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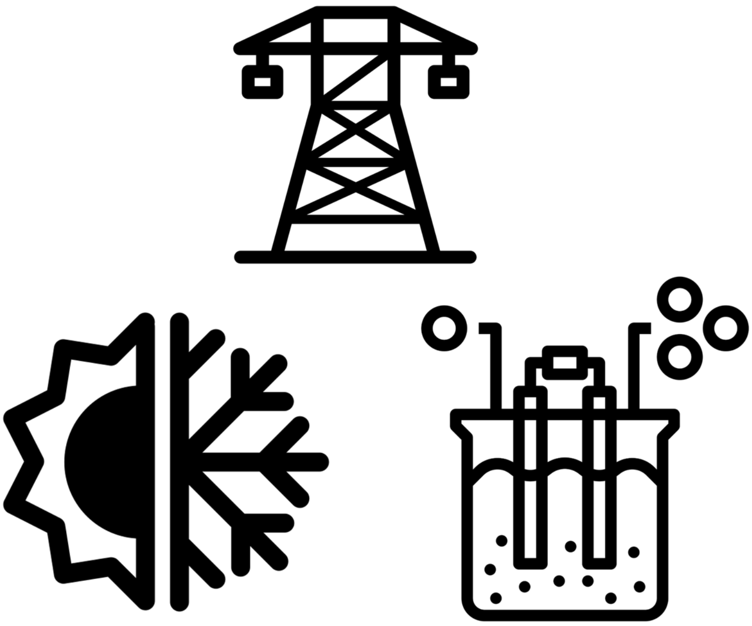
IEA DHC

INTERNATIONAL ENERGY AGENCY
TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING



IEA DHC ANNEX TS3: HYBRID ENERGY NETWORKS

APPENDIX F
COUNTRY REPORT SWEDEN

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CONTENT

1 INTRODUCTION

This Appendix is part of the IEA DHC Annex TS3 guidebook. The full guidebook is available at https://www.iea-dhc.org/the-research/annexes/2017-2021-annex-ts3

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THE OVERALL PICTURE

Sweden aspires to have net-zero carbon dioxide emissions by 2045 and the ambition is that 85% of the emission reductions should happen within Sweden. To achieve this, the goal is that by 2040 the electricity production should be 100% renewable and the energy use should be 50% more efficient by 2030 compared to 2005. (Government Offices of Sweden, 2016)

Today the share of renewables in the electricity system is already large, with 39% hydropower and 12% wind power in 2019. In addition to this, nuclear power supplied 39% of the power and conventional thermal power had a 10% share of the production in 2019. The wind power generation has seen a large increase in the last 15 years (Scb, 2020).

Sweden has a long tradition of district heating, where combined heat and power plants have played a large role in integrating the heat and power sectors. Alongside the district heating sector, heat pumping technologies have had an important role in the Swedish heating sector, both in the district heating systems and residential buildings (Johansson, 2021).

The future development of the Swedish energy system will depend very much on the development of electrification of both transports and industry. While the goal is to have 100% renewable power production by 2045, the mining and steel industries, located primarily in the north, have presented ambitious initiatives where they plan to make their processes carbon neutral through the use of hydrogen. The HYBRIT project alone, where the actors aim to produce fossil free steel, is expected to increase the power demand by 15TWh, almost 10% of the electricity use in Sweden (LKAB, SSAB, Vattenfall, 2020). The mining company LKAB states in its strategy that if fully developed, their new processes will require 55 TWh of electricity per year. (LKAB, 2020)

Today a large proportion of the power production from hydropower is located in the north and exported to the south. The vastly increased power demand in the north through industrial electrification may change this situation, adding further strain to the power system in the south where lack of power has already become a problem at times, highlighting the importance of power balance and available capacity.

A part of the solution to the balance and capacity issues could be a stronger integration between the power and heating sectors. The heating sector in Sweden already has a large share of electric heat pumps in residential buildings as well as power production potential and storage capacity in the district heating systems.

1 **The electrification of transport and industry will have a large impact on the power demand.** If fully implemented, the steel and mining industry could need over a third of the Swedish power production. Combined with electrification of the transport sector and an increased RES share, this will greatly impact the need for balance and production capacity.

2 **Extensive use of district heating provides large potential for integration of heat and electricity sectors.** The Swedish district heating sector is well developed and could provide balancing of the fluctuations caused by high share of variable renewable energy production from wind power, and cheap storage of energy through the use of heat storage systems.

3 **Market based interconnection to neighbouring countries.** The Swedish energy system is interconnected with neighbouring countries such as Norway, Denmark, Germany, Netherlands, which enables exchange of electricity and provides mutual system flexibility.

4 **Historic high degree of flexibility in the energy system from CHP plants and heat pumps.** Historically the district heating sector has been supplied to a large extent by highly flexible CHP plants. It is uncertain what role CHP will have in the future due to increased utilisation of excess heat from industries, electrofuel production, and geothermal processes. At the same time, heat pumping technologies are widely used in Sweden in residential buildings, providing further flexibility.

5 **Ambitious 2030, 2040 and 2045 energy and emission targets.** The Swedish government and political parties have agreed on net-zero emissions by 2045, 100% renewable power production by 2040, and 50% improvement of energy efficiency by 2030 compared to 2005.

A.1.1 KEY STATISTICS

After the oil crisis the Swedish district heating sector transitioned from being largely dependent on oil to other energy sources, mainly biomass, waste heat and heat pumps.

