

Empirical case-study: The Swedish heat pump transition

The heat pump technology is over 150 years old but has received a large increase in attention over the last few years. In an energy scenario developed by IEA (2013) heat pumps are estimated to supply 10% of all heating in the OECD region by 2020 and a total of 30% by 2050. IEA claims that heat pumps are critical and important to create low-carbon thermal comfort in buildings. In a report by IPCC (2008) the theoretical potential for decrease of CO₂ by using heat pumps is estimated to 1,2 billion tons of CO₂ per year, in other words 6% of the worlds total global CO₂ emissions.

Heating is an important area for transition studies. In Sweden the housing and service sector represents 38% of all energy consumption, a figure that roughly corresponds to the global average (Energimyndigheten 2012a; Energimyndigheten 2013a). The transition that the Swedish heating sector has undergone is sometimes referred to as a silent revolution because of the relatively low level of attention that has been given to the large-scale sustainability transition the sector has undergone (Bergendorff 2010). Since 1990 the CO₂ emissions from the Swedish heating sector has decreased by two thirds (Energimyndigheten 2012a). This development is foremost attributed to the reforms made in the Swedish district heating grids and to the large-scale heat pump expansion in Sweden (Swedish Energy Agency 2015).

The European heat pump market had been expanding since the early 2000s up until the crisis of 2008 (Forsén & Nowak 2010). Since 2008 the total sales have remained more or less the same with signs of increasing sales over the last few years (Nowak 2015). Compared to other nations Sweden has a unique position when it comes to heat pumps. It tops the statistics on heat pump market penetration (Nowak 2015) and has for a long time been one of Europe's largest heat pump markets in absolute figures as well. The largest ground source heat pump market is still found in Sweden¹ (Forsén & Nowak 2010).

An overview of Swedish heat pump market development is seen in Figure 1. The high level of ground source heat pumps and the relatively high share of large heat pumps in the district heating grids (not seen represented in Figure 1) puts Sweden as the unthreatened number one heat pump country in Europe, counting heat supplied by heat pumps per capita.

¹ In 2015 the largest European heat pump market was the French market, followed by the Italian and Swedish markets. The characteristics of these three markets are however quite different. The largest heat pump market segments in France are for sanitary hot water heat pumps with air as heat source, the Italian market is completely dominated by air-air heat pumps, and the Swedish market is the largest market in Europe for the more powerful and expensive ground source heat pumps (Nowak 2015).

