Introduction and development of the Swedish district heating systems - Critical factors and lessons learned

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Critical factors and lessons learned

D5 of WP2 from the RES-H Policy project

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The RES-H Policy project

The project "Policy development for improving RES-H/C penetration in European Member States (RES-H Policy)" aims at assisting Member State governments in preparing for the implementation of the forthcoming Directive on Renewables as far as aspects related to renewable heating and cooling (RES-H/C) are concerned. Member States are supported in setting up national sector specific 2020/2030 RES-H/C targets. Moreover the project initiates participatory National Policy Processes in which selected policy options to support RES-H/C are qualitatively and quantitatively assessed. Based on this assessment the project develops tailor made policy options and recommendations as to how to best design a support framework for increased RES-H/C penetration in national heating and cooling markets.

The target countries/regions of the project comprise the Austrian regions of Styria and upper Austria, Greece, Lithuania, The Netherlands, Poland and the UK –territories that represent a variety in regard of the framework conditions for RES-H/C. On the European level the projects assesses options for coordinating and harmonising national policy approaches. This results in common design criteria for a general EU framework for RES-H/C policies and an overview of costs and benefits of different harmonised strategies.

This report

District heating systems (DH systems) can play an important role in increasing the use of RES for heating purposes, but also in reducing total primary energy demand. Due to economies of scale, the DH systems provide an opportunity of using deep geothermal heat as well as unrefined biomass (e.g. waste wood, straw, forestry residues) and municipal solid waste (MSW). The DH systems also enable the utilisation of surplus heat in industries (industrial waste heat) and thermal power plants via combined heat and power production (CHP), thus reducing primary energy demand. In Europe, DH systems are particularly common in Sweden, Finland, Denmark, the Baltic countries and Eastern Europe. This report focuses on Sweden, where district heating accounts for 50% of the delivered energy for heating of residential and non-industrial premises. Apart from the high penetration rate, the Swedish district heating sector is an interesting study object because of the transition from a near-complete reliance on oil to an energy supply with a high proportion of biomass.

The aim of this report is to describe the introduction and development of the Swedish DH systems and to identify what factors that have shaped this development. Elements that will be studied include for example the use of fuels and energy sources, CHP production, total DH supply, ownership and economics. Particular attention is paid to different policy incentives and regulations that directly or indirectly have influenced the DH systems. Non-policy factors that have shaped the district heating development are, however, also discussed. The main questions that are addressed in this report are:

- What policy instruments and regulations have promoted, or in other ways influenced, the expansion of the DH systems?
- What non-policy factors have influenced the expansion of the DH systems?
- What policy instruments and regulations have influenced the use of fuels and energy sources, RES in particular, in DH production?
- What non-policy factors have influenced the use of RES in DH production?

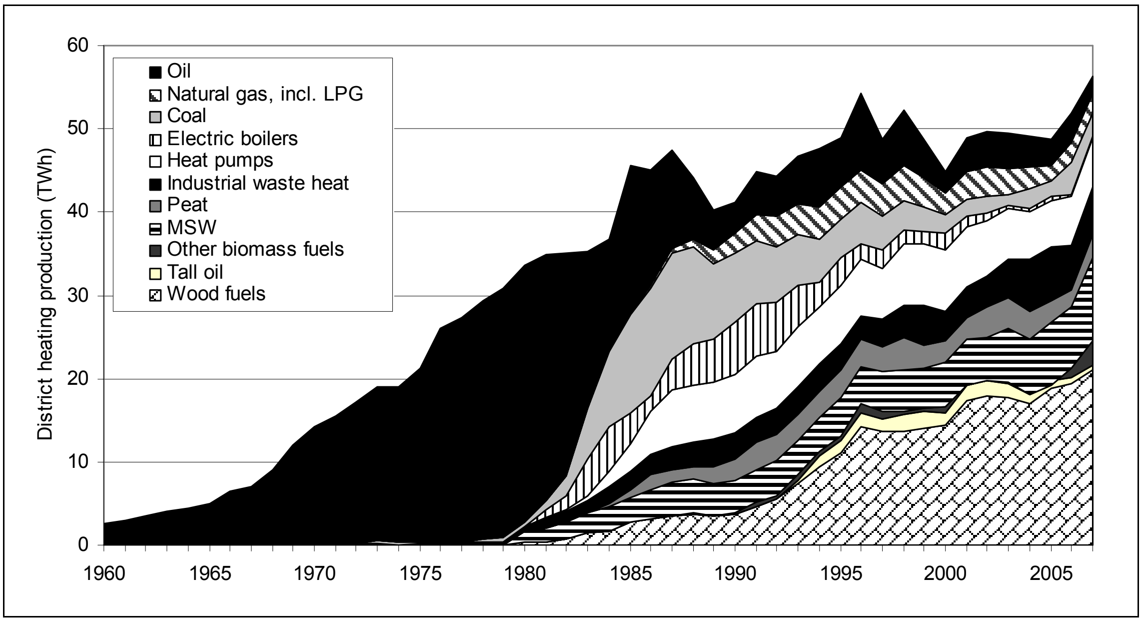
The work behind this report was mainly conducted through literature studies using government official reports, reports from the Swedish Environmental Protection Agency, the Swedish Energy Agency and the Swedish District Heating Association, and academic publications encompassing articles in scientific journals, reports and PhD theses.

1 Executive summary

District heating systems (DH systems) can play an important role in increasing the use of RES for heating purposes and in reducing overall primary energy consumption. In Europe, DH systems are particularly common in Sweden, Finland, Denmark, the Baltic countries and Eastern Europe. This report focuses on Sweden, where district heating accounts for 50% of the delivered energy for heating of residential and non-industrial premises. This aim of this report is to describe the introduction and development of the Swedish DH systems and to identify what factors that have shaped this development. These factors are also discussed in a European context.

The first DH system in Sweden was in operation in 1948, but the more rapid build-up of these systems started in the 1960s. Now virtually all Swedish towns have a DH system. District heating accounted for 86% and 69%, respectively, of the energy use for heating of multi-dwelling buildings and non-residential premises, while the corresponding proportion was 10% in one- and two-dwelling buildings Total DH production in 2007 amounted to 56,3 TWh (47,5 TWh was delivered) and was dominated by biomass, which accounted for 44% of the production (Figure 1).

Figure 1 DH production in 1960-2007, broken down into fuels and energy sources. The curves have not been corrected for outdoor temperature variations



Source: 1960-69: approximations from DHA (2001); 1970-2007: SEA (2008a)

For district heating to emerge in a particular setting requires the existence of an actor that is willing to make long-term investments and that this organisation has organisational resources to run the system. In Sweden, as well as the other northern or western European countries, the building of DH systems started from municipal initiatives. The initial DH utilities were managed by municipal administrations and were later transformed into municipally owned companies. Some of these have later been sold to large national/international utilities which now account for 42% of the DH the supply (in terms of energy) while the municipal energy companies are responsible for 58%. Another important factor to the establishing of DH systems is public perception. There has traditionally been a high acceptance for community-wide technical solutions in Sweden. District heating has also enjoyed a generally good reputation due to reliable supplies and competitive prices in relation to other heat options.

DH systems are inevitably associated with large investments, but a number of positive factors have motivated the building of these systems. In the 1950s and 60s efficient electricity production in CHP plants was the main motive for building DH systems. The first 10 DH systems in Sweden involved oil-fired CHP plants. Later on, as the DH systems expanded, the decision to build nuclear power and low electricity prices made investments in CHP production unattractive. The cogeneration potential in the Swedish DH systems has therefore in general been poorly utilised. However, a few years ago the interest for CHP returned as a result of increased electricity prices and the introduction of the Swedish scheme for tradable renewable electricity certificates in 2003. In 2007 the electricity production in the DH systems amounted to 7,5 TWh. Biomass and Municipal Solid Waste (MSW) accounted for 41% and 20%, respectively, of the production. In countries with a large fraction of the electricity production in condensing power plants, DH systems could play an important role in reducing the demand for primary energy resources. In many European countries this is probably the most compelling argument for building DH systems.

Apart from CHP, primary energy savings can also be achieved by utilising industrial waste heat, which has been the key driver for building DH systems in some Swedish towns. In 2007 the total utilisation of industrial waste heat in DH production amounted to 5,8 TWh. Much of the recovered industrial waste heat originates from forest industries, the dominant process industry in Sweden, but waste heat is also supplied by refineries, steelworks, chemical and food-processing industries, and one sugar mill. Hence, in other European countries which accommodate any of these industries there is likely to be industrial waste heat available. Another motive for investments in DH systems has been to improve air quality. The rationale for this is that it is easier and cheaper to control a few emission points than thousands of them. Positive effects on urban air quality were particularly noticeable in the 1960s and 70s.

The Swedish DH sector has played an important role in achieving national policy objectives since it has been able to quickly respond to government policies. In association with the oil crises in the 1970s DH systems proved to be an ideal object for oil replacement, the main objective of energy policy at that time. Until the late 1970s there was a near-complete reliance on oil in DH production. However, prompted by high taxes on oil products that were introduced in the 1970s, there was a major shift from oil to a variety of fuels and energy sources, for example coal, MSW heat pumps and industrial waste heat. A second major fuel shift was initiated in the early 1990s as a response to the energy tax reform in 1991. This reform strengthened the environmental profile of the energy taxation system by increasing the taxation of fossil fuels in heat production, mainly by the introduction of the carbon tax. The carbon tax was set to 250 SEK/tonne CO_2 (about 28 EUR/tonne) and has then been gradually increased, reaching 1010 SEK/tonne (101 EUR/tonne) in 2007. The energy tax reform greatly influenced the relative competitiveness of fuels, and immediately made biomass the cheapest fuel in heat production. As a result of the reform, the use of fossil fuels in DH production has been greatly reduced while that of biomass has expanded considerably reaching 24,2 TWh/y in 2007. Apart from the biomass expansion, there has been a great increase in waste (MSW) incineration in the past few years. This development has mainly been driven by the bans on landfilling combustible and organic waste.

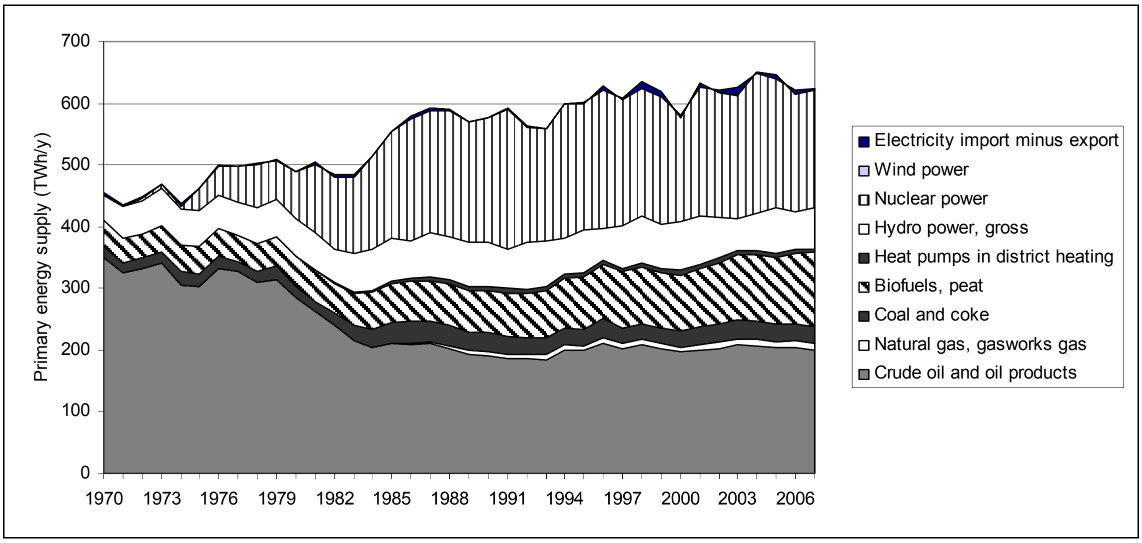
Hence, the Swedish DH sector has been able to accommodate large volumes of unrefined biomass and MSW, fuels that are inconvenient or inappropriate to use in individual heating. DH systems could in a similar way play an important role in increasing the use of biomass and waste for energy purposes in other European countries. These systems also enable the use of deep geothermal heat. Unlike Sweden many other European countries have very good geophysical conditions for deep geothermal heat, a largely untapped resource.

Electricity has been the major competing system to district heating in Sweden. In the late 1970s and 80s, low electricity prices and powerful electricity companies that marketed electric heating resulted in the installation of a great number of electric boilers and resistance radiators. Electricity is still the main competitor to district heating, but now in the form of heat pumps. Heat pumps and other forms of electric heating may also be the main competitor in some other European countries, while in others it may be natural gas. Natural gas was not introduced until 1985 in Sweden and has played a negligible role in heating of buildings. In many other European countries, on the other hand, natural gas is the dominant source of heating. Extensive natural gas grids that supply gas to buildings obviously pose a barrier to the introduction of DH systems, but nothing that can't be overcome.

2 Energy in Sweden and the policy setting

The structure of the Swedish energy system and the key features of energy policy provide the overall setting in which district heating has developed. The primary energy use per capita, and the electricity consumption in particular[1], is fairly large in Sweden compared to that in other EU countries. The main reason for this is the industrial structure and to some extent climate conditions. The Swedish energy sector has undergone major changes during recent decades (Figure 2). At the beginning of the 1970s oil was the dominant energy source, accounting for about 80% of the primary energy supply. Electricity production at that time consisted almost exclusively of hydropower. Since then oil consumption has been reduced by one third and nuclear power has come into operation, now accounting for about half of the electricity generation. In 1985 natural gas was introduced in Sweden, but it has so far made a fairly modest contribution to the total energy supply. The infrastructure for natural gas is restricted to the southwest of Sweden, stretching from Trelleborg via Malmö to Gothenburg. In the past couple of decades there has also been a considerable expansion in the use of biomass which now accounts for about 18% of primary energy supply (SEA, 2008a). Primary energy consumption increased in the 1970s and 80s as nuclear power production was introduced, but due to reduction in oil consumption final energy consumption has remained fairly stable over the past decades.

Figure 2 Total primary energy supply in Sweden 1970-2007



Source: SEA (2008a)

According to Vedung (2001) Swedish energy politics and policy from 1973 onwards cannot be understood without reference to the role played by nuclear power, something

1 The Swedish electricity consumption per capita is about double that of the EU average.

which has also had great implications on the district heating sector. Until the 1960s Swedish electricity supply relied heavily on the expansion of hydropower production. Due to the increasing controversy surrounding the exploitation of rivers for hydropower, attention turned to nuclear power. Twelve nuclear reactors were built and came online in 1974-1985. The nuclear expansion hence overlapped the oil crises and increased reliance on electricity became an important means of reducing the oil consumption. Already in the 1950s and 60s there was a growing awareness of the huge dependence on imported oil. This dependence was further highlighted during the oil crises, which made reduced oil consumption the main objective of energy policies in the 1970s and early 80s. The two main policy strategies adopted to achieve this were energy conservation and the replacement of oil with mainly domestic resources. DH systems proved to be an ideal object for oil replacement due to the opportunity to switch from oil to for example peat, waste, industrial waste heat, coal and biomass, thus prompting policies promoting expansion of DH systems. However, electric heating of buildings also expanded considerably in this period and became the main competitor to district heating due to the low electricity prices following the nuclear expansion.