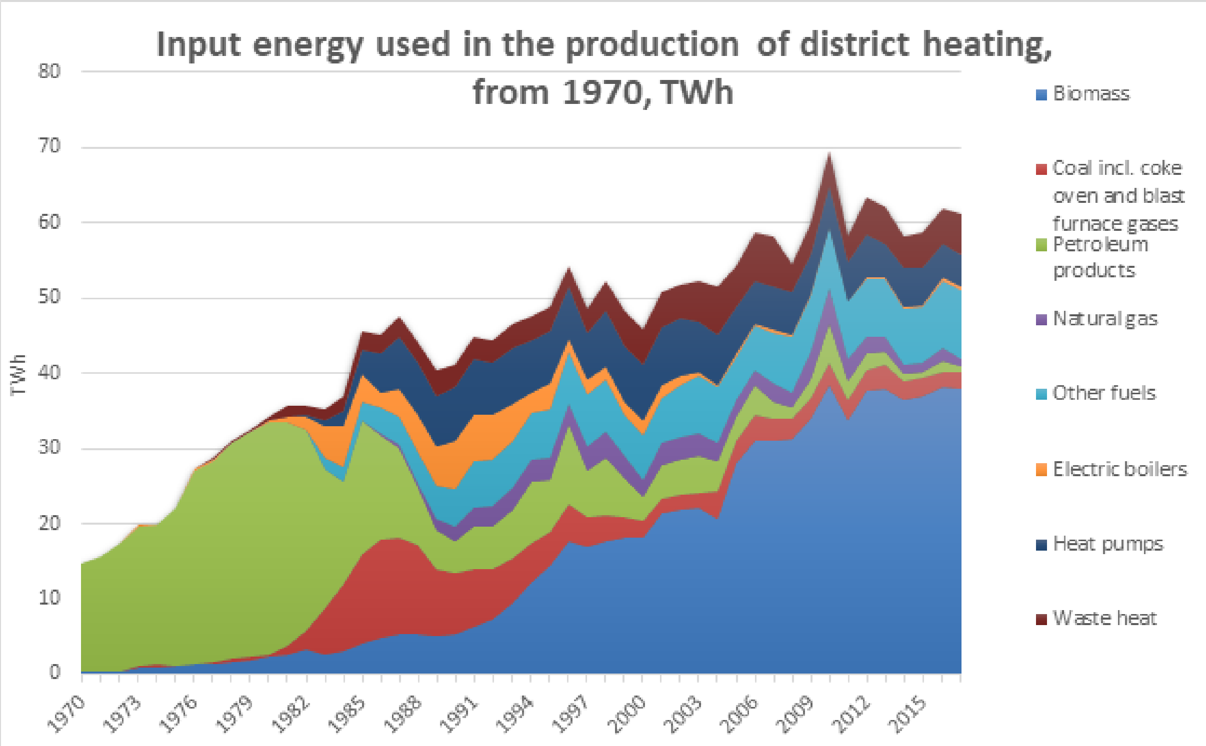

Figure 1 Input energy in district heating production in Sweden 1970-2016 (Swedish Energy Agency, 2021)

The power system on the other hand has for a long time been dominated by hydropower and eventually nuclear power. Since the early 2000s the share of wind power has increased and is expected to increase significantly in the coming years. In 2020 the share of renewables in the Swedish power production was 62 %, consisting mainly of hydropower, wind power and to some extent biomass CHP. Solar power contributes quite little to the share of renewables in Sweden, but increased by 70% between 2018 and 2019, the total number of systems in Sweden amounted to almost 44,000 with a total installed power of 698 MW. (Swedish Energy Agency, 2021).

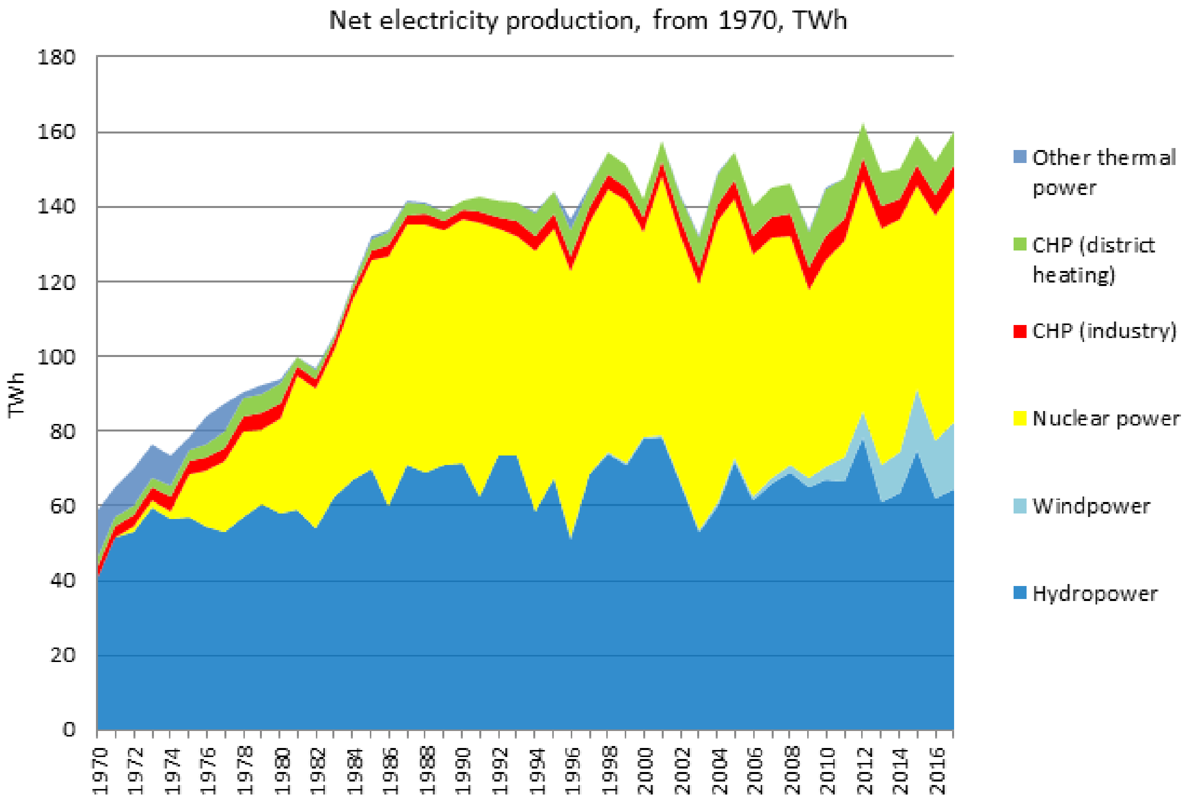

Figure 2 Net electricity production by source, 1970-2016 (Swedish Energy Agency, 2021)