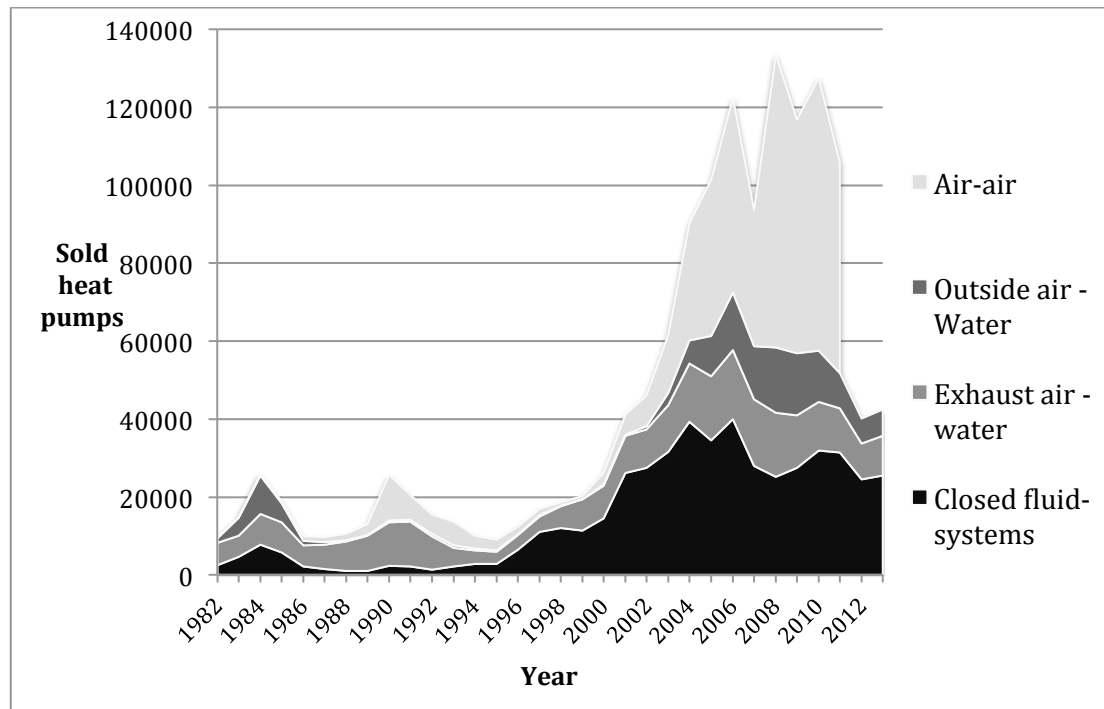


Figure 1. Heat pump sales in Sweden 1982-2013 (SVEP 2013)²

A majority of the Swedish small houses that were equipped with oil burners or direct electric heaters forty years ago have now converted to heat pumps. More than half of all small houses in Sweden, over one million, has an installed heat pump (SVEP 2013; Swedish Energy Agency 2015:13). According to heat pump expert Jan-Erik Nowacki (2013) heat pumps consume roughly 10 TWh of electricity annually, which roughly gives 30 TWh of heat. So about 20 TWh of renewable energy is picked up from the air and ground by heat pumps in Sweden each year and supplied as high grade heat to Swedish buildings.

Swedish manufacturers have played an important role in supplying customers with heat pump products adapted to Swedish climate and heat pump services. A majority of all the 1,5 million sold heat pumps in Sweden (SVEP 2013), excluding the air-air heat pump segment, have been of Swedish brands. The Swedish companies NIBE, Thermia and IVT are also some of Europe's largest heat pump manufacturers and the largest manufacturers of ground source heat pumps (EREC 2004).

The Swedish heat pump industry was formed during the late 1970s and early 1980s and grew together with the Swedish heat pump market. The industry has passed through several ups and downs and is currently a medium sized industry with a turnover of roughly 600 million³ € and exports of around 100 million €

² Note that the statistics for air-air heat pumps in Figure 1 is based on estimations made by the heat pump association SVEP. SVEP stopped doing these estimations in 2012 because of lacking information on these sales, and therefore these sales are not included for the last two years.

³ This figure is based on estimations made by EHPA (Nowak 2015) together with export statistics from SCB (Statistics Sweden) and cross-examined against figures from the consulting firm Gaia Consulting Oy (WWF Finland 2008)

annually⁴. Some of Europe's largest heat pump manufacturing facilities are found in Swedish cities like Markaryd, Tranås, Arvika and Ljungby. According to Bosch Thermoteknik (2016) Sweden is "the motherland for industrial manufacturing of heat pumps".

Heat pump technologies and different heat pump business logics

A heat pump can simply be described as refrigerator working in reverse, i.e. a machine that 'pumps heat' from a cold side to a warm side. A heat pump takes up heat from a heat source (air, ground, water) and delivers heat to a heat sink (typically inside of a building). A heat pump that takes up heat from the outside air and gives off to the inside air is called air-air heat pump (AAHP). If the heat pump takes up heat from the outside air but gives off heat to a water based heating system its called air-water heat pump (AWHP). If the heat is taken up from the outgoing ventilation air it is an exhaust air heat pump (EAHP). A heat pump type that uses the ground as a heat source, which is common in Sweden, is called ground source heat pumps (GSHP).

