds tekniska högskola, Högskolan I Halmstad and KTH was involved. The authors listed a number of scenarios and challenges ahead for the heating market, both marketwise, politically and technologically. Below follows some of the main challenges according to the report:

- **Which will be the dominant drivers for how the heating market will evolve; more energy efficient buildings, more individual technologies or increased energy yield in combined systems?** Depending on various assumptions when it comes to customer requirements, technological development, design of political means of control and price trends, the scenarios will vary dramatically: the district heating's market share for heating 2050 spans between 36% and 56%, and total delivered energy spans the 49-76 TWh interval.
  Since the transformation of the heating market is a slow and costly process, long term rules are important.
- **Energy efficiency - great opportunities, hard to implement**. How much will the heating demand decrease – if at all? What are the actual costs for energy efficiency measures? Will

the expected increased energy efficiency of existing buildings really happen? More comprehensive measures are not implemented until the buildings are renovated or rebuilt, whereas many minor measures are just implemented to a moderate extent. The extent to which energy efficiency measures are implemented will have a great impact on the future heating demand.

- **The renovation and energy efficiency upgrade of the Million Programme is a big challenge** (The million Programme was an ambitious public housing programme implemented in Sweden between 1965 and 1974**).** Even if the Million Programme buildings do not have a remarkably high level of energy use, they are still in great need for renovation, and implementing energy efficiency measures in Million Programme areas with weak solvency and high required rate of return poses a great challenge to the involved parties.
- **The market for heap pumps is changing.** Thanks to a large market penetration in one- and two-dwelling buildings, the heat pump market gradually turns into a market for renewal of older installations rather than a conversion market where heat pumps gain ground from other heating alternatives. Large scale heat pump installations in multi-dwelling buildings and non-residential premises may be a growing market – but that is quite unsure.
  The efficiency of heat pumps is increasing, and the pace at which this happens is influenced by energy tariffs, political means of control and the market conduct, but also by building characteristics, where the potential of lowering the systems' temperatures is an important aspect.
  Another important aspect for the competitiveness of heat pumps is the future demand for cooling, especially so residential cooling. An increased demand for cooling probably will strengthen the competitiveness of heat pumps. In the "combined solutions" scenario, where heat pumps and solar and district heating become common, the heat pumps will be both a local heat source for the building, but occasionally also a heat source for the district heating system. This path of development for heat pumps is however more difficult to assess.
- **In the long run, the heating market may rather turn into an energy market.** Combined systems and stagnating heating deliveries put *energy solutions* in focus, including that the customer and the supplier integrate their systems. "Open district heating" is a first step, where customer and supplier interchangeably sell and buy heat to and from each other.
- **The heating market will be influenced by information and communication technology (ICT) and smart grids.** The technological development for monitoring, energy storage, visualization and analysis of energy data is accelerating. Being an actor in the heating and energy businesses will be increasingly complex.

For the power market new challenges are also coming. Due to a political energy agreement all electricity from nuclear power should be replaced by 2040. Today nuclear power represents around 40% of the Swedish electricity mix. This should be done without increased use of fossil fuels.

The Swedish power grid gets more and more connected to other countries, new cables are built increasing the possibilities to import and export electricity. Thereby the Swedish electricity market will be closer connected to the European electricity market.

A future scenario with an increased share of electricity from renewable energy sources like sun and wind will lead to larger variations in the electricity production. This will change the demands on balance power.

3 Market potential for district heating/cooling

In (Sköldberg, 2013) the potential for cogeneration, district heating and cooling in Sweden was estimated based on the EU directive on energy efficiency (2012/27/EU). The authors concluded that there is a potential for increasing both district heating and district cooling, but especially for district heating the potential is limited due to the large market share today. The potential for additional district heating was calculated to 8 TWh by the year 2030 (4 TWh by 2020). But in the same time a decrease in heat demand from already existing customers are foreseen due to improved energy efficiency and conversion to other heating alternatives.

For district cooling the relative potential to grow is larger. The potential for additional cooling has been estimated to 2 TWh, from 1 TWh today to 3 TWh by the year 2030 *(1 TWh by 2020)*

This means a possible growth of additional, newly installed district heating from 2011 to 2030 of about 16%, and about 8% to 2020. The authors however foresee a slight decline in *total* deliveries of district heating during the period. For district cooling, on the other hand, there is a potential growth from 2010 to 2030 of 200% and from 2010 to 2020 of 100%. For district cooling, the authors underline that the potential is based on very rough estimates.