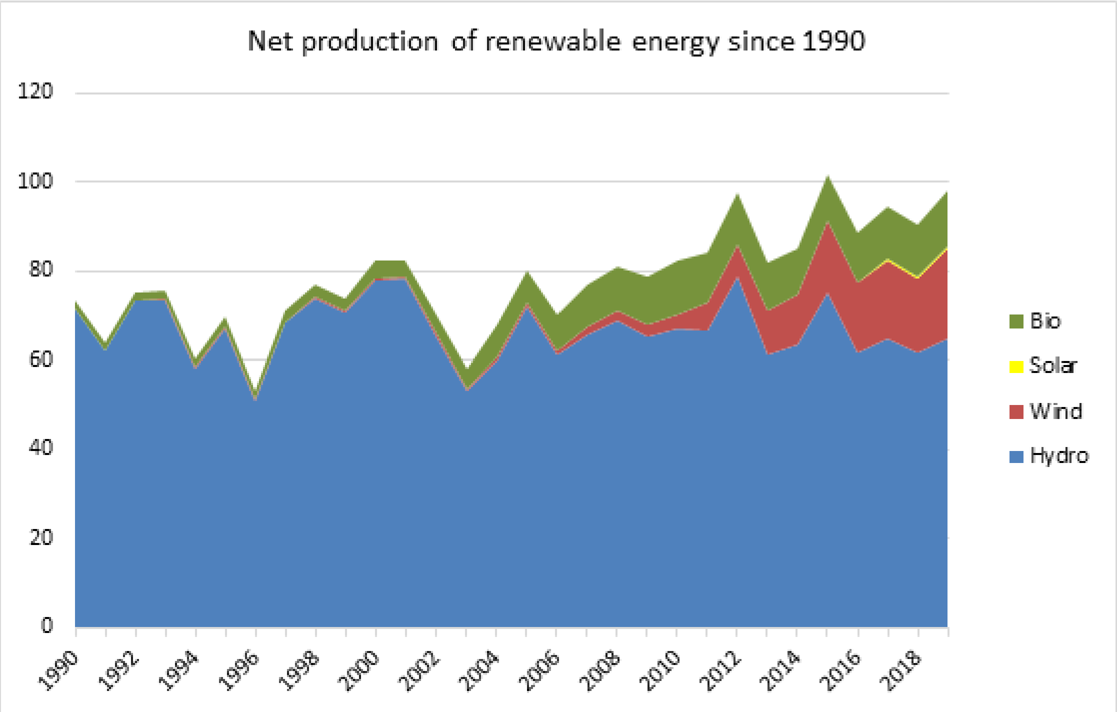

Figure 3 Net renewable electricity production 1990-2018 (Swedish Energy Agency, 2021)

The development of greenhouse gas emissions can be seen in Figure 5. The territorial CO_2 emissions in Sweden have been reduced by 29 % since 1991, when international transports are included (as in Figure 5), the decrease is about 20 %. The heating of buildings in the residential and service sector has seen a particularly large decrease (91 %) with the reduction of use of oil for heating purposes. The district heating and power sectors have also reduced their emissions by 39%. Other sectors have a longer way to go, both domestic and international transports are largely fossil based and although the industrial sector has reduced its emissions by 21%, more needs to be done to reach the climate targets.

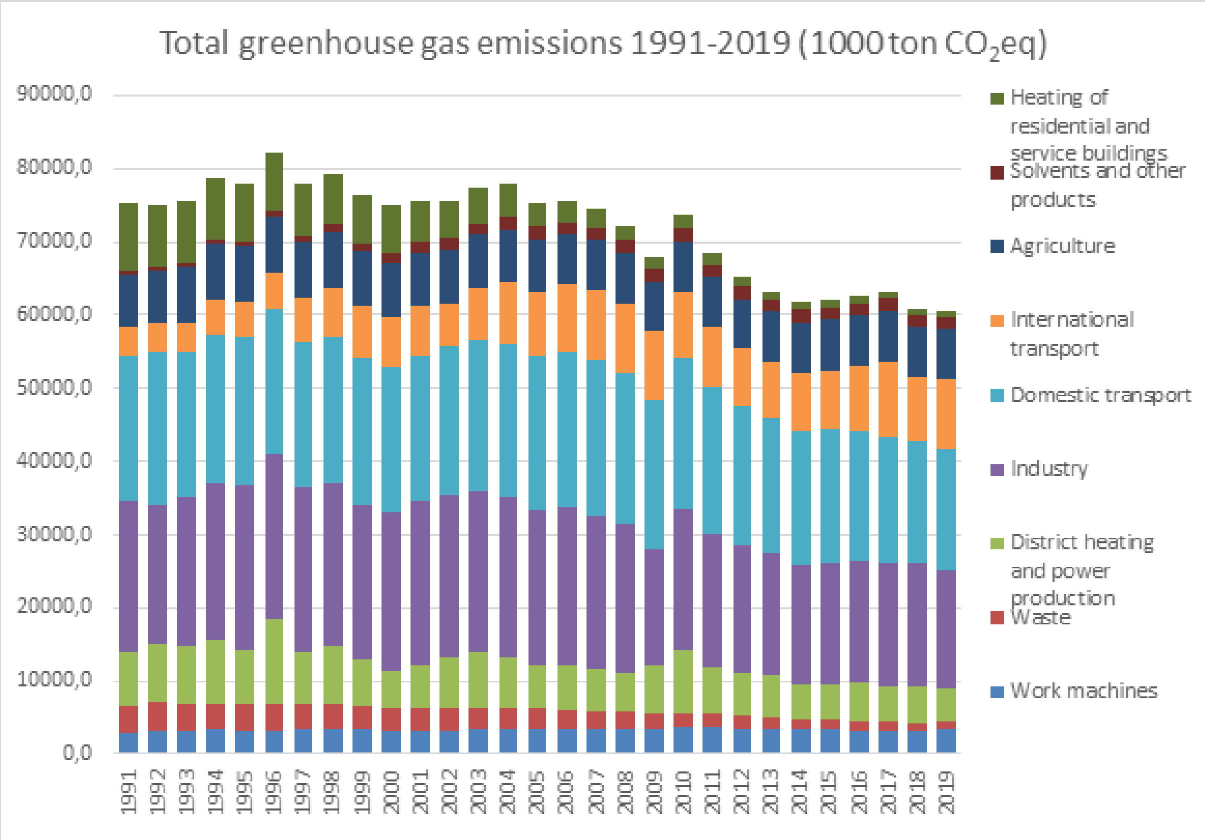

Figure 5: Total greenhouse gas emissions. 1991-2019 (The Swedish Environmental Protection Agency, 2021)

POLICY AND STRATEGY

Being part of the European Union (EU), Sweden is obligated to contribute to realizing the common European 2030 40% greenhouse gas emission reduction target. Sweden also aspires to have net-zero carbon dioxide emissions by 2045 and the ambition is that 85% of the emission reductions should happen within Sweden (Government Offices of Sweden, 2016). This chapter describes these targets in more detail and past and present initiatives to fulfil the targets.

A.1.2 POLITICAL GOALS AND AGREEMENTS

In June 2016 five out of seven parties in the parliament agreed on a long-term strategy for the Swedish energy system. This agreement set the target of net-zero emissions by 2045 and 100% renewable power production by 2040. In January 2018 the climate law was adopted, this law makes the current and future governments legally bound to drive policy that takes its stating point in the climate targets. A basic principle of the law is that climate targets and budget targets are to be given the prerequisites to work together.