There are different business logics for these different heat pump types. The AAHP is the typically cheapest and least powerful heat pump type. AAHP can often be bought at the local hardware retail store. Historically these heat pumps have primarily been manufactured by American companies, followed by Japanese and Korean manufacturers. Lately Chinese AAHP manufacturers have also expanded on the international market. The value network of AAHP follows a typical retail business logic with simple installations that only requires one installer with electrician competence. The AWHP and GSHP are more capital intensive investments than the AAHP. Installation of heat pumps to a water heating system requires both plumber and electrician competence with a higher skill level than for AAHP installations. In Sweden AWHP and GSHP are typically sold through specialized heat pump installers that are dedicated and have an established partnership with a specific heat pump brand (e.g. IVT, Thermia or CTC). The EAHP follows a third business logic as they are typically only installed in new built houses and not existing buildings. This requires another set-up of downstream channels than for other heat pumps. The EAHP only uses the air within the building as a heat source is therefore considered as an energy recovery technology rather than a renewable energy producing technology.

Before the first heat pump value networks appeared in Sweden

The first heat pump value networks appeared in Sweden during the 1970s. Before the 1970s the energy and heating regime in Sweden was quite stable and based on oil, bio fuels (wood) and direct electric heating. Energy planning was not seen as a political area but rather as tasks for government officials (Kaijser et al. 1988). Sweden's rapid economic growth during the 1950s and 60s had been

⁴ Statistic from SCB (Swedish Statistics) using code number KN 84186100 for the period 2006-2014 and with the code KN 84186190 for the period 1997-2005. According to INTRASTAT KN 2013 the code KN 84186100 is defined as 'Heat pumps, other than air conditioning units as per no 8415 ('Värmepumpar, andra än luftkonditioneringsapparater enligt nr 8415'), which means reversible air-air heat pumps is not included in these figures

heavily dependent on imported oil, but with stable and low prices the high oil dependence was not seen as a urgent problem.

The first commercial heat pump installations in the 1950s and 60s were not primarily heat supplying units. Instead they were reversible site-built air-conditioning/cooling units made by refrigeration companies for special need customers, e.g. hospitals, sports facilities or industry plants. When the interest for heat pumps rose in the 1970s the only companies that both had the competence and commercial experience of heat pumps were found in the refrigeration industry.

The October war in 1973 led to a global oil crisis. Sweden's energy sector was at the time to 75% dependent on oil imports (Energimyndigheten 2008). The increasing oil prices put a larger public and political focus on the energy sector, as did the initiated plans of nuclear power expansion in Sweden. It is in this period that the first value networks focusing on selling and installing small heat pumps started to emerge in Sweden.

The formation of the first heat pump value networks

The first known manufacturing of a GSHP product in Sweden began in Arvika around 1972. The manufacturer Thermia was at the time a supplier of heating equipment to wholesalers in the HVAC industry. Their heat pump production began as contract manufacturing after they had been approached by a Swedish affiliate to a Danish company. This affiliate had an idea of an integrated heat pump and water boiler product based on a Danish heat pump design, which Thermia helped them develop and produce. After the first oil crisis the demand grew and Thermia took over the product and launched it under their own Thermia brand. The Swedish HVAC industry was at the time clearly divided into the different links of the value chain and so these first GSHP (ground source heat pumps) were all sold through wholesalers to retailers and installers who in turn sold it to the first customers, as illustrated in Figure 2 (see the appendix for high resolution versions of the value network illustrations).