3.1 Potential for district heating

The total economic potential for increased district heating is considered rather small in Sweden. The Swedish district heating market is mature with a market share for space heating and DHW of almost 60% and 285 of Sweden's 290 municipalities have district heating grids today. The total amount of sold district heating in Sweden is predicted to decrease to 2025. This is due to energy savings that will reduce the amount of sold heat. Another reason is that heat pumps are predicted to increase their market share in mainly larger buildings. (Göransson, 2009) (Sköldberg, 2013). In (Energimyndigheten, 2017) there is a predicted reduction of the total district heating use to 2035, but then the scenario assumes district heating to increase again to 2050, this is due to predicted higher electricity prices after 2035 making heat pumps less competitive.

The market potential for adding new district heating is predicted to 8 TWh to 2030 (4 TWh to 2020) compared to 2011. Of this 5 TWh is calculated to installations in already existing buildings and 3 TWh in new. But in the same time the total amount of sold district heating is foreseen to decrease with 3-4 TWh to 2030. Thereby energy savings and other heating technologies is forecasted to reduce the delivered district heating to buildings where district heating is already installed with approximately 12 TWh. (Sköldberg, 2013)

3.2 Potential for district cooling

District cooling has increased steadily since 1990 but from very low numbers, and the installation speed has decreased slightly during the latest years, see Figure 13. For estimations of the potential for the Swedish district cooling market in total there are limited sources available. One estimation says that the district cooling market will deliver 3 TWh cooling 2030 (Sköldberg, 2013). In 2016 approximately 1 TWh district cooling was delivered giving a potential increase of 2 TWh in 14 years.

3.3 Reduction potential of primary energy and CO_2

An increased use of district heating and cooling have a potential to reduce the primary energy use and greenhouse gas emissions. How large the reduction potential is depending on the figures used for primary energy and CO_2 emissions both for individual fuels but also for electricity and district heating/cooling. There will also be large differences in result depending on if one uses a bookkeeping approach or and consequence (forward-looking) approach, focusing on the margin production.

Looking forward in a future scenario a consequence approach that identifies the effects of a specific change in electricity or district heating use might reflect the situation in the best way. Using this approach (Sköldberg, 2013) calculated the primary energy saving potential for adding new district heating to approximately 3 TWh 2020 and 5 TWh to 2030. The potential for avoided CO_2-emissions is calculated to 1,2 Mton CO_2 to 2020 and 1,3 Mton 2030, based on the emission factors in Table 4. The potential for largest primary energy savings is related to replacement of inefficient heating alternatives (electricity or oil) in already existing buildings. The energy saving potential related to replacement of other highly efficient heating alternatives like heat pumps in new buildings are small for district heating.

TABLE 4. EMISSIONFACTORS FOR CO_2, DATA SOURCE: (SKÖLDBERG, 2013)

Fuel	Emission (g CO2-eq/kWh)
Coal	330
Natural gas	205
Oil	270
Peat	385
Waste	90
“Hyttgas”	900

Using a bookkeeping approach gives approximately equal primary energy savings in this case as in the consequence scenario. (Sköldberg, 2013) have calculated the potential for primary energy savings using two sets of data both with a bookkeeping approach giving savings of approximately 2-3 TWh 2020 and 4-6 TWh 2030.

4 Role of Heat Pumps in district heating/cooling

No other country has the same or a larger amount of heat pumps installed in their district heating grids as Sweden. 2013 there were 73 heat pumps units in operation with a total installed capacity of 1,2 GW. Most of the installed units had a capacity of 10-30 MW (50%), 40% was smaller than 10 MW and 10% was larger than 30 MW (Averfalk H, 2017). In 2016 4,5 TWh heat was produced with heat pumps for production of district heating in Sweden. This represents 7% of the total heat sources to the Swedish district heating grids (Energimyndigheten, 2018). The main part of the energy is supplied to a few district heating grids, 1,5 TWh is produced in Stockholm by Stockholm Exergi AB, followed by Göteborg Energi producing 0,5 TWh. The five largest producers of district heating via heat pumps represents 86% of the heat produced via heat pumps in district heating grid. In total 22 of 332 grids had heat pumps in operation in 2017. (Energiföretagen, 2018).

The heat sources used by the heat pumps can be divided in four groups. Most common is treated sewage water (approximately 50% of the total installed heat capacity) followed by ambient water, industrial excess heat and others (Averfalk H, 2017). The ambient water is represented by mainly sea water, lake and river water and groundwater to low extent.

In Figure 24 below the trends for heat pumps in the Swedish district heating grids are shown. As can be seen the amount of heat pumps rapidly increased during the 80's and stabilised, but since year 2000 the share of heat pumps in the district heating mix has slowly decreased from 16% of the mix 18 years ago to 7% 2016.