According to the climate law the government needs to present yearly climate accounting in the budget bill. The a accounting should describe the development of the emissions related to the targets, most important decisions made in the past year and the subsequent impact on the development of the greenhouse gas emissions, as well as an assessment of the need for further measures.

Every four years the government also needs to produce a climate policy action plan. The purpose of the plan is to show how the government's climate policy in all relevant sectors contributes to the climate targets. If the assessment is that the current policy is insufficient, the plan needs to address the reasons and explain what further measures will be taken. The plan also needs to include how other decisions, both domestic and international, will impact the possibility to reach the targets (The Swedish Environmental Protection Agency, 2021).

TRENDS AND MODIFICATIONS REGARDING BUSINESS MODELS AND THE REGULATORY FRAMEWORK OF HYBRID NETWORKS

A.1.3 SUBSIDIES & LEVIES

In 2003 green certificates for renewable electricity production was introduced. The system is market based and since 2012 this market is shared with Norway. The green certificates are awarded to producers of renewable energy from wind power, some hydropower, some types of biomass, solar energy, geothermal energy, wave energy and peat in CHP. The system is constructed in a way that producers are awarded one certificate per MWh electricity produced, they can then sell the certificates and increase the profitability of their production. Retailers of electricity on the other hand are required to buy a certain quota of certificates in relation to how much electricity they sell, creating a market for the certificates. The quotas are adjusted yearly.

A.1.4 TAXES

The Swedish carbon tax was instituted in 1991 and it is levied on all fossil fuels in proportion to their carbon content as carbon dioxide emissions released in burning any fossil fuel are proportional to the carbon content of the fuel. The tax was introduced at a rate of 250 SEK (EUR 24) per tonne CO_2 emitted and it has gradually been increased. In 2021 the rate is 1200 SEK (EUR 114), based on exchange rate of SEK 10.49 per EUR. Industry outside the EU ETS has historically been charged a lower tax rate while industry covered by the system is entirely exempt from carbon tax. But things have changed and as of 2018, the industry rate outside the EU ETS is the same as the general rate. Combustion of sustainable biofuels are not subject to carbon taxation (Government Offices of Sweden, 2021).

Energy tax has also been used in Sweden since the 1990s and the use of electricity and fossil fuels used for engines and heating is taxed. For electricity the tax is paid by the consumer through the DSO and is a fixed tax per kWh of bought electricity. The energy tax is 0.45 SEK/kWh electricity in 2022. The tax applies also to e.g. heat pumps and other power to heat solutions.

The power and heating sector in Sweden was affected by removal of tax exemptions in August 2019. Fuels used in CHP's and other thermal power plants included in EU ETS now pays 91% carbon tax and full energy tax, which is a large change, especially for CHP's which previously paid 11% carbon tax and 30% energy tax. CHPs not included in the EU ETS is paying full carbon and energy taxes (Swedish Energy Agency, 2020).

In 2020 the Swedish Government introduced a tax on waste incineration which probably will reduce the waste incineration capacity over time. Tax should not be paid for hazardous waste, biofuels, animalistic byproducts or waste that is used in an incineration plant that mainly produce material, where waste is a part of the material production (Swedish Energy Agency, 2020).

A.1.5 KNOWN OBSTACLES FOR THE INTRODUCTION OF NEW OPERATION AND BUSINESS STRATEGIES FOR HYBRID NETWORKS FROM A REGULATORY POINT OF VIEW

The pricing policy of DH and in general the business of DH in Sweden has been the topic of intense discussion (Åberg, et al., 2020). The DH business has been under investigation in order to regulate how the DH businesses should be done, and how much revenue and profit such DH firms can gain is also controlled. This in turn, also impacts on the business models which are offered by DH firms to their different customers (Granström, 2011).

Currently, the business model prevalent in DH sector of Sweden, if analyzed through the lens of business value logic, is inherently that of a large technology-dominated service, with almost no servitization, and traditionally grounded and slow to react (Lygnerud, 2018). This is mostly because of the slow-moving nature of the industry, and as mentioned before, that the DH market consists of many small firms and is a natural monopoly, which is restricted geographically. But this is slowly changing, with competition from competing modular technologies such as heat pumps (Åberg, et al., 2020) and the gradual shift to providing heat as a service, which is brought on by the propagation of 4th generation DH (Ströby, 2020). This gradual shift to servitization also acts as a driver towards new business models in the DH sector, which are also possible due to hybrid energy system configurations in the Swedish energy system.

The price model of DH is an integral part of the DH business model, and recent studies show that it is dominated by energy and power related tariff structures (Li, et al., 2019). But studies in Sweden also show that DH firms are seeing the value of changing their business models and price models, especially given the flexibility provided by hybrid energy systems. For example, in (Kensby, et al., 2019), the calculations done on six archetypical Swedish DH grids show that increasing the temporal granularity of the pricing model for power to a commercial customer (owner of a multi-family housing building) was cost efficient for both DH company and the customer. This is possible through the flexibility that is provided by the customer, either by using the building's thermal inertia as heat storage or running the customer-owned heat pumps when the marginal cost of heat from the heat pumps is lower than the marginal cost of heat from the production units belonging to the DH grid. Such innovations are possible in hybrid energy systems. The flexibility and the ensuing cost reduction for both the customer and the DH firm are an essential driver for new business models.

Similarly, in (Ottosson, et al., 2020), multiple customer-side heating technologies are combined with archetypical Swedish DH grids, and the results show that there are cost benefits to both the customers and the DH firm in integrating flexibility-enabling technologies and thus resulting in hybrid energy systems. Even though the CHPs (on the production side of DG) and HPs (in the customer side) provide complex interactions with the electrical grid, most scenarios tested with multiple pricing models for power, heat and flow rate show net cost benefits for both the DH firm and the customer. The results also show that there are environmental benefits with lesser fuel and energy used, and more effective use of energy as a resource for both the customer and the DH firm, which also acts as a driver. Often, DH companies in Sweden have environmental goals related to energy resource use, which act as a driver for hybrid energy system implementations (Oskar Räftegård, 2013).

But the same complexity is a major barrier to the transition of business models which may facilitate hybrid energy systems. Also, the traditional nature and the way of doing business when it comes to DH in Sweden is a barrier to business model change.