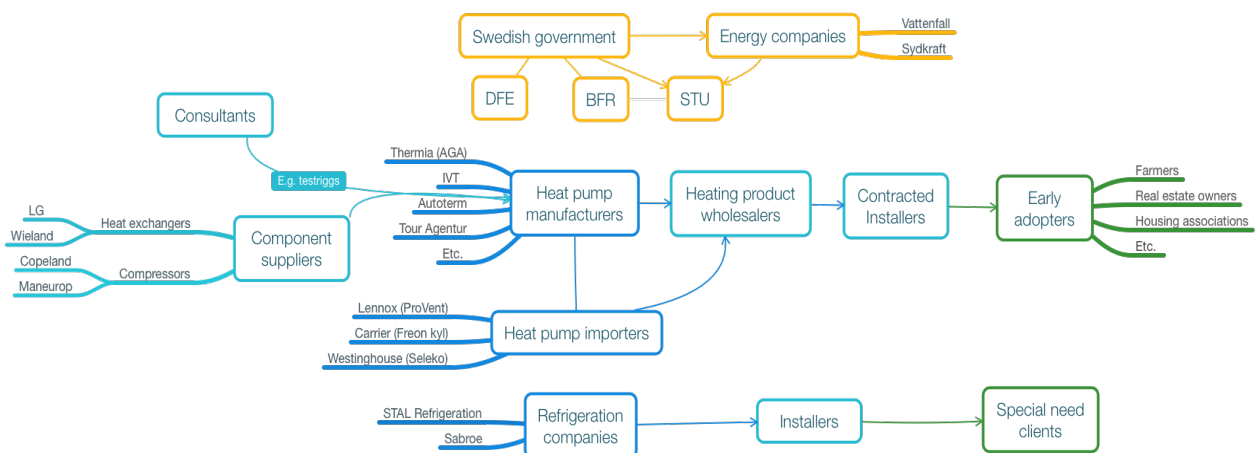


Figure 2: Illustration of Swedish heat pump value networks in mid 1970s

At the same time the imports of small AAHP (air-air heat pumps) increased. The AAHP industry had developed in the US since the 1940s and most imported AAHP were of American brands such as Lennox, Carrier and Westinghouse. There were no imports of AWHP (air-water heat pumps) or GSHP (ground source heat pumps), these heat pump units were all manufactured by Swedish companies. However, the AWHP that were available on the market were often based on imported AAHP that had been adapted by Swedish workshop companies to fit with to water based heating systems that were common in Sweden at the time (Vattenfall 1978).

The companies in the refrigeration industry that had supplied site-built heat pumps during previous decades did not change their business model to adapt to the increasing demand from house owners, but continued to focus on larger installations.

In 1975 the Swedish government launched an energy research program with state funds aimed towards alternative energy and heating technologies. The heat pump product was both untested and unfamiliar at the time and was only briefly mentioned in the program (Palme & Johansson 1975). The first governmental organisations to engage in the emerging heat pump value networks were the Building Research Council (BFR) and the Board for technological development STU, which controlled the government funds for research projects aimed at energy usage projects in the built environment, including heat pumps (Ullsten & Tham 1979:268). The temporary delegation DFE, also included among the supporting actors in Figure 2, was appointed to prepare the Government's 1978's energy research program by compiling and evaluating the efforts within the first energy research program.

Two other important supporting actors were the state owned energy company Vattenfall and Vattenfall's second Sydkraft (today Eon), which was owned by several municipalities in the south of Sweden. Vattenfall had a big influence on the energy sector in Sweden as both TSO and appointed as responsible by the government to lead the nations energy development.

Vattenfall and Sydkraft began a joint heat pump project in 1973 with procurement of heat pump test facilities, often joint with the government agency STU, together with house constructors and heat pump suppliers (Vattenfall 1973; Ahlmark & Johansson 1978). The aim of the test project was to gain experience on how to increase the efficiency of energy usage and the results from the tests were presented in joint publications. The tests first focused on AAHP, then came to include AWHP and eventually GSHP and larger sized heat pumps as well. When the energy companies ordered installation of heat pumps it typically occurred through contractors which in turn used their own sub-contractors, making the coordination difficult for the main contractor (Vattenfall 1978b).

From the mid 1970s and up until the mid 1980s these Swedish energy companies engaged and made quite large investments in heat pump development projects. The energy companies saw themselves as the natural centre for development of new energy technologies in Sweden. They also had

board directives to act for the common good of Sweden. They took on the role of financing tests of new heat pump products and procuring, testing and giving feedback to the existing heat pump manufacturers. Later their roles also included educating heat pump installers.

Increased cooperation between value networks with the oil crises

After the Iranian revolution and the second oil crisis in 1978-1979 the interest in heat pumps from commercial actors increased further with increasing government funds towards research and development projects and a rapidly growing demand from customers. In the late 1970s Sweden was in the middle of a rapid expansion of nuclear power, so the increasing heat pump demand to a large degree depended on cheap electricity prices and expensive oil prices.