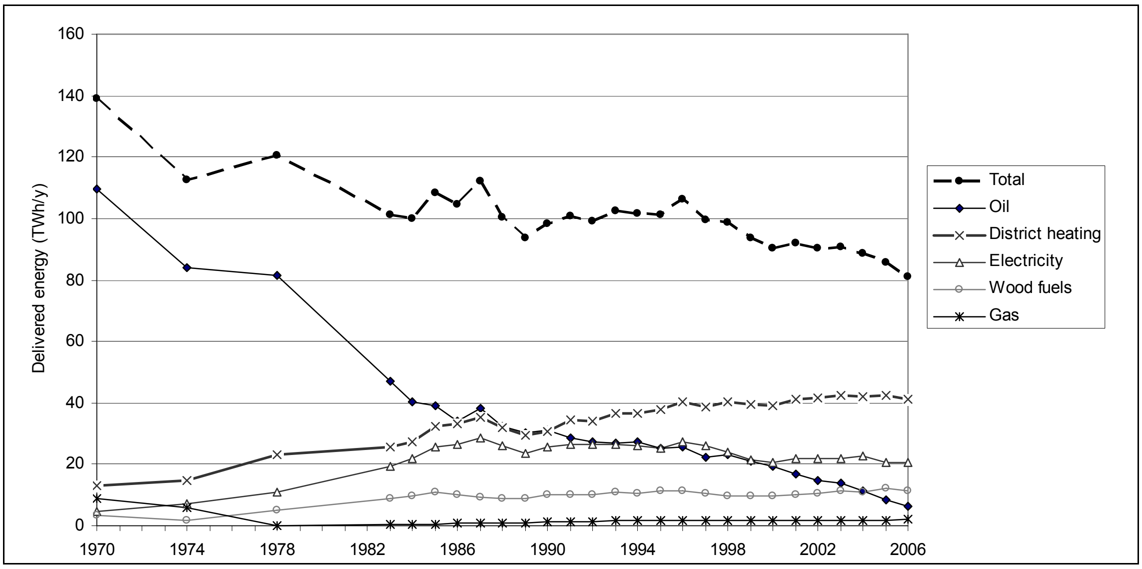
While Swedish nuclear power expanded, so did public resistance to its continued use. After a referendum in 1980 it was decided that nuclear power should be phased out by 2010. In 1988, after the Chernobyl accident the Swedish parliament decided to commence the phase-out in 1995. This decision was later reviewed and the dismantling of nuclear reactors was made contingent upon the availability of electricity from other resources. This was addressed by intensified RD&D efforts on electricity production from RES and investment subsidies targeting these technologies. In 1997 the final date for the phase-out (2010) was abandoned due to concerns over negative effects on the security and competitiveness of electricity supply, and hence Swedish industry. So far, two reactors have been shut down, one in 1999 and one in 2005, but the electricity production level has been sustained due to upgrading of the remaining reactors. In February 2009, the Swedish government made a proposal of permitting future replacement of the existing reactors, something that was previously prohibited.

Since the early 1990s, climate change mitigation and secure and competitive energy supply have been important policy objectives. In 1991 the energy taxation system was reformed and the carbon tax was introduced. As Sweden became an EU member state in 1995, EU energy and climate policies and legislation now frame Swedish energy policy. Another important event in the 1990s was the Swedish electricity market liberalisation in 1996, i.e. the separation of transmission and distribution from production and trade. Similar reform processes also took place in neighbouring countries, and electricity networks in northern Europe have gradually become more integrated. Today the Nordic countries (except for Iceland) share a common marketplace for electricity, Nord Pool where the prices are determined by the marginal production cost in the Nordic system (most often Danish coal-based electricity production). As a result of the reform and increased network integration with neighbouring countries, the electricity prices in Sweden have increased, and are now more in line with those on the continent.

3 Heating of buildings in Sweden

The heating of buildings mainly includes space heating and production of hot tap water. Figure 3 shows the heating of buildings in Sweden over the past 36 years, a development that can roughly be divided into three phases. Swedish statistics on heating of buildings include residential (one- and two-dwelling buildings and multi-dwelling buildings) and non-residential buildings, excluding buildings on industrial sites.

*Figure 3 Energy carriers delivered **for heating purposes** to one-and two-dwelling buildings and non-residential premises in Sweden for the period 1978-2006*



Source: Carlsson (1992) and SEA (2008b)

The *first phase, 1970-1985*, was a period of great changes. Most importantly, there was a significant shift from oil heating to district heating and electric heating (electric boilers or direct electric heating with resistance radiators). Prompted by oil substitution policies, the use of oil was reduced by almost a factor of 3 between 1970 and 1985 (SEA, 2008b). In the same period district heating increased from 12,9 to 32,3 TWh/y and electric heating from 4,6 to 25,5 TWh/y (ibid). District heating expanded in multi-dwelling buildings and non-residential buildings. Electric heating, on the other hand, expanded mainly in new one- and two-dwelling buildings. A great number of such dwellings were built in this period, most of which were equipped with resistance radiators which are cheap to install since they don't require central heating, i.e. a waterborne system. Another form of electric heating that emerged in this period is heat pumps, though the great demand for this heating equipment came later (this development is described by Nilsson et al. (2005)). The use of heat pumps complicates the interpretation of heating statistics. It should be noted that only the electricity consumed in heat pumps is included in the electricity supply for heating. Hence, the actual demand for heating is larger than the delivered electricity.

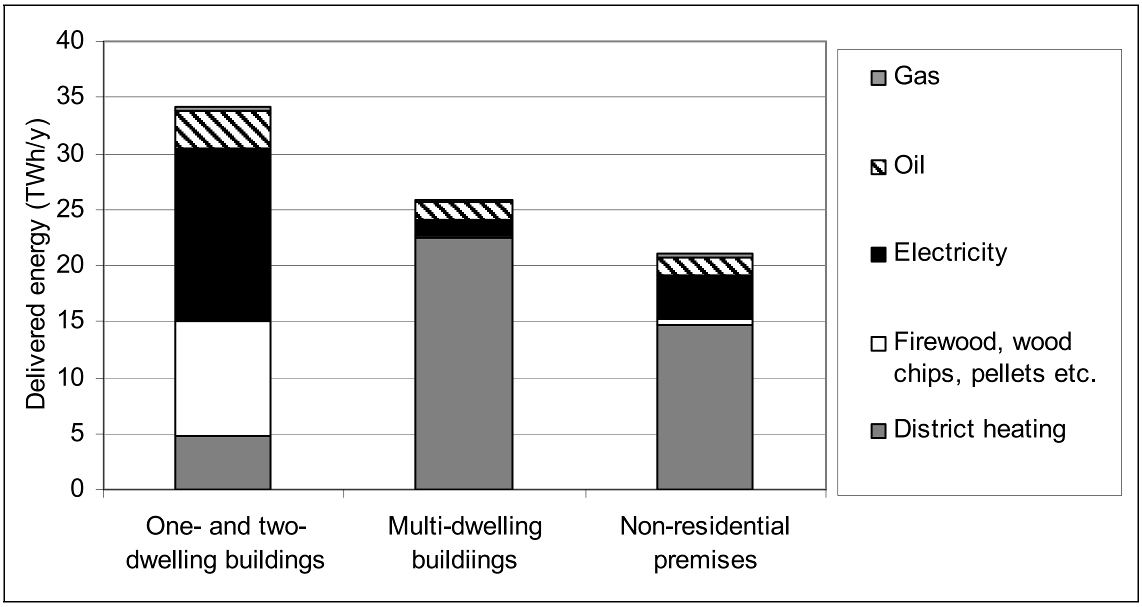
Building construction rates were high in the 1970s and early 80s (the floor area expanded by more than 30%), and this period is also characterised by improvements in the energy efficiency of buildings (Carlsson, 1992). Energy conservation measures that were undertaken include for example add-on insulation of buildings, draught-proofing of windows and optimisation of radiator systems. Partly as a result of these measures, the specific energy use for heating (kWh per m2) was roughly halved in this period. All this reduction should, however, not be ascribed to energy conservation measures or the addition of new more energy efficient buildings. Some of the reduction in specific energy use should be ascribed to the shift in heating systems. When shifting from oil or another fuel to district heating, the energy losses associated with the conversion from fuel to heat are transferred from the building to the DH utility. The shift from a fuel boiler to an electric boiler also reduces the energy delivered to the building due to the higher conversion efficiency of electric boilers compared to fuel boilers. Still, the fact that the specific energy use for buildings with a particular heating system was reduced confirms improvements in energy efficiency. For example, the specific energy use for multi-dwelling buildings with district heating was reduced by one third in this period (Werner and Sköldberg, 2007).

The second phase, 1985-2000, is characterised by constant specific energy use for heating. Energy conservation measures were undertaken, but most of the gains were balanced by an increase in room temperature and increased hot tap water consumption (Fröling et al., 2007). In this period district heating continued to steadily increase and flexible heating systems, such as multi-fuel boiler and heat pump in combination with another heat source, became popular.

The *third phase, 2000 and onwards*, involves some important shifts in heating systems. Oil heating has decreased significantly and is soon likely to be phased out. At the same time there has been a dramatic increase in the installation of heat pumps. Between 2000 and 2007, the number of one- and two-dwelling buildings with heat pumps increased from 119 000 to 658 000 (SCB, 2001 and 2009). In 2007 262 000 of the buildings accommodated ground-source heat pumps that utilise heat in surface soil, bedrock or water (lake, river). The remaining buildings accommodated air-sourced heat pumps. The use of heat pumps has also increased in multi-dwelling buildings, but still account for a small part of the heat demand in this building segment. While electricity consumption has increased in heat pumps, it has decreased in electric boilers and resistance radiators. In the 2000s there has been an increased use of wood pellets for heating, especially in one- and two-dwelling buildings where the use increased from 89 000 to 461 000 tonnes/y between 2000 and 2007 (SCB, 2001 and 2009). The total use of biomass, which mainly consists of fuel wood, has, however, remained fairly stable over the past decades.

In 2006 the energy delivered for heating purposes in the residential and service sector totalled 81 TWh (86 TWh if corrected for outdoor temperature variations) (SEA, 2008b). District heating was the most common type of heating and accounted for 50% (41 TWh) of the energy delivered for heating (SCB, 2008a). In addition, 7 TWh of district heat was used in industry, thus making total DH supply 48 TWh in 2007. Industry is, however, not included in the 81 TWh. The penetration rate of district heating varies greatly between different types of buildings (Figure 4). In multi-dwelling buildings and non-residential premises district heating accounted for 86% and 69%, respectively, of the energy delivered for heating purposes while the corresponding proportion for one- and two-dwelling buildings was 10% (SCB, 2008a). The most common heating system in one- and two-dwelling buildings is different combinations of heat pumps, which accounted for 32 % of the heated area.

Figure 4 Energy carriers delivered for heating purposes to one-and two-dwelling buildings, multi-dwelling buildings and non residential premises in 2006



Source: SCB (2008a)

4 Historical development and current status of the Swedish district heating sector

4.1 History in brief

The first modern DH systems were built in the US the 1880s and in Europe in a number of German cities in the 1920s. In Sweden, the first publicly owned district heating system was in operation in 1948 in Karlstad. Before that, a few small, non-public systems that distributed heat to a hospital or a small group of multi-dwelling buildings were in operation. After Karlstad, the cities of Malmö and Norrköping started to build DH systems in 1951, Gothenburg, Sundbyberg and Stockholm in 1953, and Linköping and Västerås in 1954. The more rapid development, however, started in the 1960s (Werner, 1989), after which the heat deliveries have continued to grow although with a declining growth rate in the past 10-15 years. Now, virtually all towns/cities in Sweden have a DH system. District, heating is the dominating form of heating in multi-dwelling and non-residential buildings in the main town (administrative centre) of 247 of the total 290 municipalities in Sweden (Wirén, 2008). The municipalities have played an important role in the development of district heating in Sweden. The building of the first DH systems was organised by the municipal administrations which initially ran the DH utilities. These utilities were then transformed into municipally owned companies, some of which have later been sold to large national/international energy companies. The municipal engagement in district heating was natural considering that many of the municipalities were already responsible for local electricity distribution, sewage and water supply - other technical infrastructures. The municipalities also own many buildings which need heating. Sweden has a tradition of strong local government, and the municipalities have financial resources since they are allowed to tax the inhabitants.

Despite the large investments associated with the distribution system, the following positive factors motivated such investments (Johansson et al. (2002) adopted from Werner (1989)):

- The opportunity to produce electricity cheaply and efficiently in CHP plants.
- Economy and fuel flexibility (cheap heavy oil could be used instead of expensive light oil; otherwise unusable heat sources, such as industrial waste heat, could be utilized; economy of scale makes the specific investment in production units smaller)
- Efficiency (professional maintenance is affordable at large plants; technological scale effects)
- Environment (economy of scale in emission control)

From a consumer perspective, district heating was, and often still is, attractive due to convenience and competitive prices in relation to other heat options. On the down side is the monopoly position of the DH supplier. Due to the large capital costs for infrastructure, the distribution of district heating has the features of a natural monopoly. Hence, there is only one supplier of district heat at the local level. The district heating supplier does, however, not have monopoly on heat since DH customers have the possibility to disconnect and shift to another heat source.

District heating was first developed in densely populated city centres and areas with many multi-dwelling buildings. The introduction of district heating was facilitated by the fact that after the Second World War many buildings have gradually become equipped with central heating, i.e. a water-based heat distribution system. In 1945 the proportion of buildings with central heating was 46%, which had increased to about 96% by 1975 (Werner, 1991). Public buildings such as schools and hospitals, as well as multi-dwelling buildings owned by municipal housing companies, often provided an initial basis for heat supplies. Currently 86% and 69%, respectively, of energy delivered for heating purposes to multi-dwelling buildings and non-residential premises is district heating (SCB, 2008a). Due to its high penetration rate in these market segments, the potential for expansion in these original markets is rather limited. In recent years areas with a lower heating density have been connected, which is partly due to investment subsidies and local initiatives. Depending on the source of heating replaced, the advantages of this would be better urban air quality, lower CO_2 emission, or less pressure on the electricity supply. Also, a larger number of customers would increase the total heat load and thus the potential for CHP.

The early DH systems involved oil-fired CHP plants, which were in fact old retrofitted condensing power plants that had previously served as reserve and peak load to complement hydropower (Werner, 1999). Apart from the early phase in the 1950s and 60s, the opportunity to produce electricity has been poorly utilised in the Swedish DH systems (see Section 4.5). An important driver and effect of the expansion of DH systems in the 1960s and 70s were improved urban air quality (ibid). The improvements were, however, not only a result of better emission control, but also of tall chimneys. Initially the fuel was almost exclusively heavy fuel oil, which was cheaper than the light oils used in small boilers, but since the early 1980s profound changes have taken place with regard to energy inputs to DH systems (see Section 4.3).