Some policies in Sweden, regarding energy use in buildings may also acts an unintended barrier to business model change. Building energy efficiency measures is another aspect, where different building certifications, such as BREEAM-SE and Miljöbyggnad have defined levels of energy use to be certified (Boverket, 2020). The energy use is calculated according to Boverkets byggregler (BBR) where the different heat sources have different weight factors. Recent changes in Boverkets byggregler, BFS 2020:4, increased the competitiveness of DH. However, the COP of a HP only needs to be 2.57 on a yearly average basis for it to result in a lower energy use compared to DH. This takes away incentive for the customer to still maintain a business relationship with the DH firm or to buy heat from the DH grid. In addition to this, the Swedish government has assigned Boverket and Energimyndigheten (Swedish Energy Agency) the mission to evaluate additional requirements of the BBR to consider socio-economic aspects of energy use. It is of importance that not only the energy demand but also the power needed from the electricity grid is considered in the choice of heat source. In the future, with more congested power lines, it may be beneficial for business models to encourage hybrid energy systems, yet, policies such as those highlighted above may unintentionally stop the transition.

CURRENT ENERGY SYSTEM OF SWEDEN

This chapter provides an overview of the primary energy production technologies and energy demands in Sweden, with an outlook towards how the future energy system is expected to develop and how technologies should be integrated across different sectors and energy grids.

The final energy use is relatively evenly distributed between transports, industry and the residential and services sectors (which includes both residential housing and commercial buildings).

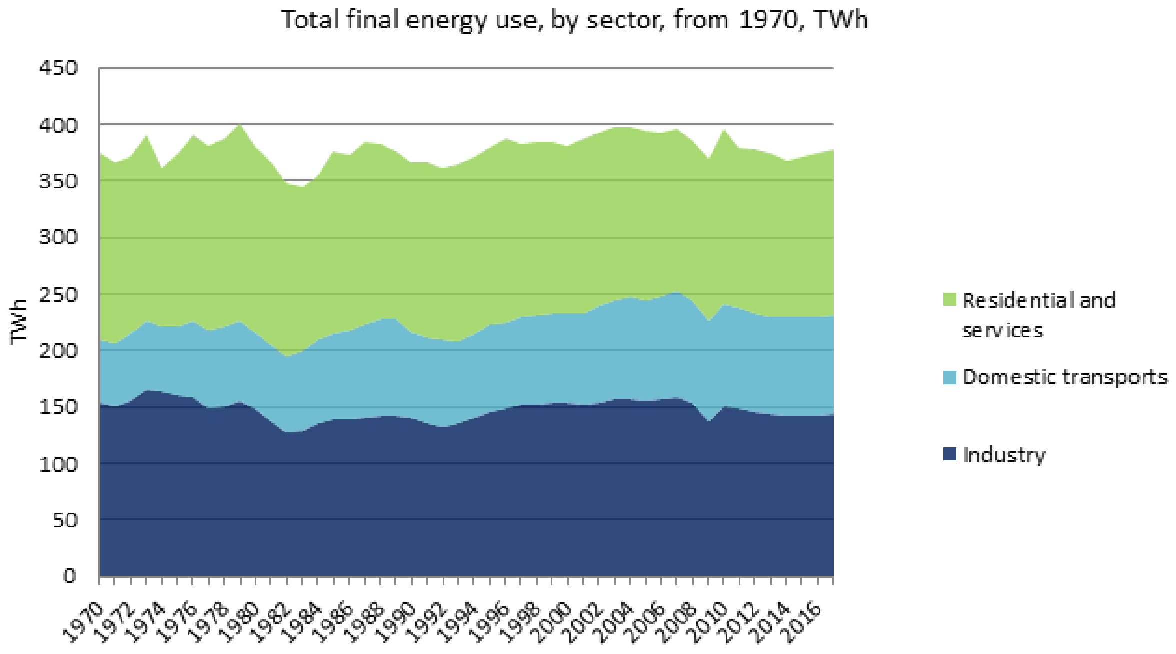

Figure 6: Final energy use per sector. (Swedish Energy Agency, 2021)

A.1.6 PRODUCTION OF ELECTRICITY, DISTRICT HEATING AND DISTRICT COOLING

An overview of the Swedish electricity production can be seen in Figure 7. The power production in Sweden is already mostly renewable or from nuclear power, resulting in low CO_2 emissions in an international perspective. The vast majority of the production is today supplied by nuclear power and hydropower, but there is an increasing share of wind power. Additionally some electricity is produced by CHP.

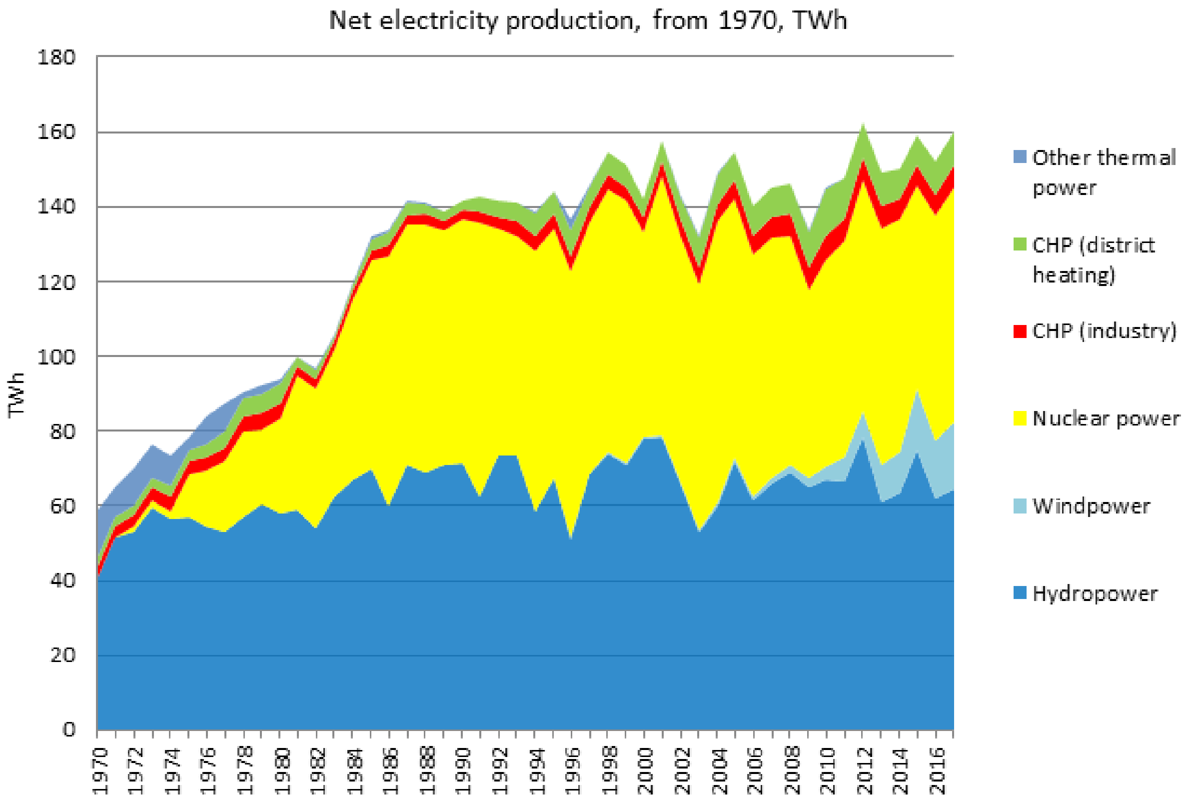

Figure 7: Net electricity production in Sweden 1970-2017 (Swedish Energy Agency, 2021)