During the period 1978 to 1984 there were different governmental heat pump support initiatives that continuously succeeded one another. The support instruments was formed to be price-affecting to temporarily increase heat pump demand. The support instrument took shape of subsidised loans or direct subsidies (Engebeck & Zingmark 1987).

In 1979 Vattenfall launched a large scale solar and heat pump project called the "Solar project" which finished by 1986-87. In the end of the program around 60 million € had been spent on different development projects, out of which 80% had gone into heat pump projects (Vattenfall 1989b).

When the market expanded the heat pump suppliers rapidly increased, as is typically the case in early stages of a new industry (Klepper 1997). It is in this period, during the early 1980s, that the value network around small heat pumps was the most complex. There was no established dominant design and the multitude of suppliers had varying backgrounds. Several governmental actors engaged in attempts to bring stability to the complex and growing heat pump value network, illustrated in yellow in Figure 3. Especially Vattenfall took a central role as a mediator between different actors within the industry.

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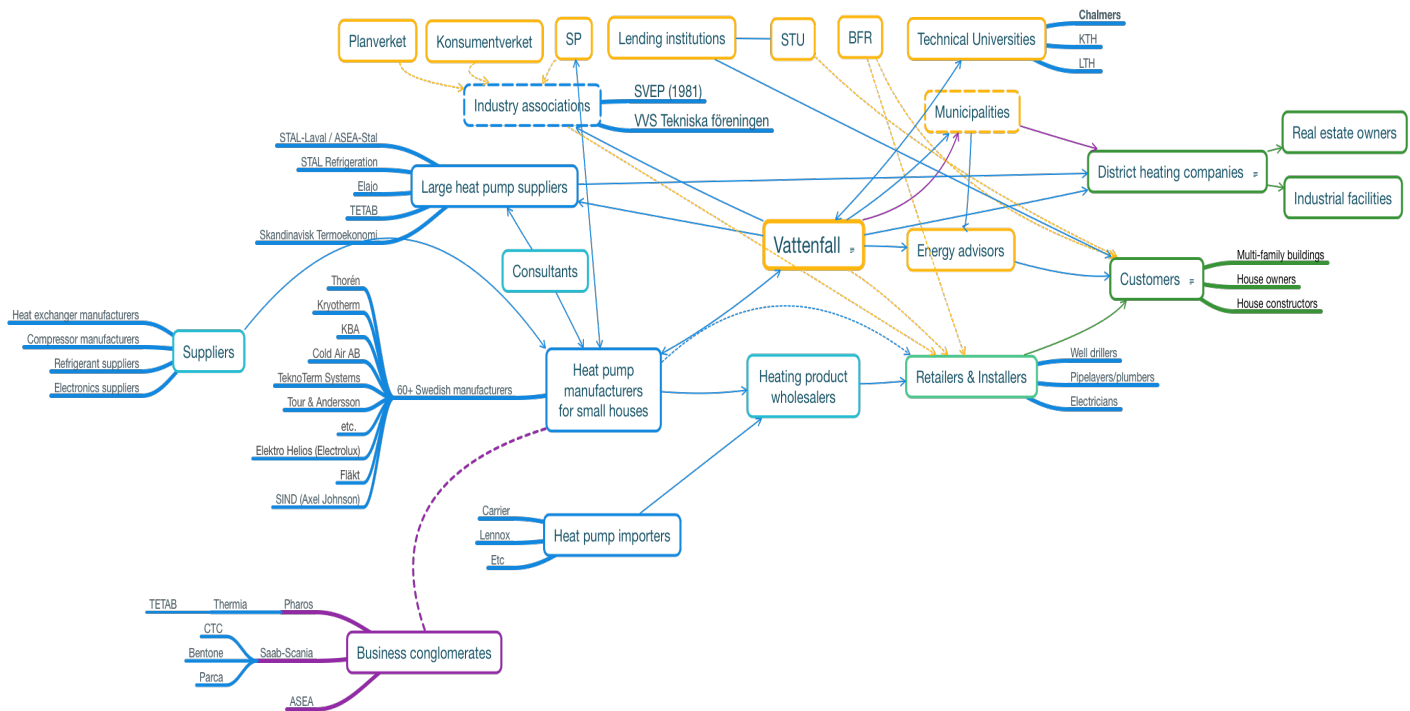


Figure 3: Heat pump value networks in Sweden in the early 1980s

In just a few years more than 100 heat pump brands had appeared on the Swedish market. Several business conglomerates, illustrated in purple in Figure 3, engaged in the heat pump technology by acquiring incumbent heat pump firms.