4.2 Ownership

There has been a great transformation in the ownership of DH utilities, something that may have implications on future DH tariffs and infrastructure development. Initially, most local DH utilities were run by the municipal administrations, but most of them have now been transformed into municipal energy companies, which act more freely and with less political control. In 2004 utilities owned by municipal administrations accounted for only 2% of district heating supply (Andersson and Werner, 2005). From the early 1990s and onwards, a considerable number of municipal energy companies have been sold to large national (and international) energy companies. In 2004 municipal energy companies accounted for 58% of the district heating supplies in terms of energy and national/international companies, consisting of Vattenfall, E.on and Fortum, for 39% (ibid). After the deregulation of the energy markets some municipal companies have developed into regional companies (still referred to as municipal companies) by acquiring other municipal companies. For many municipalities the decision to sell the municipal energy company was founded on financial problems which many Swedish municipalities struggled with in the 1990s. For others, the decision was founded on the political difficulty of running the energy company in a business-like fashion something that was required after the 1996 deregulation of the energy markets (electricity and district heat) in Sweden (see Section 5.1. Mårtensson and Fredriksen (2005) suggest that municipal authorities may be tempted to sell their DH utility (at market price) if they for political reasons are unable to set the “correct” DH tariffs.

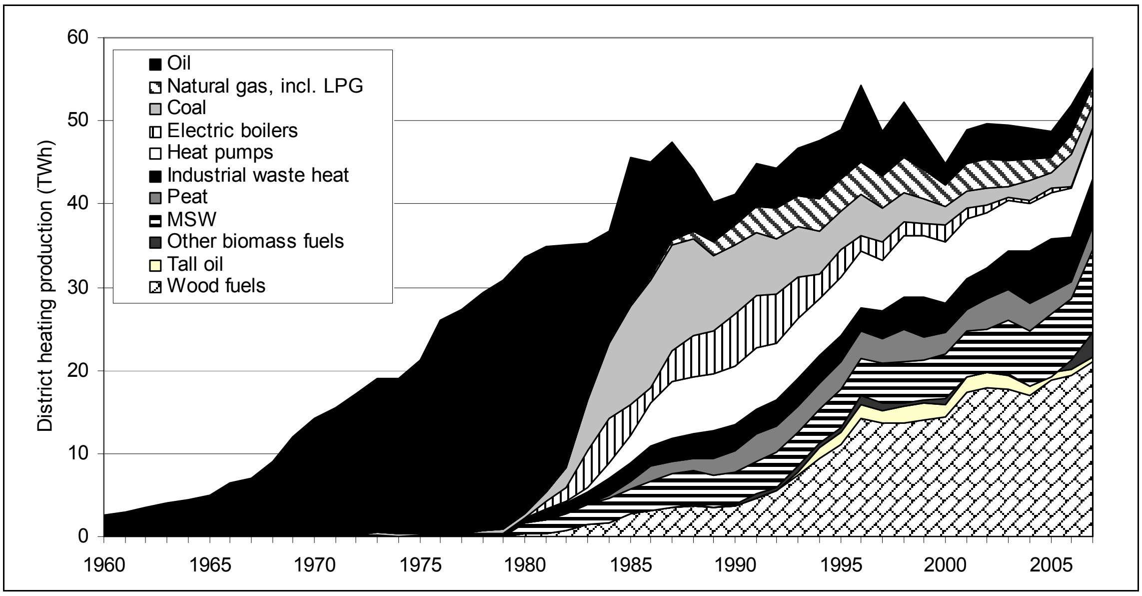
It is difficult to say whether the transformation in ownership has influenced the investments in DH systems. Assuming the large national/international energy utilities apply shorter payback periods on investments than municipally owned companies would imply a decrease in the investments in the DH sector over the past 10-15 years. This may be the case, but it's not evidently so since the large energy utilities, as well as the municipally owned companies, have made investments in DH systems, either by expanding existing ones or by building new systems.

4.3 Fuels and energy sources

There have been profound changes over the past decades as regards fuels and energy sources in the DH systems as a response to changes in relative energy prices, including the effects of policies (Figure 5). Until 1980 there was a near-complete reliance on oil in DH production, after which there has been a major shift to a variety of fuels and energy sources. In the 1980s oil was replaced by solid fuels including biomass, peat, municipal solid waste (MSW) and especially coal. Electric boilers and large heat pumps also began to be installed in this period. In 1985 natural gas was introduced in Sweden and entered DH production. In the 1990s many of the coal-fired plants were converted to biomass which expanded considerably and have continued to do so ever since. Apart from the biomass expansion the 2000s is characterised by a considerable expansion in the use of MSW and the near phase-out of electric boilers.

The biomass expansion in DH production was particularly rapid in the early 1990s as the carbon tax was introduced, increasing from 3,9 TWh/y in 1990 to 17,0 TWh/y in 1996. The use of biomass has continued to increase, although more slowly, and reached 24,2 TWh/y in 2007 (SEA, 2008a). The biomass use consists mainly of wood fuels (37% of the total energy supply), such as forestry residues and waste wood (e.g. demolition wood and loading pallets) and wood pellets. The remaining biomass is mainly tall oil, a by-product from pulp production. The biomass has for the past 10-15 years included both domestic and imported fuels. The biomass imports emerged in the early 1990s as a result of the high biomass demand in Sweden compared to that in other countries. The biomass imports comprised e.g. wood fuels from the Baltic countries, wood pellets from Canada, and waste wood and other waste from Germany and the Netherlands. The imports were estimated to be 3-4 TWh/y in 1995 (Vinterbäck and Hillring, 2000), 6-9 TW/y in 1997 (ibid) and 5 TWh/y in 2000 (Ericsson and Nilsson, 2004). The biomass imports have continued since then and are likely to be in the same order of magnitude as previously, or possibly smaller, although there is no recent estimate that can confirm this. Parallel to the biomass expansion, there has been a significant expansion in the incineration of MSW, particularly in the past 5-10 years. Between 2001 and 2007 the DH production from MSW increased from 5,5 to 9,9 TWh/y (SEA, 2008a).

Figure 5 DH production in 1960-2007, broken down into fuels and energy sources. The curves have not been corrected for outdoor temperature variations



Source: 1960-69: approximations from DHA (2001); 1970-2007: SEA (2008a)

In the past decades there has also been a continuous increase in the utilisation of industrial waste heat which increased from 0,6 to 5,8 TWh/y between 1980 and 2007 (SEA, 2008a). A significant part of the industrial waste heat is supplied by pulp and paper mills which is the dominant process industry in Sweden. Apart from the pulp and paper mills, industrial waste heat is also supplied by some chemical and food processing plants, steelworks, refineries and one sugar mill. Industrial waste heat often plays a prominent role in the DH systems where it is used, especially in some small towns. Industrial waste heat is, however, also important in some larger towns such as Gothenburg where industrial waste heat from two refineries account for 28% (1,1 TWh/y, 2007) of the district heating supply.

The use of fossil fuels has been substantially reduced since the early DH production and accounted for 7,2 TWh/y of the DH production in 2007 (SEA, 2008a). The coal that remained (2,9 TWh/y) was co-fired with biomass, mainly in order to improve combustion properties. Peat is often used for the same purpose. Oil on the other hand is nowadays only used for *peak load,* i.e. on the coldest days of the year. The base load capacity generally consists of industrial waste heat and/or heat from MSW incineration plant, and after (or if these energy sources are unavailable) biomass-fired CHP production or heat pumps. Base load heat production is characterised by low running costs and high capital costs.

In 2007 the DH production amounted to 56,3 TWh, 5,2 TWh of which was lost in the distribution (SEA, 2008a). The energy supply was dominated by biomass, which accounted for 24,6 TWh (44%) of the production. The remaining production was based on 9,9 TWh of MSW (18%), 5,8 TWh of industrial waste heat (10%), 2,9 TWh of coal (5%), 2,0 TWh of oil (4%), 2,3 TWh of natural gas (4%), 2,8 TWh of peat (5%), 0,2 TWh of heat from electric boilers (0,4%) and 5,8 TWh of heat from heat pumps (10%) (ibid). The large heat pumps have a capacity of up to 40 MW and are often located at waste water treatment plants using municipal or industrial waste water as heat source. The use of RES mainly consists of biomass, but also includes 5 TWh of MSW, assuming the biodegradable part accounts for 50% of the total MSW (the default value in Eurostat statistics). In addition, about 1,5 TWh of the heat from heat pumps is classified as geothermal heat with account to the classification in the proposed RES Directive (SEA, 2008c). Solar thermal makes a negligible contribution to the DH production. In all RES accounted for 31,1 TWh (55%) of DH production in 2007.

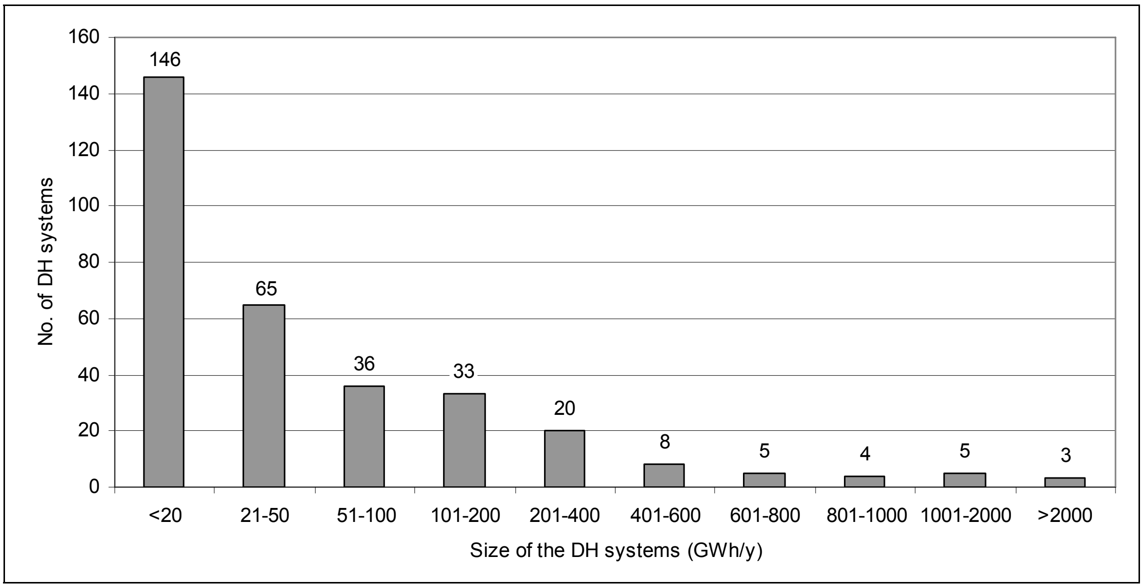
4.4 Distribution of district heat

Swedish DH systems are built as closed systems that are separated from the heating systems of the buildings by an intermediate heat exchanger (substation). The district heat is distributed in the form of hot water which circulates through the pipelines in the DH systems and is returned to the plant for reheating and redistribution. It is also possible to use steam as heat carrier. In Sweden, steam is only used as heat carrier in a few cases which involve CHP plants that supply steam to industries (Werner, 1991). Internationally, steam is completely or partly used in the DH systems that were built before approximately 1940 (Werner, 2004). The heat losses are greater when using steam as heat carrier, and the temperature of the forward water should in general be as low as possible in order to minimise heat losses. The temperature of the forward water in the Swedish DH systems varies between 70 and 120°C depending on the heat load demands. The highest temperature is used in the winter and the lowest during summer. The temperature of the return water varies between 40 and 65°C.

The Swedish DH systems contain a mix of three generations of distribution pipes which are described by Werner and Sköldberg (2007). The first-generation pipes were double steel pipes insulated with mineral wool that were laid in a common concrete square box duct. These pipelines were expensive to build but reliable. In the 1960s, steel pipes in separate asbestos cement casings were introduced. These second-generation pipes were less expensive and less reliable. The third-generation pipes were introduced in the 1970s and are now the dominating type of pipes in Swedish DH systems. They consist of prefabricated steel pipes with polyethylene casings and are insulated with polyurethane foam. The Swedish DH systems are on the whole in good conditions according to Werner and Sköldberg (2007).

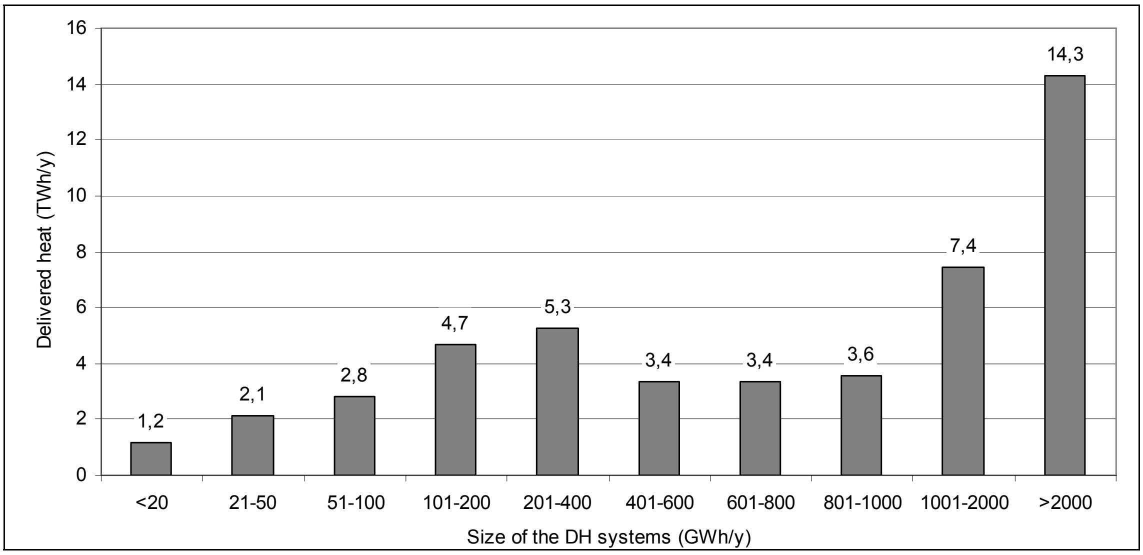
The size of DH systems varies greatly with an annual heat load that ranges from a few GWh to more than 8 TWh (Stockholm). There are a great number of small DH systems (Figure 6). In fact, 146 of the total 325 DH systems have an annual heat load of less than 21 GWh. Despite their great number they only account for about 2% of the total DH supply (Figure 7). In contrast, the eight largest DH systems account for almost a third of the total DH supply.