The electricity system in Sweden is connected to neighbouring countries by electricity transmission lines. This enables export during high production hours and imports during low production hours. Sweden has large hydropower reservoirs and can supply neighbouring countries with power when e.g. the wind power production is low. In Figure 8 the total import and export from Sweden to neighbouring countries can be seen for 2010-2018, showing that Sweden is in total a net-exporter of electricity.

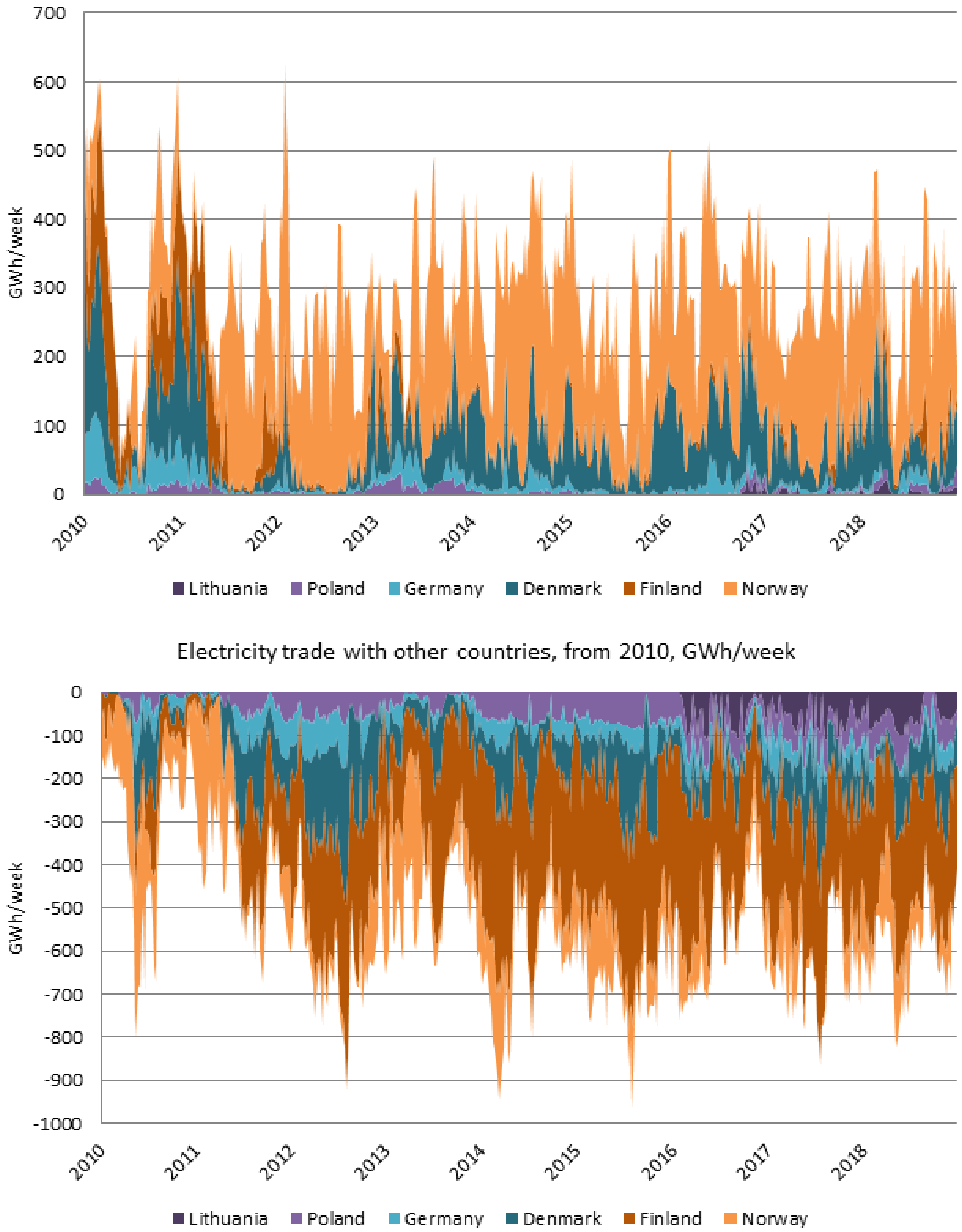

Figure 8: Import and export of electricity in Sweden (Swedish Energy Agency, 2021).

The Swedish district heating sector was dominated by oil in the 1970's but has since transferred to a mix of mainly biomass, waste, heat pumps, and waste heat. In 2018 62 % of the district heating was supplied by biomass. In 2002 the law was changed so that deposition of combustible waste was prohibited which increased the amount of heat from waste incineration. Waste is represented by both biomass and “other fuels” in Figure 9, since organic waste is classified as biomass and fossil waste as “other fuels”. While the amount of biomass used for district heating has increased remarkably since 1970, it may have reached a peak due to the competing needs for biomass from other sectors. The remaining petroleum products used in the district heating sector consists largely of peak load boilers.