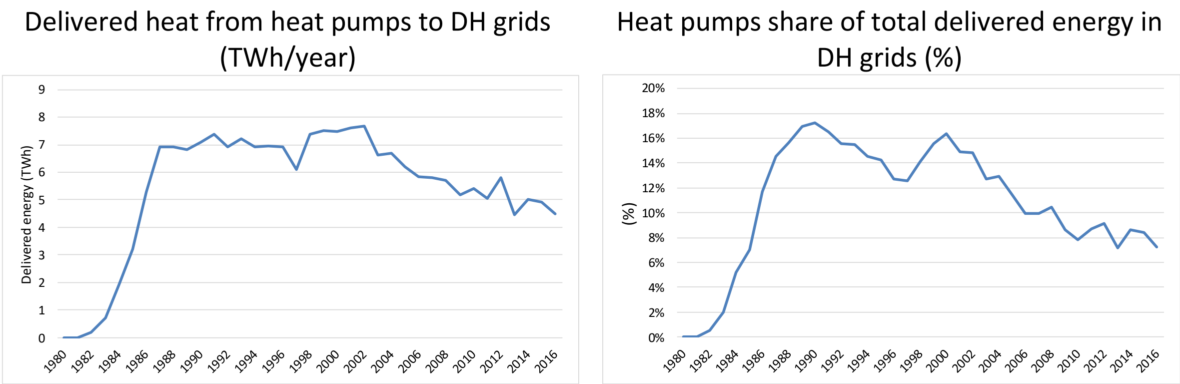

FIGURE 24. DELIVERED HEAT FROM HEAT PUMPS TO THE SWEDISH DISTRICT HEAT GRIDS IN TWH (LEFT) AND PERCENTAGE (RIGHT). DATA SOURCE: (ENERGIMYNDIGHETEN, 2018)

4.1 Market potential for Heat Pumps in district heating/cooling systems

One reason for the decrease of heat pumps in the district heating mix during the last year is the fuel and production prices in relation to the electricity price. The heat plants prioritise low production costs and other supply sources have become more competitive, especially CHP-plans using waste or biofuel has today low production costs compared to heat pumps. In the same time the total amount of delivered district heating has flattened or even decreased (Khodayari, 2018) (Averfalk H, 2017).

Thereby the interest today to increase the use of heat pumps from an economical point of view seems to be low, but this can change fast if the energy prices changes.

In an article Avefalk indicates that another reason for the decreased heat production with heat pumps in the grids is the replacement of CFCs and HCFCs as refrigerants due to their ozon-depleting potential. After the replacement mainly HFC-134a is used and the replacement of the CFC/HCFC refrigerant caused a decrease of the average heat production of 15-20% for large heat pumps in the district heating grids. (Averfalk H, 2017)

To make production of district heating via a heat pump economically feasible the combination of a low electrical price and high COP for the heat pump is needed. The heat pumps COP is dependent of the temperature of the heat source and the temperature lift needed. A warmer heat source gives a higher COP and a small temperature lift also gives a higher COP. Thereby a lower district heating temperature in the grids will make the heat pumps more efficient. A low district heating temperature also has other advantages like smaller heat losses to the ground.

For the future, low or ultra-low temperature district heating grids in combination with heat pumps can be an interesting solution. One Swedish example of an ultra-low grid is E.ONs ectogrid that is under construction in Lund (E.ON, 2018). Using a low temperature in the grid has several benefits like less losses to the surroundings and possibilities to use excess heat from sources with lower temperatures. Dependent of the temperature in the grid heat pumps will be needed for primarily production of DHW but maybe also space heating. The same approach can be used for using the district heating return flow as a heat source. The temperature in the return flow is many times high enough for space heating but to produce DHW a heat pump is needed to increase the temperature. (Lindahl, 2018) (Beiron, 2010)

A combination of district heating and heat pumps can also play an important role for increased flexibility in future smart electricity grids. In a future electricity system with a larger share of electricity from renewable sources, like wind and sun, the access (and most probably also the prices) of electricity will variate more. To have the possibility to either use heat pumps or combustion plants for production of heat increases the flexibility. The heat pump can then be located either in the district heating grid or at the end consumer.

Both ultra-low district heating grids and the use of the district heating for increased flexibility in the power grid demands heat pumps in combination with district heating to work. This kind of solutions can be one part of the key to reduce greenhouse gases emissions. They are still at the research or pilot stage, but when this kind of solutions becomes more common the potential for heat pumps in district heating grids will increase.

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