Figure 6 Distribution of the number of DH systems between different size ranges based on the annual deliveries of district heat in 2005



Source: DHA (2008)

Figure 7 Distribution of the DH production between different size ranges of the DH systems based on the annual deliveries of district heat in 2005



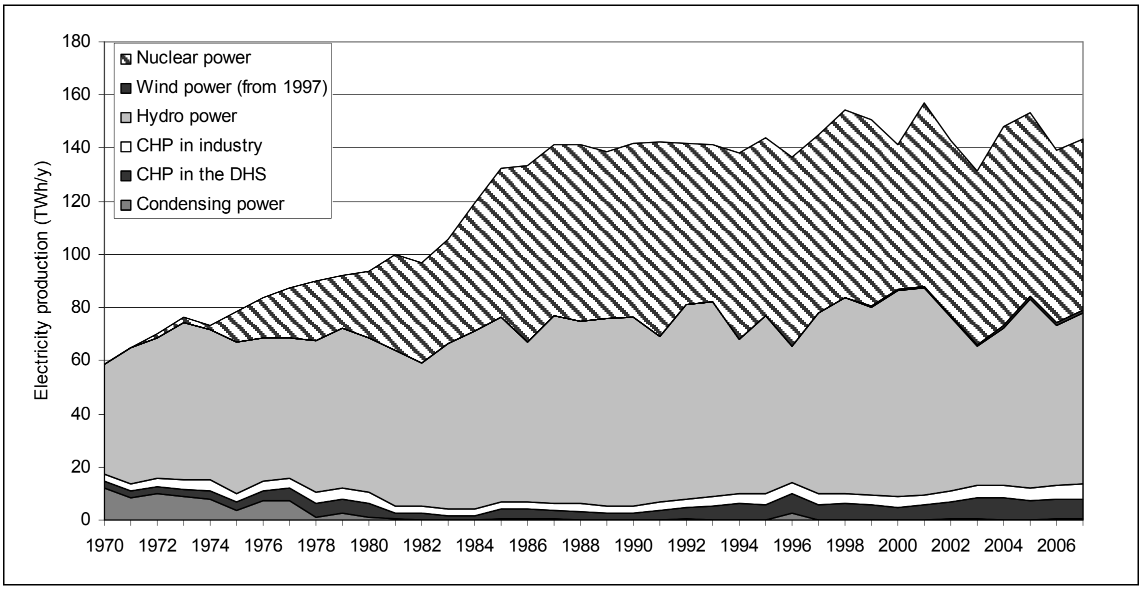
Source: DHA (2008)

There is an ongoing trend of merging neighbouring DH systems, thus making them larger but fewer. The benefits of doing this are economies of scale in DH production and enhanced opportunities for electricity production. CHP production is generally not profitable in very small DH systems. The mergers may also enable greater use of industrial waste heat if this is available. Examples of such mergers include the 17 km culvert connecting the DH systems in Lund and Eslöv and the 16 km culvert connecting the DH systems in Helsingborg and Landskrona.

4.5 CHP production

The Swedish DH systems have for most of their history been poorly utilised for CHP production and CHP has played a minor role in the Swedish electricity supply, which has been dominated by hydropower, and since the mid-70s nuclear power (Figure 8). CHP was, however, the main motive for building DH systems in the 1950s and 60s when it seemed likely that Swedish hydropower would not be able to meet the increasing future demand for electricity (Kaijser, 2001). The first 10 DH systems that were built in the 1950s and 60s all included oil-fired CHP plants. After that, however, the political decision to invest in nuclear power production effectively blocked further investments in CHP production (Hård and Olsson, 1994, Werner, 1999). Municipal energy utilities were also discouraged by Vattenfall, the state-owned power producer, to build CHP plants. As the dominant power producer, Vattenfall saw its position threatened when several towns built or announced plans to build CHP plants. One way of discouraging investments in CHP plants was to grant long-term electricity contracts and favourable prices to municipal energy utilities that promised not to build CHP plants (Kaijser, 2001). For two of the nuclear power plants, utilisation of the waste heat in DH systems was investigated but never realised.

Figure 8 Swedish electricity production in 1970-2007

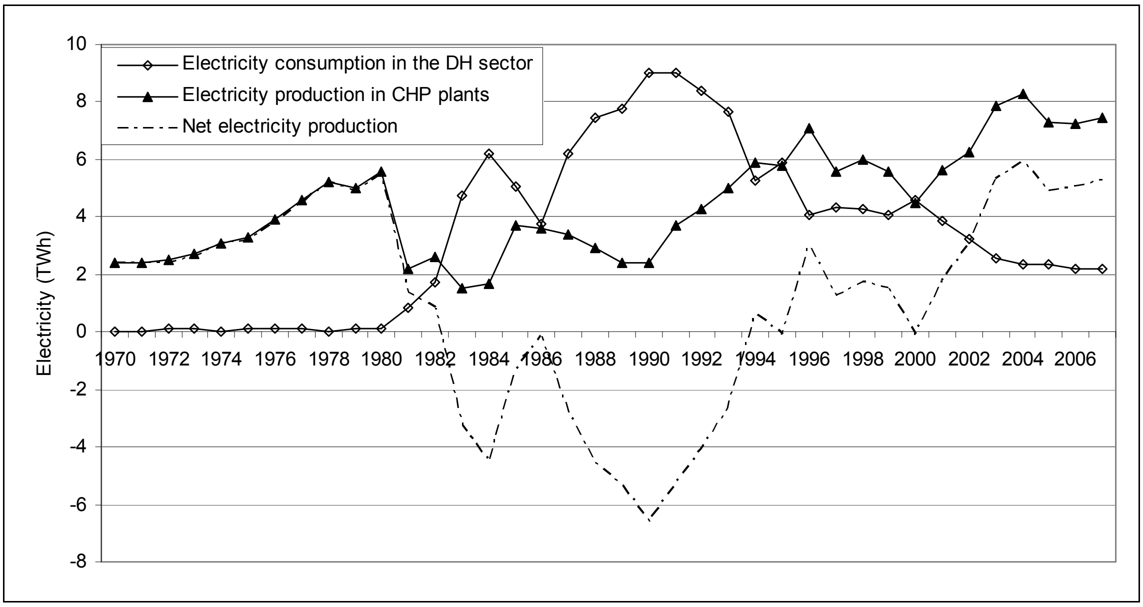


Source: SEA (2008a)

In the 1970s many of the oil-fired CHP plants were converted to coal due to increasing oil prices. In the 1990s when investment subsidies were introduced for biofuel-based CHP production many of the coal-fired CHP plants were converted to biomass or co-firing of biomass. Several new biomass-fired CHP plants were also built. However, due to low electricity prices many CHP plants did not utilise the full electricity production potential, and electricity production in the DH systems remained very low in the 1980s and 90s considering the great expansion of the DH systems in that period. In fact, the increased use of heat pumps and electric boilers in DH production resulted in negative net electricity production in this sector during parts of the 1980s and 90s (Figure 9).

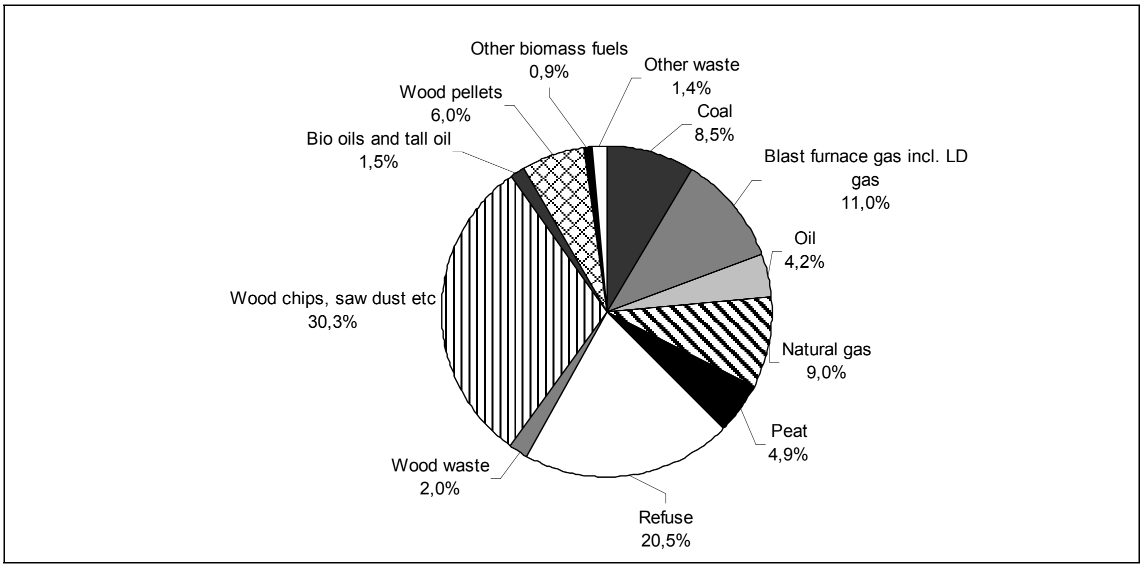
In the past few years there has been a renewed interest in CHP production driven by increased electricity prices and the Swedish scheme for tradable renewable electricity certificates (see Section 5.5). In 2007 electricity production in the DH systems amounted to 7,5 TWh. The fuel consumption consisted to a large part of different types of biomass (40,7%) and MSW (20,5%) (Figure 10). A market survey (Hirsmark and Larsson, 2005) and subsequently announced investment plans indicate that the CHP production in both the DH systems and the forest industry will continue to increase in the coming years. In 2007 51% of fuel-based district heating, excluding heat from flue gas condensers, was produced in CHP plants. Although this is a higher percentage than in previous years, there is still potential for expanding CHP production by replacing heat-only plants with CHP plants or by retrofitting them into CHP production. Some heat-only boilers are, however, likely to be maintained due to their relatively low capital costs which make them suitable for peak load. Apart from the heat load and proportion of the DH supply that is produced in CHP plants, the electricity production also depends on fuel mix and boiler technology. The high proportion of MSW and biofuels, in combination with flue-gas condensation, restrict the electricity generation potential. Flue-gas condensation refers to condensation of the water vapour in the flue gases, something that improves overall energy efficiency. This technology is common in the medium- and large combustion plants and accounted for 3,0 TWh of the DH production in 2007 (SCB, 2008b). In terms of technology, the electricity production in CHP plants in both the DH systems and the forest industry is dominated by conventional steam turbines. In the 1980s and 90s, several large development projects involving biomass-integrated gasification combined cycle technology were launched aiming to increase the electric efficiency. No commercial applications have yet come out of these development projects. Combined cycle technology is, however, applied in two new CHP plants firing natural gas. The plants are located in Gothenburg (inaugurated in 2006) and Malmö (March 2009), respectively.

Figure 9 Electricity production in the DH systems and the calculated electricity consumption, both for the period 1970-2007. The electricity consumption was calculated assuming an efficiency of 0.95 for the electric boilers and that the heating pumps have a COP of 3



Source: SEA (2008a)

Figure 10 Fuel distribution in electricity production in the DH systems in 2007



Source: SCB (2008b)

4.6 Economics and costs

The production and distribution of district heat entail costs that must be balanced by revenues from the sale of district heating and possibly investment subsidies. The revenues are fairly well known due to the annually published statistics on DH tariffs and heat sales in each municipality. The DH tariffs in Sweden vary greatly between the municipalities, from about 0,4 to 0,9 SEK[2]/kWh (0,044-0,10 €/kWh) in 2008, and they are generally slightly higher for one- and two dwelling buildings than multi-dwelling buildings (EMI, 2008). The great variation in tariffs between the municipalities can be explained by differences in costs, and since the deregulation also by different philosophies on pricing and annual returns, depending on ownership. The average DH tariffs are generally somewhat lower for the municipally owned energy companies than for large national/international energy companies (Andersson and Werner, 2005). It is also clear that some municipally owned companies are not governed by economic rationality only, but also by political goals (Mårtensson and Fredriksen, 2005). As regard pricing, some companies more or less apply cost-based pricing, something that was mandated until 1996, while others are guided by the alternative costs for their customers.

It's in general difficult to obtain company information on costs associated with DH production and distribution. Based on interviews with people in DH companies Wirén (2008) has assessed the typical costs of DH production and distribution, the results of which are presented in Table 1. The main cost drivers are fuel and capital costs, which typically account for 45% and 33%, respectively, of the total cost. These costs of course differ between DH systems depending on the fuels and technologies used, age, total heat load (economy of scale) and linear heat density (heat supply/metre of pipe). For example, the DH production cost depends on whether the district heat ace cogenerated in electricity or not, and if this yes what allocation principle that is applied for distributing other costs between heat and electricity production. Concerning fuel costs, it may be noted that the lowest DH tariffs are found in Luleå where the DH production is based almost exclusively on industrial waste heat, which the municipal energy company purchases from the local steelworks at a presumably low price. Another contributing factor for the low DH tariffs in Luleå is that the municipal energy company aims for an annual return of 3%, which may be compared with e.g. 12% at Fortum AB.

The linear heat density is an important factor to the distribution costs (cost per MWh heat supplied) and is determined by i) the settlement structure, ii) the penetration rate of district heating in the service area and iii) the heat demand of the customers. High linear heat density is preferable because it requires fewer metres of pipe per MWh supplied and thus entails less heat losses. Therefore densely populated areas typically containing multi-dwelling buildings are the most favourable areas for district heating. It

[2] 1 EUR=11,1 SEK (Feb. 2009), but the typical exchange rate for the past few years has been 1 EUR=9 SEK.

is only in recent years that DH systems have expanded into areas of one- and two dwelling buildings, a development that has partly been driven by investment subsidies. The company strategies concerning this market segment, however, differ greatly; some companies deliberately stay out of this market while others are quite active in the enrolment of customers.

In order to keep distribution costs low and the linear heat density high, it is also important to have a high penetration rate of district heating in the service area. The high capital costs associated with the distribution system make the energy company sensitive to competing systems that may erode the market for district heating. Therefore, timing is essential for the success of enrolling customers associated with the introducing or expansion of district heating. A crucial opportunity is offered when new settlement areas are being planned and when the heating systems in existing buildings are in poor condition. In order to maintain the competitiveness of the system it is also important to retain customers. The loss of important customers undermines the ability to recover capital costs. Similarly, large reductions in customer heat demand also threaten the economics. Hence, major efforts in energy conservation of consumer buildings are not in the interest of the DH utility. So far, however, there has been no major contradiction between district heating and energy conservation in Sweden. The explanation for this is that the major efforts in energy conservation were made in the 1970s and early 80s while the DH systems were expanding. After that, measures in energy conservation have been offset by room temperature increases and increased consumption of hot tap water and therefore not influenced the heat demand. However, if significant efforts in energy conservation were to be undertaken today, resulting in reduced demand for heat, this would certainly be a challenge for the district heating sector.

Table 1 Energy company costs associated with DH production and distribution (Wirén, 2008)

	Production	Distribution	Others	Total	
	SEK/MWh			SEK/MWh	%
Fuel	160	20	0	180	45
Capital	80	50	5	135	33
Operation & maintenance	40	10	0	50	13
Staff	20	5	10	35	9
Total	300	85	15	400	100
Total (%)	75	25	21	4	100

5 Policies and regulations that have shaped the Swedish district heating sector

5.1 Specific district heating regulation

Activities in municipally owned energy utilities were regulated until 1996 on the basis of the Local Authority Act (SFS 1991:900), which regulates municipal businesses. Three principles governed the actions of municipal companies on the energy markets (electricity and district heating): i) the principle of equal treatment, ii) the principle of locality and iii) the principal of cost-based pricing. According to these principles the local authority must treat all its citizens equally and is prohibited to engage in business in other municipalities. In addition, the municipal business should carry its own cost but not be profit-seeking. When the Swedish electricity market was deregulated in 1996, the three principles were simultaneously lifted from municipal energy companies in order not to distort competition with private electricity companies. Instead, the new Electricity law (SFS 1994:618) stipulated that municipal energy companies should be operated in a business-like fashion. The principle of locality was, however, kept as regards district heating, and the three principles are still applied on utilities that are run by municipal administrations (very few).