However, many heat pump installations suffered from poor applications. Within the refrigeration industry heat pumps were always delivered as turn-key products, but in the HVAC industry there were still basically no communication at all between the manufacturers and end customers, and as previously described often a long line of sub-contractors. Heat pumps were more complicated to install in an existing heating system than the typical "pipe layer installer" was used to (compared to oil burners, wood stoves or direct electric heating) which caused many application problems for installations of small heat pumps. But the HVAC manufacturers only took responsibility for the performance of the technological components of the heat pump, and not problems that related to poor installation workmanship. This resulted in customers with failing heat pumps not receiving adequate service. Some producers of small heat pumps realized they needed to take larger responsibility for the installations of their products and started a semi-integration forwards by skipping the wholesale-step and building a network of dedicated installers instead. Soon each installation of the most famous heat pump brands in Sweden were required to be made by a certified heat pump installer. By doing so they took increased control of the installations and a big step towards adopting the business model from the refrigeration industry. Apart from the industrial companies there were many other actors involved in trying to solve the problems with poor installation and service of failed heat pumps, including

government agencies, a newly formed industry association and energy companies.

There was a struggle between the refrigeration and HVAC industry during this period, where both tries to 'appropriate' the heat pump technology. Lobbyist from refrigeration industry manage to get through a decision that the heat pump should be seen as a refrigeration technology and therefore required refrigeration competence from the installer. The response from HVAC companies, such as Thermia, was to start educating their installers in their own education programs to give them the required refrigeration competence. The HVAC industry had, unlike the refrigeration industry, a nation wide network of installers. With this advantage the HVAC industry dominated the market for small heat pumps. But for installations of larger heat pumps, that became increasingly popular in district heating grids from 1981 and onwards, refrigeration companies remained as the dominant suppliers.

Increased pressure on the heat pump value networks with the 'reverse oil crisis'

In the mid 1980s the heat pump markets drastically decreased as the oil price dropped in what is called the 'reverse oil crisis'. At the same time there were comprehensive uncertainties regarding future electricity prices due to a referendum in 1980 where the Swedes voted for closing all nuclear power plants "with common sense". With the shrinking markets a majority of all suppliers of heat pumps exited the industry after 1985 and the large business conglomerates disinvested their heat pump assets. The largest heat pump producers at the time, IVT and Thermia, were able to remain with substantial down-sizing and through frequently changes in ownership.

When experienced and locally anchored company leaders took over the ownership situation stabilised. These owners were actively engaged in the manufacturing processes and also had a wide network of new relationships which they brought with them. The new owner's contacts with financial actors played a big part both in keeping the companies afloat during the years of low heat pump sales and also to finance the companies abilities to respond to the quickly growing demand beginning in the mid 1990s. With new leadership IVT and Thermia also engaged in new collaborations. For example IVT's new owner developed a partnership relationship with the city where their manufacturing was located and sold all their industrial facilities to the city to increase their liquid assets. IVT also developed improved relations with Japanese AAHP manufacturers and focused more on this market segment which was selling more than the GSHP market segment did. The heat pump companies and their owners also actively engaged in lobbying activities aimed at government organisations, to launch new and bigger procurement programs aimed at heat pumps.

Suppliers of EAHP were largely unaffected by the 'reverse oil crisis' due to changes that had been made in formal regulations. Since 1980 the Swedish building regulations demanded houses to be built using heat recovery, e.g. EAHP.

The EAHP value network were well aligned with current formal rules, demanding heat recovery in new built houses, and cognitive rules among house constructors to choose EAHP instead of the alternative FTX heat exchangers.