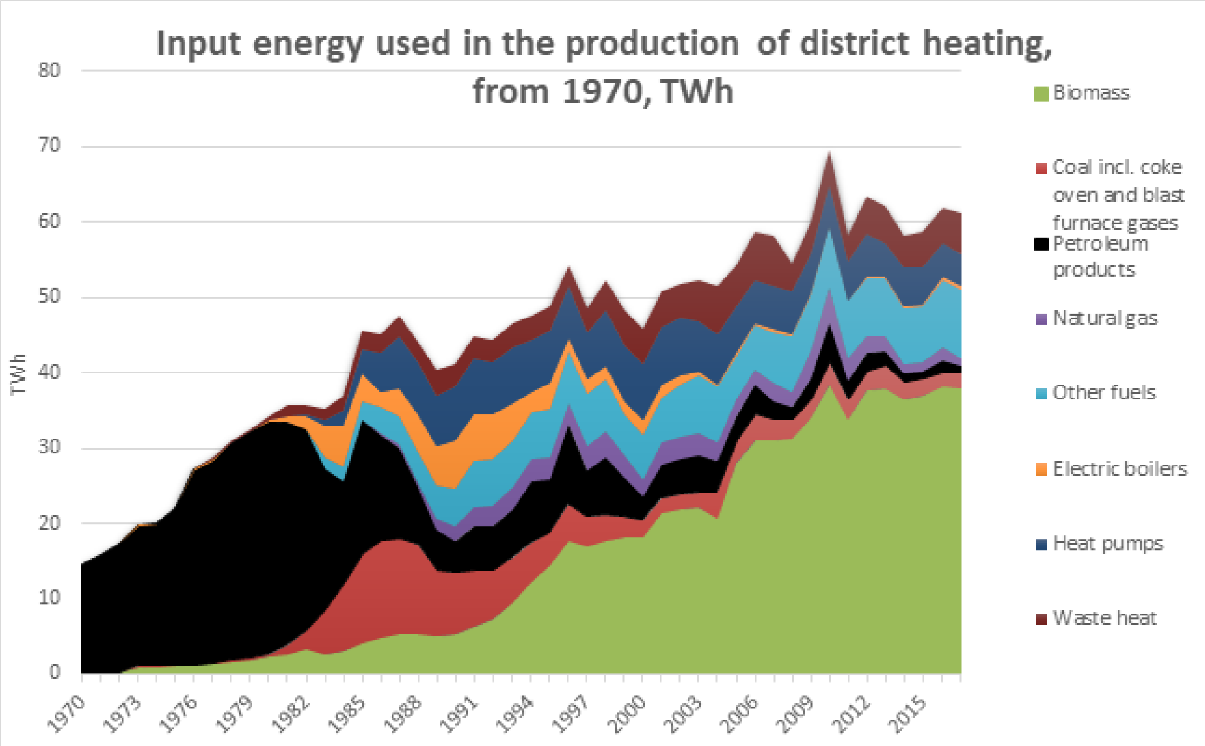

Figure 9: District heating production in Sweden 1970-2017 (Swedish Energy Agency, 2021).

A.1.7 ENERGY CONSUMPTION IN HOUSEHOLDS

In Sweden the energy used in households consists mainly of energy for heating and electricity. Gas for cooking is unusual. District heating make up a large part of the energy use in the residential and service sector. In buildings with individual heating, biomass and electricity (heat pumps and electric boilers) are dominating. The use of petroleum products for individual heating has decreased significantly since the 1970s, this development is mainly due to the expansion of heat pumps since 1990s. The reduction in energy use in this sector is related to both the switch to heat pumps from oil boilers and to energy efficiency measures in buildings (Swedish Energy Agency, 2020).

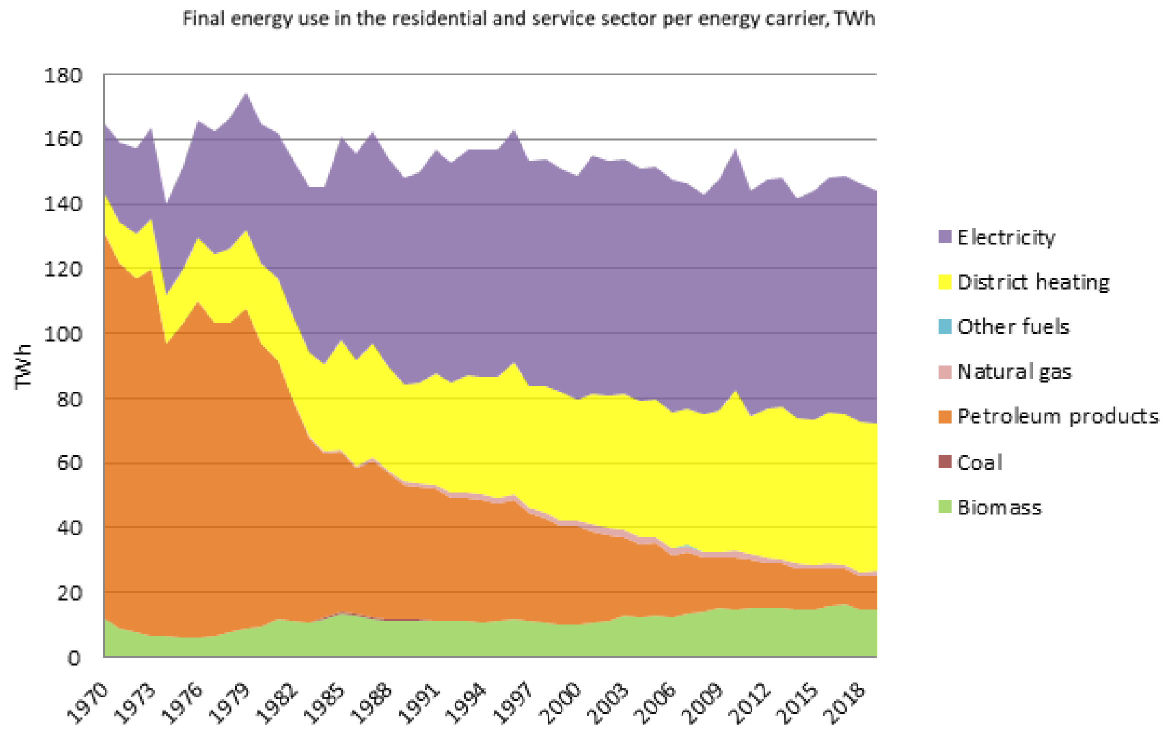

Figure 10: Energy consumption in the residential and service sector 1970-2018 (Swedish Energy Agency, 2021).

A.1.8 ENERGY CONSUMPTION IN TRANSPORT AND INDUSTRY

The transport sector is still largely dependent on fossil fuels. The share of biofuels (biodiesel, ethanol, biogas) has increased in the past 20 years. In 2018 21% of the energy used in the transport sector was from biofuels. The main increase is from biodiesel, but biogas also has a growing share. An important factor in the increase of biofuels is the law adopted in 2018 that states that all fuel producers need to reduce the emissions through mixing fossil fuels with a gradually increasing share of biofuels. In 2020 diesel needed to reduce emissions by 21% and gasoline with 4.2 %.