Due to the DH consumers' dependency on one DH supplier, the free pricing of district heat has been under debate in Sweden since the deregulation. The debate has grown stronger as an increasing number of municipal companies have been sold to national/international companies, which represent a variety of energy services – electricity, gas, and now district heat. Hence, although heat markets are local, they now interact with the larger markets for electricity and gas which implies the risk for cross subsidies. On account of that risk the Swedish Competition Authority has on several occasions argued for the regulation of DH enterprises (Westin and Lagergren, 2002). There have also been a number of government official investigations on the relationship between the DH suppliers and customers. Few examples of abuse of dominant position have been found among DH suppliers, but the vulnerable position of the customers has nevertheless been recognized. The Energy Market Inspectorate has therefore been given the role of continuously monitoring the DH sector.

Moreover, in order to strengthen the position of customers a new District Heating Law (SFS 2008:263) was adopted and entered into force in July 2008. The law obliges transparency in the pricing of district heat provisions and contains directions for contract conditions. The law also introduced a district heating board as an independent body within the Swedish Energy Agency. The purpose of the district heating law is to mediate in disputes between energy companies and their customers, as well as between energy companies and industries that want to supply industrial waste heat.

Since deregulation there have also been investigations into Third-Party Access (TPA) to DH systems, that is where the third parties gets non-discriminatory access to the DH system. This was initially rejected, but is now being investigated again. TPA could, for example mean that industries may sell industrial waste heat directly to customers via access to the DH system. The ongoing investigation is also addressing the possible design of a regulatory framework for TPA. One argument for TPA is that this would increase the utilisation of industrial waste heat and another is that competition between suppliers would benefit DH consumers. Previous investigations have, however, not been able to determine that this would be the case since TPA not only increases competition but may also increase the costs for the DH producers, mainly due to increased administration and the increased risks associated with investments (SOU 2005:33). At community level TPA may also complicate municipal planning and coordination of waste management and DH production.

5.2 Municipal energy planning and land-use planning

The municipalities have traditionally played an important role in the Swedish energy system as local distributor of electricity, DH supplier, and owner of a large number of buildings which require heating and electricity. This role was further emphasised in 1977 as the Swedish parliament passed a law requiring municipalities to develop municipal energy plans (SFS 1977:437). The purpose of the law was to clarify the role of the municipalities as a tool for implementing national energy policy (Vedung, 1988). The law obliged the municipalities to address energy efficiency and energy security within their planning activities. In 1980 the law was complemented with the requirement to formulate oil reduction plans, which in 1985 were replaced by a requirement for more comprehensive energy plans. Since 1991 the law requires the municipalities to have a plan for the supply, distribution and use of energy, in which the effects of these activities on the environment, health and natural resources, are described.

Even though the law has been in place for three decades, about 27% of the municipalities lacked a municipal energy plan in 2006, and many of the existing plans are quite old (SEA, 2006). A general critique of the law has been the lack of sanctions and clear requirements on what the plan should encompass (Olerup, 2004). The actual effects of the law on energy supply and use in general and on district heating in particular are uncertain since it is a framework law. As such it does not force municipalities to act in a certain way or give them the authority to influence the energy decisions of other actors (Khan, 2004).

The Swedish municipalities have a monopoly on land-use planning as declared in the Planning and Building Act (PBA) (SFS 1987:10). This means that state authorities can only override a municipal planning decision if a national interest has not been taken into account, if there has been a lack of co-operation between municipalities or if projects will threaten people's health and security. The importance of land-use planning for district heating lies mainly in the overall planning of the siting of DH production plants and the permit-granting for such plants.

The municipal energy and land-use planning legislation does not give the municipality the right to mandate the use of district heating or another particular heating source in buildings in the municipality or parts of the municipality. Possibly, the municipalities may require connection to the DH system (however not use) when they sell land for new buildings and settlement areas. In the municipality of Lund, such conditions are not made in sale contracts with building construction companies. Where district heating is a realistic option, for example if the neighbouring area is connected, the municipality, however, suggests connection to the DH system and provides contacts to the DH utility (Lunds Energi, 80% municipally owned) (Linse, 2009). Other municipalities than that of Lund may be more active in marketing district heating. Nevertheless, the municipal approach to energy and land-use planning in general seems to be more laissez-faire today than it was in the 1960s, 70s and 80s. For example in the 1980s some municipal energy companies refused to deliver electricity for heating purposes to buildings in the DH service area (Summerton, 1992). This opportunity no longer exists in reality since the electricity market in Sweden has been liberalised and consumers are free to choose electricity supplier, i.e. consumers may purchase electricity from another supplier than the one that owns the local electricity networks.

5.3 Energy and environmental taxation

Energy taxes have a long history in Sweden. The first energy tax was introduced on petrol in the 1950s, and in the 1970s high taxes on oil products were introduced. In the early 1990s the environmental profile of the energy taxation system was strengthened as climate change mitigation became a priority in energy policy 1990s changes were introduced in the taxation of energy. A carbon tax was introduced while the energy tax was simultaneously reduced by 50%. Also, value added tax was levied on final energy use (refundable for industries and energy companies). The changes in the taxation of energy were part of a wider tax reform that intended to make taxation on different areas such as income, capital and energy more congruent, and to enhance the environmental focus. The energy taxation system is fairly complex. There are different taxes on electricity, fuels and emissions, and the tax levels vary between sectors. The main reason for the differentiated tax levels is the concern for the competitiveness of the Swedish energy-intensive industries.

Apart from the carbon tax, the tax reform in the 1990s introduced a tax on sulphur dioxide emissions and an environmental charge on the emissions of nitrogen oxides. The SO2 tax was introduced in 1991 at 30 SEK per kg SO2 emitted and has remained constant since then. The tax is levied on coal, peat and oil (> 0.05 wt% sulphur). The nitrogen oxide charge was introduced in 1992 and applies to heat and power plants with a fuel use exceeding 25 GWh/year. The emission charge has remained constant at 40 SEK/kg. The nitrogen charge is fiscally neutral, i.e. the charge is refunded to each production unit in proportion to its production of useful energy (heat and electricity). The nitrogen charge and SO2 tax will not be discussed further in this section which focuses on the energy and carbon taxes, and their effects on the relative energy prices and heating costs.

5.3.1 Tax rates for different fuels and sectors

The carbon tax was introduced in 1991 and is levied on fuels used in heat production, but also on transportation fuels. No carbon or energy taxes are levied on fuels used in electricity production. The fuel fraction used for heat production in CHP plants is, however, taxed. In contrast to heat, electricity is taxed at the consumption level and the tax level varies depending on the geographical location and end user. In 2007 the general electricity tax amounted to 0,26 SEK/kWh except for northern Sweden where it amounted to 0,20 SEK/kWh. Electricity used in manufacturing processes was exempt from the electricity tax until July 2004, after which the EU minimum tax of 0,005 SEK/kWh has been applied.

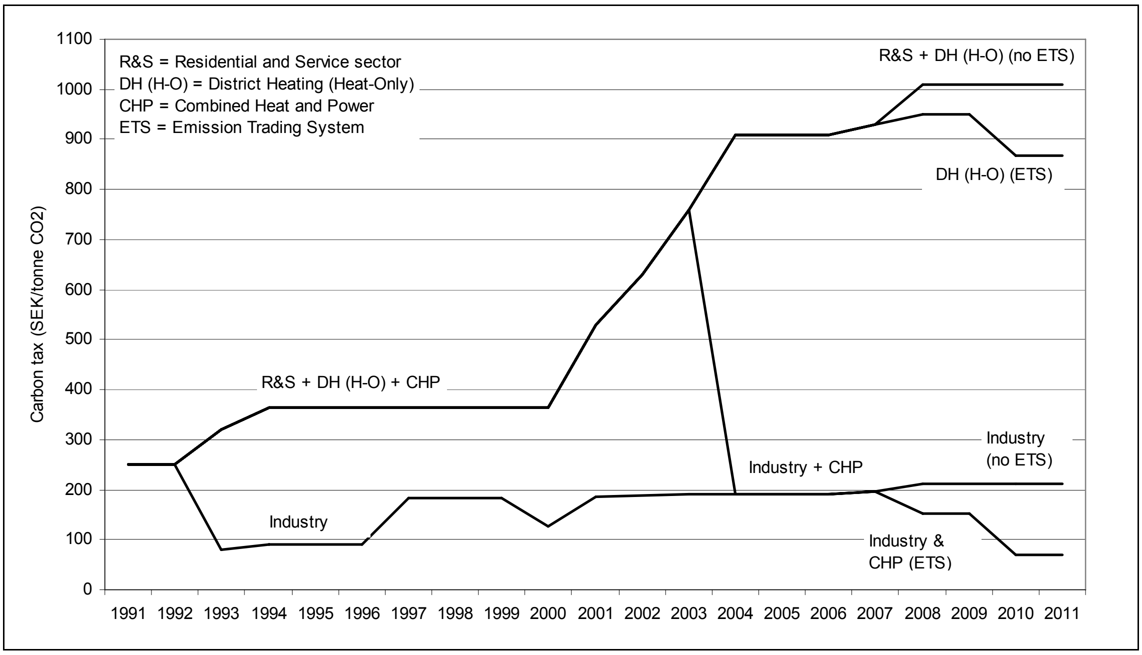
Biomass is exempt from the energy and environmental taxes and only the sulphur tax is applied on peat. MSW was exempt from the energy and environmental taxes until 2006, but has since then paid energy and carbon taxes (see Section 5.6). The carbon tax was introduced at the level of 250 SEK/tonne CO_2 (28 EUR/tonne) (1991) and has subsequently been gradually increased (Figure 11). Initially all heat producers paid energy tax and full carbon tax. In 1993, however, the energy tax was lifted from industry and the carbon tax for this sector was reduced to 25% of the general level. The differentiated taxation system has remained since then although the applied tax reduction percentage has varied over the years. For the past few years industry's carbon tax has amounted to 21% of the general carbon tax. For energy intensive industries special rules apply that allow further reductions in the carbon tax.

The general carbon tax was increased to 365 SEK/tonne in 1993-1994 and remained at that level until 2001 when a second green tax reform was launched. This reform reduced the energy tax and introduced successive increases in the general carbon tax which reached 1010 SEK/tonne in 2007. All producers of district heat paid energy tax and full carbon tax until 2004. In 2004 the energy tax was lifted from CHP plants and the carbon tax for these plants was reduced to 21% of the general level, i.e. to the same level as industry. At the same time the possibility to freely allocate the fuel use between heat and electricity production in the CHP plants was removed. Hence, for CHP plants that co-fire biomass and fossil fuels it was no longer possible to allocate the fossil fuel consumption to the electricity production and the biomass consumption to the production of district heat, something that was previously frequently done for tax purposes.

In 2005 the EU Emission Trading System (ETS) was launched, something which has brought about certain adjustments in the Swedish carbon taxation system (Figure 11). Since the introduction of the ETS, most Swedish district heating producers are targeted by two parallel climate policy instruments. In Sweden the ETS applies to all combustion plants with a fuel capacity of at least 20 MW, or that are connected to a DH system with a total heat load capacity of at least 20 MW. Hence, nearly all Swedish DH production is affected by the ETS. In the first trading period (2005-2007) all emission allowances were allocated for free. For the second trading period (2008-2012) no emission allowances have been allocated for free to existing heat and electricity production plants.

Because of the new situation with two parallel climate policy instruments, the Swedish parliament in the spring of 2008 approved reductions in the carbon tax levels for combustion plants that are also comprised by the ETS. Since July 2008 CHP plants and industries (comprised by the ETS) pay 15% (instead of 21%) of the general carbon tax while heat-only plants pay 94% (instead of 100%) of the general level (SOU 2008:24). Further reductions are scheduled; as from 2010 CHP plants and industry will pay 7% of the general carbon tax and the district heating plants 86% (ibid). If or when the ETS becomes more effective the carbon tax is likely to be lifted from the combustion plants that are comprised by this instrument.

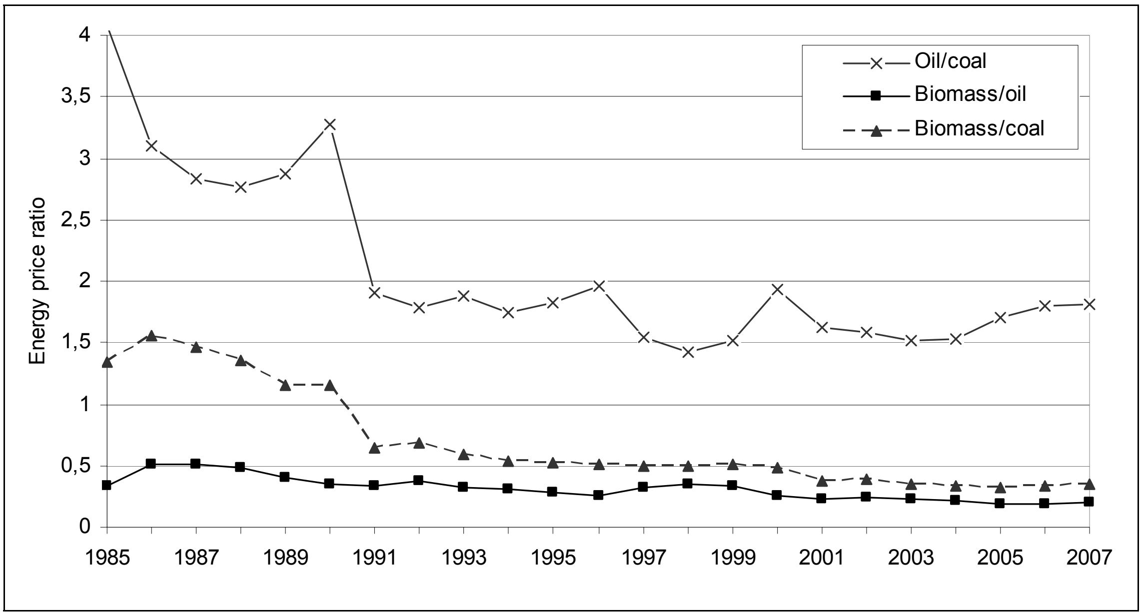
Figure 11 Development of the carbon tax levels levied on fuels used in ***heat production*** *in different sectors. Biomass and peat are exempt from the tax*



5.3.2 The effects of the taxes on relative energy prices

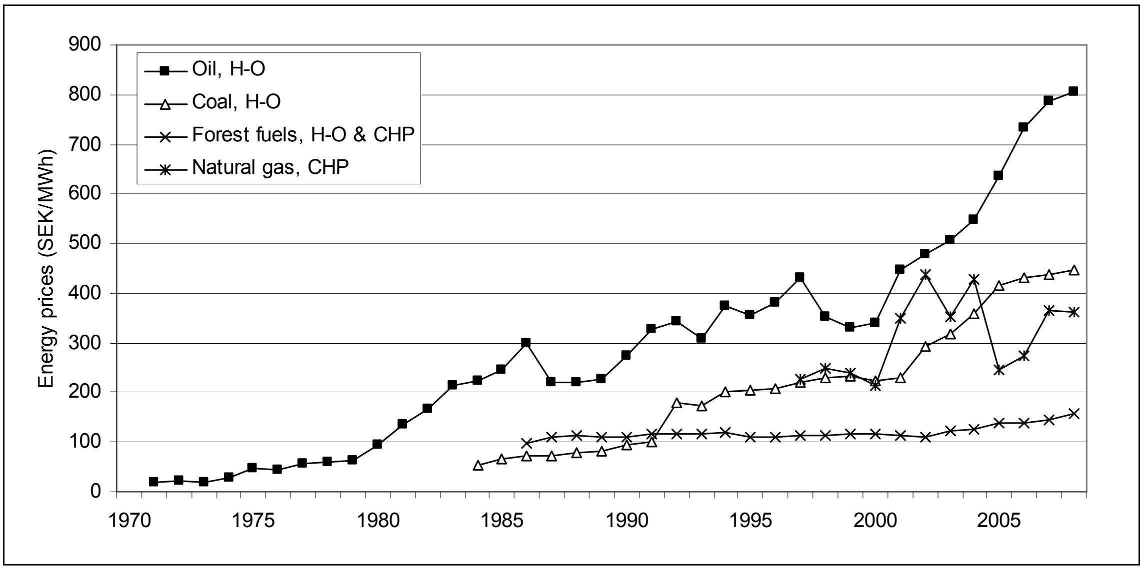
The energy taxation system has greatly influenced relative energy prices by making fossil fuels more expensive (Figure 12). Figure 13 illustrates the development of fuel prices, including taxes, in DH production. The energy tax reform immediately almost doubled the price of coal and made biomass the most competitive fuel in heat production. It seems quite clear that the energy tax reform is the main explanation for the biomass expansion in DH production in the 1990s and onwards (see e.g. Bohlin (1998)). Hence, the shift to biomass was for many energy utilities a rational economic decision. In line with this, biomass expanded more rapidly in heat-only production than in CHP production where biomass was often co-fired with fossil fuels. This was rational, since the tax system until 2004 made it possible to allocate the fossil fuel used in CHP production to electricity production. This possibility was removed in 2004 when the carbon tax on fuels in co-generated heat production was reduced. As a consequence, CHP production with natural gas has become an option, although so far the tax cut has largely been offset by the increasing market price of natural gas. Nevertheless, two CHP plants firing natural gas have been built in the past few years (as previously mentioned in Section 4.5).

Figure 12 Energy price ratios for oil, coal and biomass based on average prices (in Sweden) for heat produces who pay full energy and environmental taxes



Source: SEA (2008a)

Figure 13 Swedish energy prices, including taxes, on fuels that are used in DH production in heat-only (H-O) or CHP plants



Source: SEA (2008a)

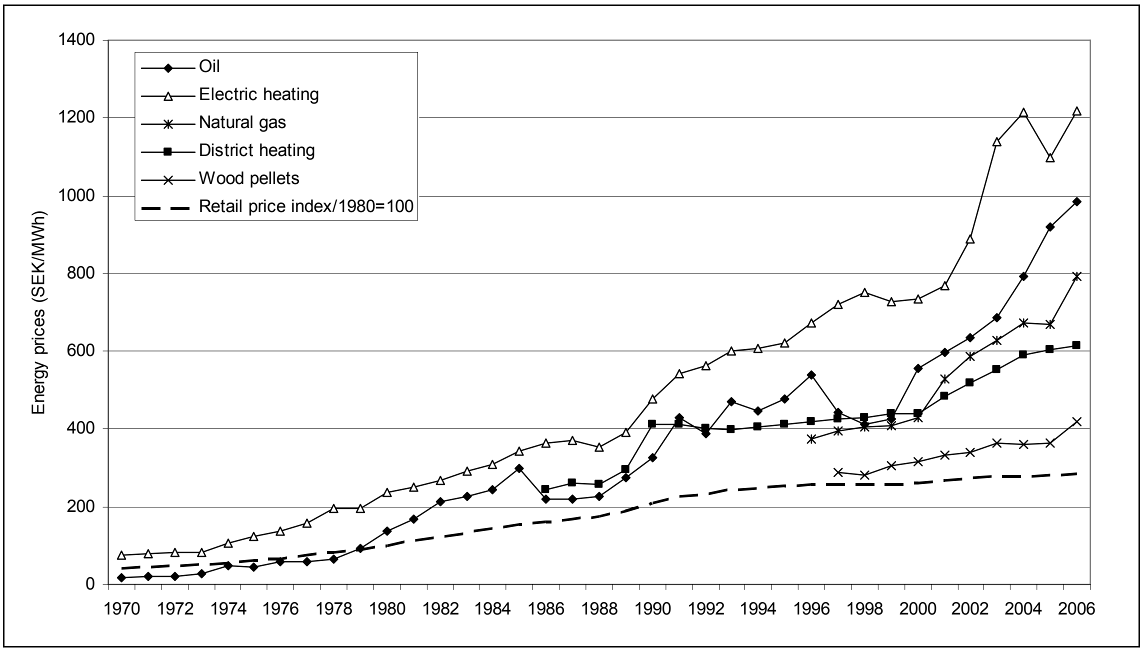
5.3.3 The effects of the taxes on heating costs

The energy taxation system and changes in relative energy prices have also influenced the relative heating costs associated with different heating options. Figure 14 illustrates the energy prices, including taxes, for heating of buildings. Energy prices have increased considerably in the past five years, not only due to the taxes but also due to the world market price increase of oil and the electricity price increase on the Nordic electricity market. Since 2003, the electricity price also includes a tariff for tradable renewable electricity certificates (see Section 5.5). The energy price increases have not only increased the cost of oil and electric heating, but also affected DH production costs and DH tariffs. The fuel flexibility of the DH sector, however, makes this sector less vulnerable to oil and electricity price increases than building owners with oil or electric heating systems. Still, DH tariffs have increased quite significantly in the past five years, after being constant the previous 10 years.

The energy tax reform has on the whole improved the competitiveness of district heating, as well as that of wood pellets and heat pumps. Calculations by the EMI (2008) show that district heating was the most competitive heating option for the typical one- and two dwelling building in 2007 with an annual cost of about 20 000 SEK/y (Figure 15). Bedrock heat pumps and wood pellets were only slightly more expensive. District heating, bedrock heat pumps and wood pellets were also the most competitive options in the typical multi-dwelling building (Figure 16). It should, however, be noted that the costs vary greatly between municipalities and individual buildings. For example, the DH tariffs can be twice as expensive in the most expensive municipalities compared with the cheapest (explained in Section 4.6). Hence, in municipalities with relatively high DH tariffs, heat pumps and wood pellets may be cheaper heating options.

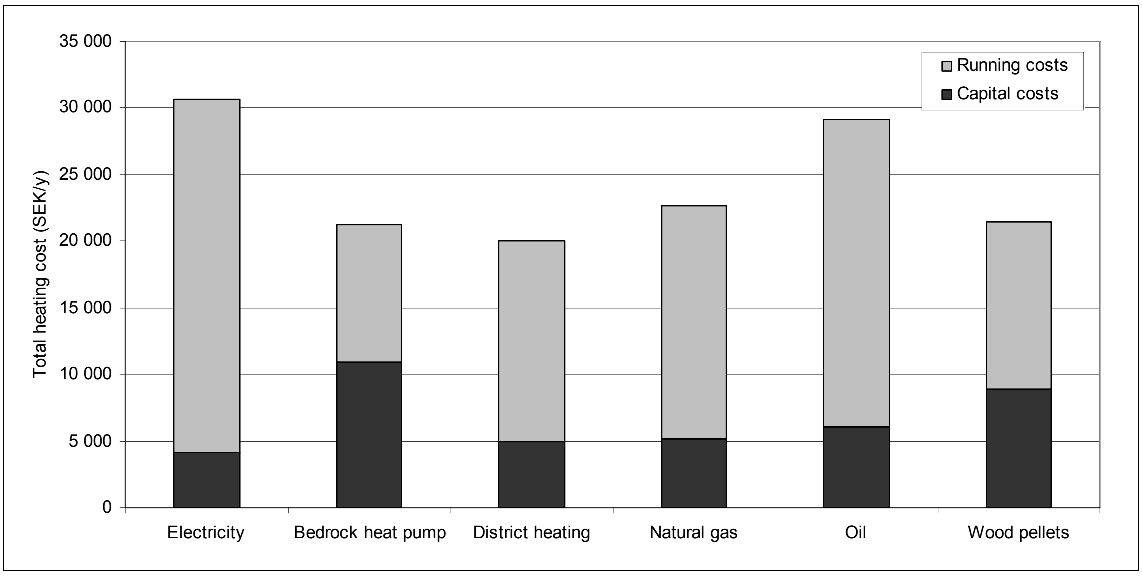
In contrast to the rapid changes in the energy supply to DH production, the energy reform didn't set off any immediate dramatic shifts in heating systems of buildings, nor a massive increase in the use of biomass. For the residential and service sector, the ability to react to energy prices, including government policies, is different from that of energy utilities. The choice of heating system is often more limited by the alternatives available and physically feasible (space constraints) in the specific location. Also, information about new heating systems may be limited, and positive experience of the present system may slow down the change to new systems, even if these have a long-term cost advantage (Johansson et al., 2002). Convenience is also an important aspect and has been a disadvantage for biomass (wood pellets) compared to heat pumps.

Figure 14 Energy prices for heating of buildings, including taxes (energy, carbon and VAT), and the retail price index for the period 1970-2006



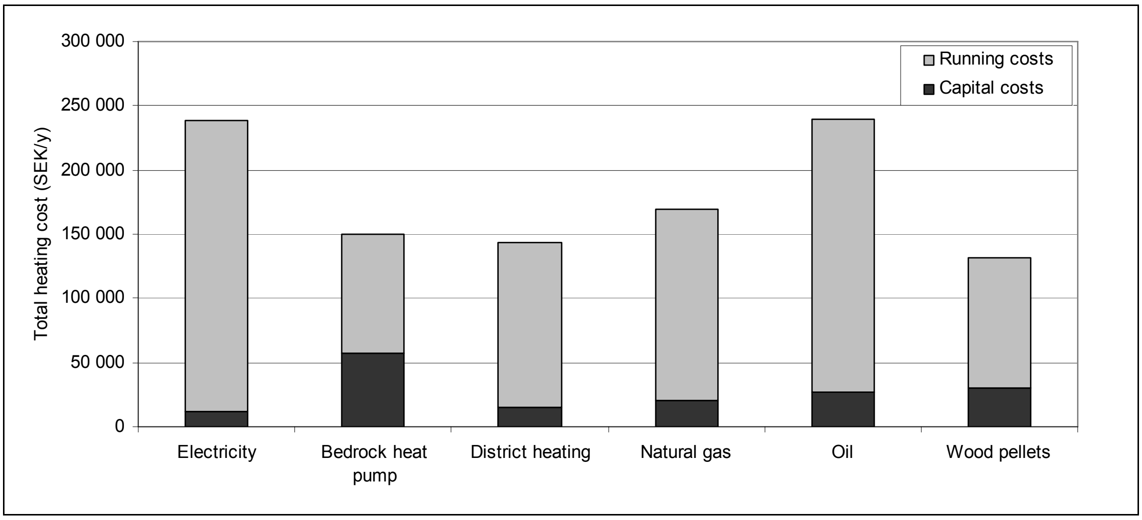
Source: SEA (2008a) and EMI (2008)

Figure 15 Average annual heating costs for owners of one- and two-dwelling buildings in Sweden for different heating systems



Source: EMI (2008)

Figure 16 Average annual heating costs for owners of multi-dwelling buildings in Sweden for different heating systems



Source: EMI (2008)

5.4 Investment subsidies

5.4.1 Replacement of oil and direct electric heating in buildings

During the past 40 years district heating has directly or indirectly been promoted through a number of state subsidies and favourable loans. Many of these economic incentives have aimed at the replacement of oil heating and more recently of direct electric heating. Some of these incentives have targeted DH utilities (e.g. the subsidy programmes described in Section 5.4.3) and others building owners. Among the building owners, mainly housing organisations were targeted in the 1970s and 80s, while more recently households have also been targeted. Hence, there have been several subsidies available over the past decades, but this section focuses on two recent/ongoing subsidy schemes that target building owners.

In 2006 two subsidies were introduced for the replacement of i) oil heating in one- and two-dwelling buildings and ii) direct electric heating in all residential buildings. The eligible options include district heating, ground-source heat pumps (bedrock, surface soil or lake/river water) and biofuel boilers. Heat pumps are only eligible for support if the electricity consumption for heating, including tap water, amounts to less than 35% of the calculated heat demand of the building.

The subsidy for replacement of oil heating immediately attracted many applicants. Already in March 2007 all of the 450 million SEK that had been allocated for the support for the period 2006-2010 had been spent. Each subsidy amounted to 10 000-14 000 SEK depending on the replacement option and other circumstances. The subsidies were intended to cover about 30% of the capital and labour costs but with the upper fixed limit (14 000 SEK) the subsidies have in reality covered 9-21% of the costs

(Boverket, 2008). Heat pumps have been the most popular replacement option and account for 43% of the awarded subsidies. District heating and biofuel boilers accounted for 20% and 37%, respectively (ibid). Although the subsidy has speeded up the replacement of oil heating, the subsidy has been criticised for poor cost efficiency (Boverket, 2008). Firstly, the administrative costs have been high. Secondly, the replacement of oil heating has been profitable also without the subsidy due to the old age of most installed oil boilers and the high oil prices, including the energy and carbon taxes.

The support for replacement of direct electric heating applies to all residential buildings. Altogether 1,5 billion SEK have been set aside for subsidies for the period 2006-2010. In addition to the requirements concerning heat pumps that were described earlier, district heating and biofuel boilers are eligible options provided that they account for at least 70% of the heat demand of the building. Due to the high investment costs for buildings with direct electric heating that lack a hot water distribution system, the size of these subsidies are higher than those for the replacement of oil heating. The upper limit of the grant is 30 000 SEK for one- and two-dwelling buildings.

By April 2008 480 million SEK had been granted for replacement of direct electric heating. Most of these subsidies (about 80%) involved a shift to district heating while heat pumps and biofuel boilers accounted for 15% and 5%, respectively (EMI, 2008). The distribution between the replacement options, however, differs greatly between regions mainly depending on the local availability/feasibility of the different options.

5.4.2 Biomass-based electricity production

In the 1990s biomass-fired CHP plants were eligible for investment subsidies in two consecutive subsidy schemes for the periods 1991-1996 and 1997-2002, respectively. The investment subsidies were motivated by the fact that the energy taxation system favoured the use of biomass in heat production over that in electricity production. The subsidy, as well as the parallel subsidies to wind power and small-scale hydropower, must also be seen against the backdrop of the 1988 decision to start the dismantling of nuclear power and a growing concern for climate change.