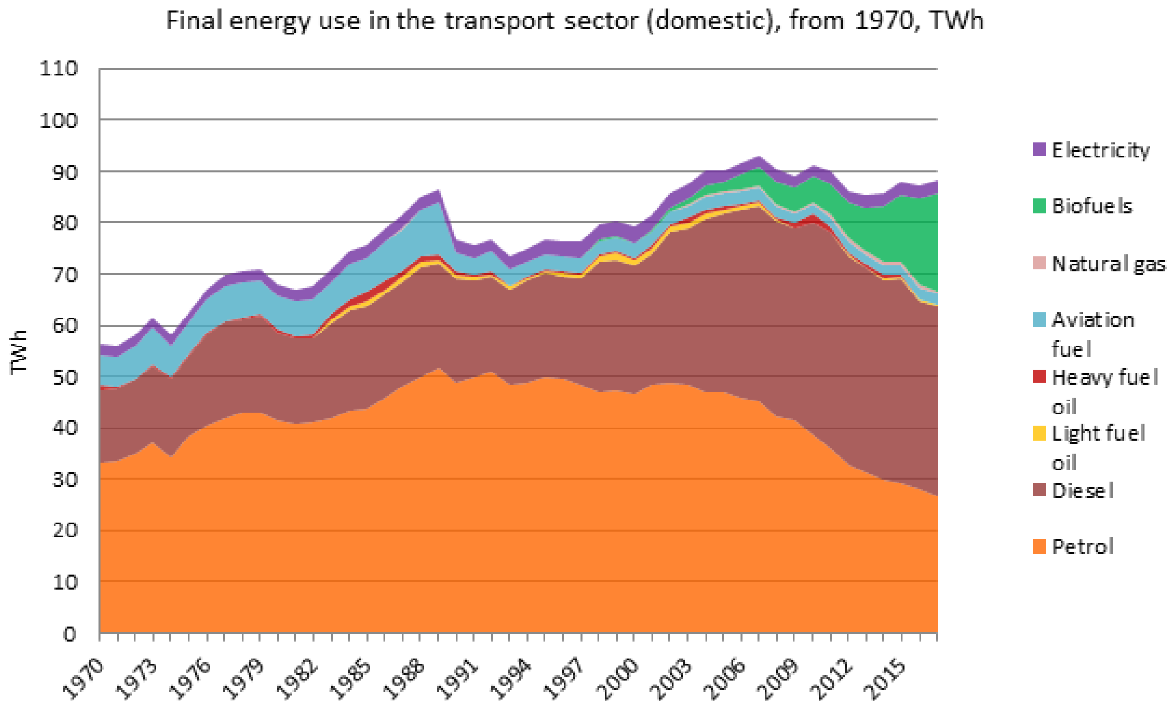

Figure 11: Energy consumption in the domestic transport sector (Swedish Energy Agency, 2021).

Sweden has large energy-intensive industries, the industry sector used 141 TWh of energy in 2018 (38% of the total energy used in Sweden) and especially the pulp and paper industry, iron and steel industry, and the chemical industry use large amounts of energy. The pulp and paper sector alone made up 51% of the total industrial energy use in 2018 (Swedish Energy Agency, 2020). While the pulp and paper industry use mainly biomass and electricity, the iron and steel industry use coal (8 TWh). Transitioning the steel industry to fossil free production through a shift to hydrogen from coal will require a significant amount of electricity. The total electricity use in the industry sector was 56 TWh in 2018 and the projected increased need for electricity for mining and steel industry could double that.

Biomass is the energy source that has increased the most since the 1970s, this mostly consists of a transfer from oil to biomass in the pulp and paper sector. The pulp and paper sector uses 90% of the biomass used by the Swedish industry sector.

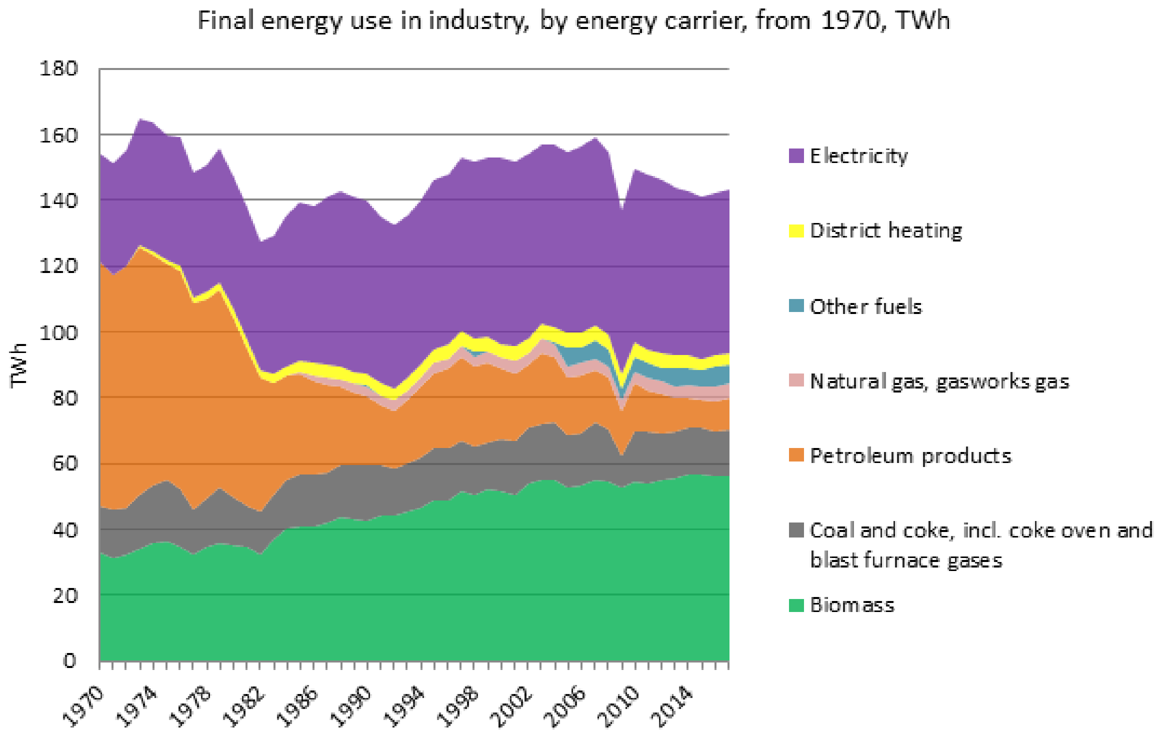

Figure 11: Energy consumption in the industry sector by energy carrier (Swedish Energy Agency, 2021).