The first subsidy scheme (1991-96) aimed at increasing biomass-based electricity production by 0,75 TWh/y and involved investment subsidies of one billion SEK. The investment subsidy to new production facilities amounted to 4000 SEK per kW installed electric capacity. Subsidies were also available for retrofitting of fossil-fired CHP plants and district heating plants (into CHP). The subsidies for retrofitting were set to 25% of the capital cost and at most 4000 SEK/kW. In all, 16 new biomass-fired CHP plants received subsidies, 12 of which in the DH systems and the remaining four in industry (Ministry of Trade and Industry, 2000).

In the second subsidy scheme (1997-2002), the investment subsidy was reduced to 3000 SEK/kW or a maximum of 25% of the investment. This investment subsidy corresponded to a subsidy of approximately 0,08-0,10 SEK/kWh$_e$ and was awarded to another nine CHP plants, which were estimated to produce approximately 0,8 TWh_e/y (Ministry of Trade and Industry, 2000).

Even with the investment subsidies, biomass-based electricity production was not economically competitive during the period of the subsidy schemes due to the low electricity prices (Ministry of Finance, 2000). Nevertheless, several new biomass-fired CHP plants were built. The reasons for this may include a strong local political commitment to renewable energy, the expectation of increasing electricity prices in the future, and the possibility of transferring the cost to heat consumers through higher district heating prices. Overall, the subsidy scheme led to a relatively small contribution to the Swedish electricity production, about 0,75 TWh/y in the first scheme and 0,8 TWh/y in the second. Jacobsson (2008), however, argues that the schemes worked as an eye-opener for district heating enterprises, a number of which turned to CHP production, and that the scheme mobilised financial resources for the development of equipments in the Nordic capital goods industries (ibid).

5.4.3 LIP and Klimp

District heating projects have received investment subsidies within two government-funded subsidy schemes: the Local Investment Programmes (LIP) and the Climate Investment Programmes (Klimp). Both of these subsidy schemes had a broad scope and did not target the energy sector specifically, but district heating projects have been an important element in the awarded programmes.

The LIP subsidies were introduced in 1998 and aimed to strengthen environmental initiatives at the local level and to promote employment. For this purpose municipalities were encouraged to co-operate with local industry and organisations around environmental projects for which they could receive financial support. Altogether 6,2 billion SEK were set aside for subsidies for the period 1998-2002. About 1,0 billion SEK of the subsidies were allocated to district heating projects, which incurred a total investment cost of 4,05 billion SEK. These projects included for example establishment of new small-scale district heating, expansion of existing DH systems, retrofitting and extension of production capacity, and construction of new DH production capacity, including e.g. the recovery and utilisation of industrial waste heat.

The LIP subsidies have been of particular importance for projects concerning the utilisation of industrial waste heat. The subsidies have improved the economics of such projects, thus making longer connecting culverts between industry and DH system viable, but the subsidies have also brought legitimacy to such projects (EPA, 2005). The LIP subsidies for projects concerning the recovery of industrial waste heat in DH systems amounted to 240 million SEK and involved 370 GWh of heat (ibid). In total, 1,15 billion SEK were invested in these projects. Apart from industrial waste heat, the LIP subsidies have also been of great importance to connection one- and two-dwelling buildings to DH systems and for the establishing of small-scale DH systems (EPA, 2004).

In 2002 LIP were replaced by Klimp which aimed at stimulating local initiatives and long-term investments for reducing the emissions of greenhouse gases. Similar to LIP, Klimp also intended to encourage cooperation between municipalities, local industries and other actors. Altogether 1,8 billion SEK were set aside for investment subsidies for the period 2003-2008. The implementation of awarded projects will, however, continue until 2012. Energy-related projects have played an important role in Klimp, accounting for 789 million SEK of the total awarded subsidies (EPA, 2008). Other important areas are waste management and transportation. Both of these areas contain a number of biogas projects, which in total have been awarded one third of the Klimp subsidies.

5.5 Tradable renewable electricity certificates

In recent years DH production from biomass has been indirectly promoted by the scheme for tradable renewable electricity certificates (TRECs), in which biomass-based CHP production in the DH systems and the forest industry has been very competitive. The TREC scheme was introduced in May 2003 as a means of achieving the national target[3] for electricity production based on RES set in Directive 2001/77/EC. The aim of the TREC scheme was initially to increase the annual electricity production from RES with 10 TWh until 2010 compared to 2002. When the scheme was prolonged in January 2007 to 2030, the growth target was increased to 17 TWh for the period 2002-2016. The TREC scheme replaced previous investment and production subsidies targeting electricity production from RES. The scheme was, however, complemented with a production subsidy for wind power which ends this year (2009) for land-based wind power but will be maintained for offshore wind power.

The TREC scheme is a market-based instrument where the certificate price is determined in the interplay between supply and demand. Producers of electricity from RES and peat[4] are eligible to TRECs on the basis of the production volume. Large-scale hydropower is not eligible for TRECs since it is already highly competitive and because further exploitation is prohibited in Sweden. Small-scale hydropower, on the other hand, is eligible for TRECs. The demand for TRECs is created by the obligation for electricity users/suppliers to purchase TRECs corresponding to a certain proportion (legislated quota) of their use/supply. Electricity that is used in manufacturing processes in electricity intensive industries is excluded from the quota obligation. In order to limit the costs for electricity consumers, electricity production facilities may only receive TRECs for the maximum of 15 years. Facilities that were in production before the scheme was introduced will be eligible for TRECs until 2012.

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3 The Swedish target is to increase the production of electricity from RES from 49% (1997) to 60% by 2010.

4 Peat is included in the TREC scheme since 2004 although it is not considered to be renewable and cannot be counted towards the Swedish target in the RES-E Directive. This directive will be replaced by the following RES Directive.

A survey of the energy companies and the forest industries shows that the TREC scheme has often been decisive in attracting investment in CHP production (Hirsmark and Larsson, 2005). The scheme is therefore an important explanation for the great increase in the biomass-based electricity production. Between 2002 and 2007 the total annual biomass-based electricity production increased from 4,3 to 9,0 TWh/y (SCB, 2008b). It should, however, be noted that the price increases on the Nordic electricity market have also contributed to increased CHP production.

5.6 Waste management legislation and taxes

Swedish waste management legislation and taxes have, in combination with the energy and carbon taxes, been strong drivers for waste incineration with energy recovery in the DH systems. The legislation includes a ban on landfilling combustible waste (from 2002), and a ban on landfilling organic waste (from 2005). In addition, landfilling of waste that has been approved exemption from the bans on landfilling is taxed. The tax was introduced in 2000 at the level of 250 SEK/tonne, and has then been gradually increased to 435 SEK/tonne (since 2006). Despite high capital costs associated with waste incineration, it has been possible to charge relatively low gate fees for the waste due to the revenues from the heat sales. As a consequence, some of the Swedish waste incineration plants have also received waste from neighbouring countries (Ericsson and Nilsson, 2004).

The legislation and taxes have caused a substantial decrease in the landfilling of waste in Sweden. Between 2000 and 2007, the annual landfilling of MSW decreased from 0,86 Mtonne to 0,19 Mtonne (Svensk avfall, 2008). In the same period the incineration of MSW (with energy recovery) increased from 1,5 to 2,2 Mtonne (2007). In 2007 46% of the MSW was incinerated (with energy recovery) and the remaining MSW consisted of hazardous waste (0,9%) or underwent material recovery (36,8%), landfilling (4,0%) and biological treatment (11,9%) (ibid). The management of industrial waste has developed in a similar way as that of MSW.

In order to promote material recovery and biological treatment of waste, the energy and carbon tax exemption was lifted from incineration of MSW in July 2006. MSW used in DH production is now subject to an energy and carbon tax of 152 and 3426 SEK/tonne of fossil carbon, respectively. The proportion of fossil carbon is assumed to be 12,6% of the weight of MSW. Combined, these taxes correspond to about 0.15 SEK/kWh. Similar to fossil fuels, heat production from MSW in CHP plants is exempt from energy tax and levied a lower carbon tax. The carbon tax is reduced by 79% if the electric efficiency is 15% or more in CHP plant burning MSW.

6 Non-policy factors that have shaped the Swedish district heating sector

6.1 Opportunities associated with municipal ownership

As described in section 4.1, the municipal administrations established and managed the early DH utilities, which were later transformed into municipal companies. There are a number of institutional factors that made the municipalities successful in introducing district heating. Perhaps the most important factor lies in their opportunity to find an initial customer base. This has generally consisted of public buildings such as schools and hospitals and multi-dwelling buildings owned by municipal housing companies. Formal and informal networks and contacts between e.g. municipal employees/officials and municipal housing companies and co-operative housing associations were important elements in this process (Summerton, 1992). Municipal housing companies emerged in the post World War II period, reflecting an effort by municipalities to take increased responsibility for housing. By 1960 the municipal housing companies owned 22% of the dwellings in multi-dwelling buildings and in 1990 the proportion had increased to 38% (SCB, 1982 and 2009). The municipal housing companies are run on a non-profit basis and each has a board with representatives who are appointed by the municipality on the basis of electoral proportionality.

The early introduction and expansion of district heating also benefited from the national housing programme. In the late 1950s and early 1960s there was a severe shortage of housing in Sweden. In order to address this, a national housing programme was started and it ended up with the enormous drive to build one million dwellings between 1965 and 1975. The aim of the programme was also to improve the living standards of the dwellings. A major part of the housing programme was managed by the local housing companies. The municipal authorities therefore had the unique opportunity to coordinate the development of district heating supply with the housing programme. A great part of the dwellings that were built in this programme was connected to DH systems.

The municipal ownership of DH utilities has also influenced the use of fuels and energy sources. One example relates to the fact that municipalities have the opportunity to coordinate the DH production with other tasks such as waste management and sewage. In this respect, incineration of MSW appears as an attractive strategy for many municipalities since it is the solution to two municipal tasks: waste management and district heating (assuming the DH system is still municipally owned). The municipalities have a legal monopoly on collection and handling of MSW. These activities are organised either by municipal companies or by regional companies owned by several municipalities. The municipal ownership has also influenced the DH systems through the principles that regulated municipal businesses until 1996, and by the fact that local and political preferences have been important aspects in the decision-making. In for example the municipality of Växjö, there has been a long-term political commitment to biomass that goes back before the energy tax reform in 1991 and that involves local actors and industries (Mårtensson and Westerberg, 2007).

6.2 Technical standards in the district heating sector

According to Fellesson (2006), the development of technical standards and joint research in the district heating sector have been important factors to the district heating development in Sweden. Much of this work has been done within the Swedish District Heating Association (DHA), but also in co-operation with international standardisation institutes. The Swedish DHA is the trade organisation for companies in Sweden that produce district heating, CHP and district cooling. The association has currently more than 130 member companies, which account for 98% of the total DH production in Sweden. Fellesson (2006) argues that the formulation of technical standards has encouraged coordinated research efforts and that the technical standards have been an important tool for dissemination of information and knowledge within the DH sector. Dissemination of knowledge and joint research efforts have been important due to the fragmentation of the district heating sector which consists of many small companies. The technical standards have also shaped the market for suppliers of technical equipment, and hence improved the compatibility between different components in the DH systems. This has reduced the risk for utilities of being locked-in to a technical system for which there is no longer any supplier on the market. There are also indications that the technical standards reduced the prices of pipes in the 1980s and 90s.

According to Werner (1991), the development of technical standards and dissemination activities of the DHA explain why pipe variations with poor performance never gained foothold in the Swedish DH systems. The DHA has gathered statistics on pipe failures since 1968. In 2007 the heat losses in the DH systems were on average 9%.

6.3 The forest industry and biomass supply

Apart from hydropower, the use of RES in Sweden mainly consists of biomass, which also covers most of the RES in DH production. Sweden has large forest resources from which most of the biomass that is used for energy purposes in Sweden originates. These resources have to a great extent been made available to the energy sector through activities in the forest industry. The forest industry in itself uses large amounts of bioenergy through the combustion of internal by-products such as black liquor and bark for production of process heat and electricity. In 2007 the use of biomass for energy purposes in the forest industry amounted to 59,7 TWh (40 TWh of which is black liquor) (SEA, 2008a). The surplus of forest industry by-products and residues is sold on the wood fuel market to energy utilities and other customers. In fact, a large part of the Swedish wood fuel market is administered by the forest industry through subsidiary woodfuel trading companies. The value of integrating the production of biofuels with the forest industry lies in the opportunity to use skills and structures that already exist in the forest industry. For example, by coordinating the harvesting of forest residues with normal forestry operations costs, the cost machinery and forest roads can be shared between the users. (Roos et al., 1999)

6.4 Public perception

The establishment and expansion of DH systems in Sweden have been consistent with a prevailing acceptance for community-wide technical solutions. Also, competitive prices and reliable supplies have given district heating a good reputation in Sweden. This picture has, however, become increasingly challenged since deregulation of the energy market, particularly in the past few years when DH tariffs have increased considerably. Public perception of district heating is on the whole still positive, but in some municipalities, mainly where DH tariffs are relatively high, the DH suppliers are facing sharp criticism from consumers. The critical voices are mainly found among owners of multi-dwelling buildings and have been particularly strong in Stockholm, where DH tariffs are among the highest in the country. It is clear that in municipalities with high DH tariffs, bedrock heat pumps, if locally feasible, are becoming an increasingly competitive heating option, especially for multi-dwelling buildings. Losing customers within this market segment would of course seriously damage the economics of the DH enterprise. One observation in this respect is that there is little difference in DH tariffs for customers in multi-dwelling buildings and one- and two dwelling-buildings although the distribution costs per MWh heat are considerably larger for the second group. Hence, it appears as if the consumers in multi-dwelling buildings are subsidising those in one- and two dwelling buildings. In order to retain multi-dwelling buildings as customers it may be necessary to offer them lower tariffs. In Stockholm some of the large building owners have now managed to get long-term district heating contracts with prices they seem to be satisfied with.

In order to increase customer confidence in district heating, the Swedish District Heating Association introduced a quality certification system, Reko [translation: Fair] district heating, in 2005. The system was elaborated after discussions with representatives of large customers, e.g. the national associations for large co-operative building societies and the Swedish association of municipal housing companies, and the system is reviewed and updated on an annual basis. In order to be certified, i.e. use the Reko label, the district heating company must meet a number of requirements, e.g. be transparent in tariffs, business and economy. By 2009 the vast majority of the DH supplies in Sweden could use the Reko label.

7 Conclusions and lessons learned for the European arena

In this section the main factors that have shaped the Swedish district heating development are identified and they are discussed in a European context with regard to their relevance and applicability. One challenge with providing lessons learned from the Swedish DH experience is that the introduction of DH systems started more than half a century ago in a somewhat different setting. For example, unlike today the energy markets were local/national and fully regulated.

DH systems exist in significant parts of Europe, but the penetration rate differs greatly between countries. Annex 1 presents the annual sales of district heating in 32 European countries, and for some of these countries the penetration rate of district heating. The table is incomplete due to the poor availability of statistics on heating.

7.1 Heat demand and heat density

DH systems are characterised by high capital costs that are only justified where there is a certain minimum heat demand and heat density. Annex 2 presents a contour map of heating indexes in Europe, to which the space heating demand is proportional. The heating indexes are based not only on outdoor temperatures, but also on the energy efficiency of the buildings (Werner, 2005). The heating index ranges from 60 to 140. Assuming a purely climatic index, the span would be much greater. However, buildings in for example Kiruna (the very north of Sweden) are in general better insulated than buildings in for example Palermo. It should also be noted that the heating index is proportional to the demand for space heating but does not address hot tap water, the demand for which is likely to differ lest within Europe. The highest heating indexes are found in Northern, Central and Eastern Europe. Sweden has a heating index of 105-140 (the vast majority of the population and DH systems are found at the lower half of this range). Although the heating indexes and the demand for heat are lower in Western and Southern Europe, the heat densities in cities/towns could still be high enough to motivate DH systems. There are for example newly built, although small, DH systems in Lisbon and Barcelona (Werner, 2006). DH systems are, however, unlikely to be justified in sparsely populated areas of one- and two-dwelling buildings in warmer parts of Europe.

7.2 The benefits of DH systems: Utilisation of surplus heat and RES

The opportunity to produce electricity efficiently in CHP plants was the main argument for building the first DH systems in Sweden. Apart from the early phase (1950s and early 1960s), the Swedish DH systems have been poorly utilised for electricity production due to the decision to build nuclear power and low electricity prices. The economics of CHP production have, however, improved in recent years as a result of higher electricity prices on the Nordic electricity market and the Swedish TREC scheme, the combination of which has spurred considerable investments in biomass-fired CHP production in the DH systems and the forest industry. In many other European countries, where electricity production is dominated by condensing power plants firing coal or natural gas, the opportunity to transform these into CHP plants is probably the most compelling argument for building DH systems. In theory, it is also possible to utilise the surplus heat in nuclear power plants, i.e. nuclear CHP. Six nuclear power plants in mainly Eastern Europe (for example Ignalina in Lithuania) delivered in total 1,7 TWh of district heating in 2003 (Werner, 2006).

In some Swedish towns the availability of industrial waste heat has been the main driver for building a DH system. A great part of the industrial waste heat that is utilised in the Swedish DH systems is supplied by the forest industry (mainly chemical pulp and paper mills) which is the dominant process industry in Sweden. Industrial waste heat is, however, also present in metallurgical industries and most process industries, e.g. refineries and chemical and food-processing industries. In other European countries which accommodate any of these industries there is likely to be industrial waste heat available. In Sweden the utilisation of industrial waste heat has been indirectly promoted by the environmental and energy taxes and more specifically for the past 10 years by investment subsidies which have made it viable to connect industries and DH systems over longer distances. A dilemma with the Swedish forest industries is that they are often located in sparsely populated areas.

The Swedish DH sector has been able to quickly respond to government policies and therefore played an important role in achieving national policy objectives. During and after the oil crises in the 1970s the DH systems proved to be ideal objects for reducing oil consumption. There was a rapid shift from oil to a variety of other fuels and energy sources, something that prompted policies promoting introduction and expansion of DH systems. Then, as a response to the energy tax reform in 1991 and bans on landfilling combustible and organic waste, the DH systems have accommodated large volumes of unrefined biomass and MSW, fuels that are difficult or inconvenient to use in individual heating due to the need for emission control. In other areas is also often inappropriate to use refined biomass such as wood pellets in individual boilers for air quality reasons.

The importance of biomass in Swedish DH production obviously relate to the large forest resources and the important forest industry, which are only matched by those in Finland. In some other European countries the agricultural sector is likely to play a more important role in the supply of biomass. Also, in some countries the overall biomass production potential may be fairly modest depending on land resources, and soil and climate conditions (Biomass potential in Europe are analysed by e.g. Ericsson and Nilsson (2006) and EEA (2006)). It should, however, be noted that the use of biomass does not necessarily require domestic biomass resources since biomass can be transported and traded. In fact, an important part (perhaps up to 30-40 %) of the biomass used in Swedish DH production is imported. This trade has mainly been driven by the higher willingness to pay for biomass in Sweden compared to other countries, but also, as regards the imports of waste wood, by the greater acceptance for waste incineration in Sweden than in many other European countries. The difference in biomass demand within Europe is, however, decreasing as other European countries are also adopting climate and RES policies. The coastal location of many Swedish towns has of course also facilitated biomass imports. Other RES than biomass have played a minor role in the Swedish DH production. Unlike many other parts of Europe the Swedish geophysical conditions for deep geothermal heat are very poor (Werner and Sköldberg, 2007). Deep geothermal heat refers to high-temperature heat (about 80°C or above) that can be extracted from depths of 500-5000 metres. Deep geothermal heat and solar thermal could make a more important contribution in other countries. Deep geothermal heat is used in a few DH systems in e.g. France, Italy and Iceland, but there is a large untapped potential for using this resource in Europe (Werner, 2006). This is also the case with solar DH production, both in Sweden and other European countries.

7.3 Policies and regulations

Swedish energy and environmental taxes have promoted district heating over other heat options and greatly influenced the use of fuels and energy sources in DH production. In the 1970s, high taxes on oil products were introduced, and in 1991 the energy taxation system was reformed, introducing the carbon tax. The energy tax reform largely explains the great biomass expansion, but it also improved the competitiveness of, and hence the use of, MSW and industrial waste heat. Sweden has no fossil fuel sources of its own (apart from peat that may be regarded as a fossil fuel) which has made high taxation on fossil fuels less controversial than what may have been the case in countries with large fossil fuel resources, employing many. The energy tax reform was part of the restructuring of the whole tax system, which is based on high taxes. The possibility to apply high energy and environmental taxes in other countries will probably depend on the structure of the existing tax system and the general attitude towards taxation per se. With the introduction of the ETS in 2005 it is not likely that countries that don't apply a carbon tax will introduce this in sectors that are affected by the ETS. It is, however, still possible to introduce a carbon tax on fuel consumption in individual heating, depending on public acceptance and household incomes. Sweden has only had minor problems associated with low-income households not being able to afford heating costs. This is partly due to fairly high energy efficiency standards in Swedish buildings and the way in which the social security system is constructed.

There have also been a number of investment subsidies and favourable loans available for DH utilities and presumptive DH consumers in Sweden. It is difficult to give an account of their overall effect on the establishment and expansion of the DH systems. It is, however, clear that subsidies have played an important role in the connection of one- and two-dwelling buildings to DH systems and the establishment of small-scale DH systems. The LIP subsidies in the 1990s were also particularly successful in promoting the utilisation of industrial waste heat.

7.4 Competing systems

Existing energy infrastructures can be a barrier to the introduction of DH systems. Electricity has been the major competing system in Sweden. In the late 1970s and 80s, low electricity prices and powerful electricity companies that marketed electric heating resulted in the installation of a great number of electric boilers and resistance radiators. Electricity is still the main competitor to district heating, but now in the form of heat pumps. Heat pumps and other forms of electric heating may also be the main competitor in some other European countries, while in others it may be natural gas. Natural gas was not introduced until 1985 in Sweden and has played a negligible role in heating of buildings. In the UK and the Netherlands, on the other hand, there are extensive natural gas grids that supply gas to buildings and natural gas accounts for nearly all the energy used for heating in these countries. Individual heating with natural gas is also the dominant form of heating in Italy, France, the Czech Republic, the Slovak Republic, Hungary and Germany (Werner, 2006). It should be noted that the infrastructure for natural gas could also accommodate RES in the form of biogas (methane from anaerobic digestion) or biomethane (methane from thermal gasification of biomass). This infrastructure, however, provide much less flexibility as regards potential energy sources than the DH systems.

The lock-in to a competing system is particularly strong if the building stock lacks central heating, i.e. a water-based heat distribution system, which is a prerequisite for using district heating. There is no statistics on the fraction of buildings with central heating, the definition of which may differ between countries. It is, however, clear that the vast majority of buildings in Sweden have a water-based heat distribution system. The main exception is buildings to use direct electric heating. According to Werner (2006) the presence of water-based heat distribution systems is higher in Northern Europe than in southern Europe.

7.5 Ownership and institutional factors

For district heating to emerge in a particular setting requires the existence of an actor that is willing to make long-term investments and that this organisation has organisational resources to run the system. In Sweden, the municipalities have played an important role in the establishment and development of the DH systems, and they are still responsible for 58% of the DH the supply (in terms of energy). The municipal initiative was natural considering the fact that many municipalities were already responsible for local electricity distribution. The pioneer DH systems involved the retrofitting of old oil-fired condensing power plants to CHP production, something that reduced the initial investment. An important factor behind their success in establishing DH systems lies in their opportunity of ensuring the first customer base among public buildings, i.e. schools, hospitals and buildings owned by municipal housing companies. Also, the housing programme, comprising the building of one million dwellings in 1965-75, contributed to the introduction and expansion of district heating since a large part of these buildings was managed by local housing companies.

Sweden has a tradition of strong local and central government. Similar to Sweden, most DH systems in other EU 15 countries, as well as the EFTA countries, started from municipal initiatives. In the new member states in Eastern Europe, on the other hand, the building of the DH systems were initiated by governmental planning. Hence, there are both similarities and differences in the institutional setting for district heating in Europe. It should also be noted that the setting may change over time. For example, in Sweden a considerable fraction of the DH utilities and systems are now owned by large national/international companies.

7.6 Public perception

There has traditionally been a high acceptance for community-wide technical solutions in Sweden. District heating has also enjoyed a generally good reputation due to reliable supplies and competitive prices. These aspects are important since the connection to DH system implies a loss of control of the heating system for the building owner and the lock-in to one DH supplier (disconnection is possible but requires an investment in new heating equipment) The acceptance for collective solutions and the perception of district heating may be very different in other countries depending on the cultural and political heritage of the country. For example, in many Eastern European countries these systems are often associated with the Soviet era. Many of these systems also suffer large heat losses and are in great need of refurbishment (IEA/OECD, 2004).

After the 1996 energy market reform in Sweden, and as an increasing number of DH utilities have been sold to international companies, the confidence in district heating has been somewhat compromised in some of the towns with the highest DH tariffs. The DH tariffs have increased markedly over the past 5-10 years (along the price increases of fuels and other energy carries). In order to address this, there have been a number of investigations of the district heating sector. None of these have, however, clearly indicated that the large national/international companies have abused their local monopoly position. Nevertheless, in order to maintain the confidence in district heating, the district heating sector is continuously monitored by the Energy Market Inspectorate and a new district heating law that aims to strengthen the position of the customers has been adopted and entered into force in July 2008.

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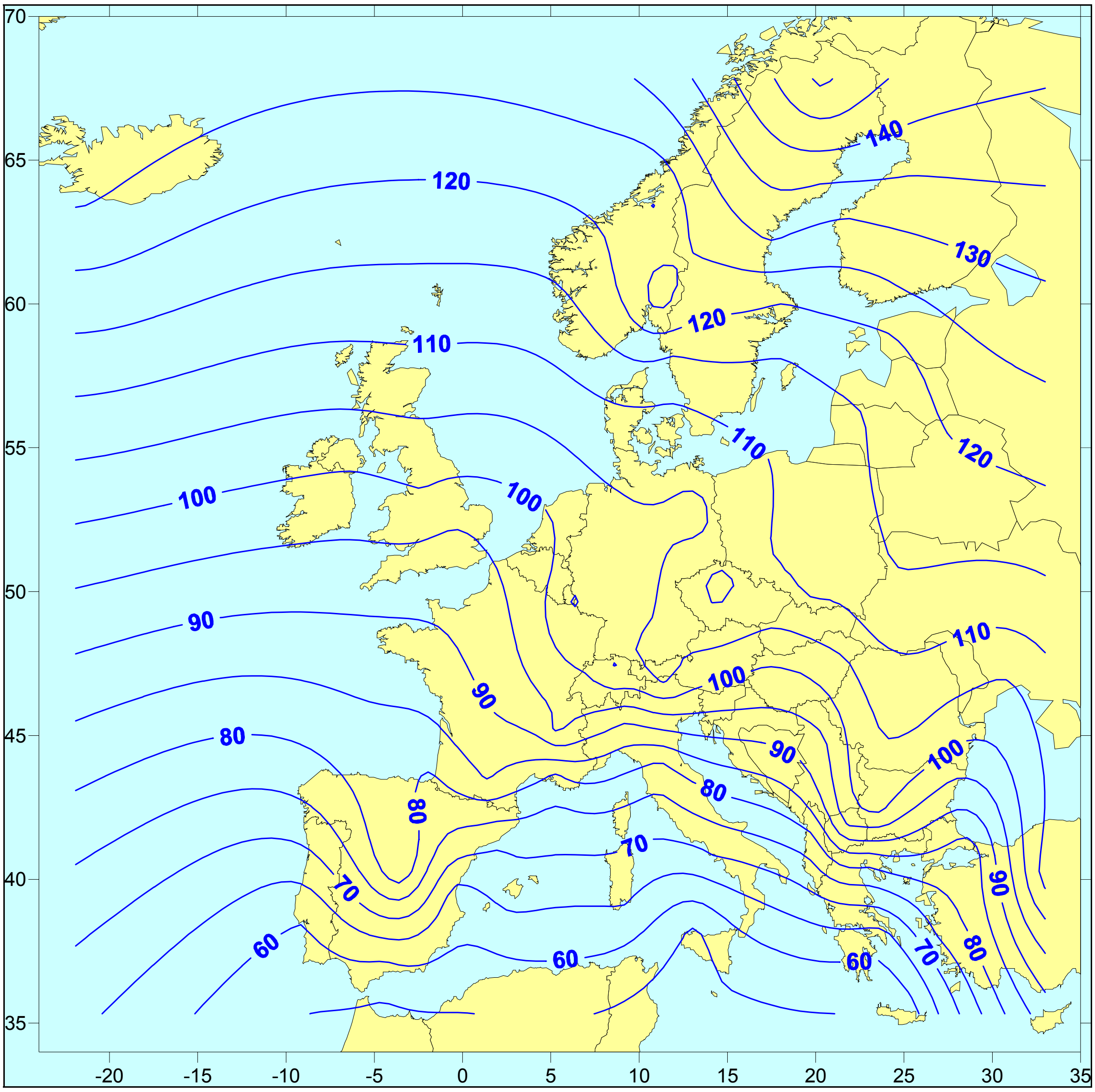
9 Annexes

Table 2 The sale of district heating in 2003 in 32 European countries and the DH penetration rate of some of these countries in 2000

Country	DH sales 2003 (TWh)	DH penetration (%) in 2000
Austria	15	12,5
Belgium	5,8	
Bulgaria	11	
Croatia	3	
Czech Republic	31	
Denmark	29	60
Estonia	5,8	52
Finland	44	49
France	24	
Germany	99	12
Greece	0,3	
Hungary	16	16
Ireland	0	
Italy	5	
Latvia	17	70
Luxembourg	0,6	
Malta	0	
Netherlands	27	3
Norway	2,2	
Poland	86	
Portugal	2,5	
Romania	28	
Slovak Republic	12	40
Slovenia	2,2	
Spain	0	
Sweden	47	50
Switzerland	4,2	
United Kingdom	21	1
Total	500	

Source: Werner (2006)

Figure 17 The European heating index (EHI) in a contour map computed from information for 80 urban locations in Europe within the Ecoheatcool project (Werner, 2005). The space heating demand should be proportional to this index. However, note that the map is not representative for all locations in each country, since the existing data grid consists of only 80 locations



Source: Werner (2005)