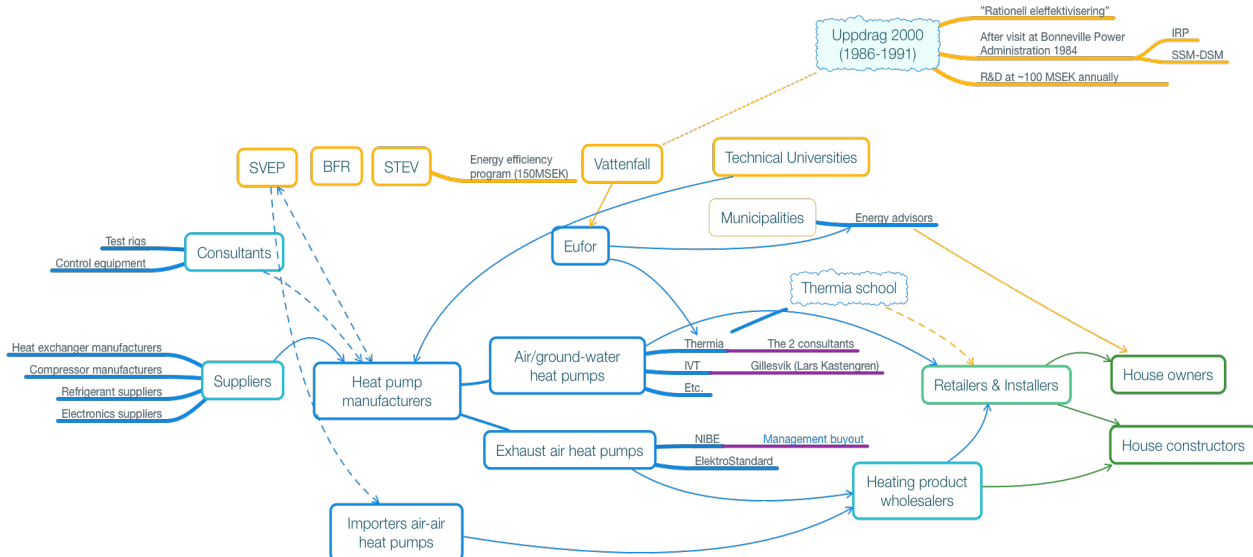


Figure 4. Heat pump value networks in Sweden in the late 1980s

With the reverse oil crisis several supporting actors cut down their support towards heat pumps. Vattenfall launched a new large scale program called Uppdrag 2000 which was much more market oriented than the previous Solar project. With commercial intent, instead of the "good of the nation" intent, Vattenfall's role as a supporting actor changed. Vattenfall also discontinued its role as a mediator between heat pump actors and instead deepened their collaboration with a few heat pump producers, one being a small company named Eufor that manufactured direct expansion heat pumps.

Increased value network structure stability when heat pumps market expanded

The extensive exit of actors during the 'reverse oil crisis' had increased the structure stability of the remaining actors in the heat pump value networks. There were fewer types of actors involved in the networks and as heat pump demand increased from the mid 1990s the number of heat pump actors increased while the number of actor types remained the same.

The increased heat pump demand in the mid 1990s depended on several factors, the energy price ratios become increasingly favourable against heat pumps at the same time as the government agency NUTEK launched a large procurement program between 1993 and 1995. The manufacturers IVT and Eufor won the competition and received both price money and promises of procured heat pumps. Changes in environmental legislations, with Sweden abandoning refrigerants hazardous for the ozone layer before any other nation, forced both winners to chance on new untested compressor types that were supposed to work with new ozone-friendly refrigerants. However these compressors soon broke down due to problems with the refrigerant and the compressor's

lubricating oil. This forced both IVT and Eufor to exchange the compressors in hundreds of their already sold heat pumps. The organizational structure of IVT was much better fitted for this task whereas Eufor – that had a completely different network set-up, largely depending on Vattenfall for sales and even doing some sales by mail order – struggled more. Around 1994 Vattenfall received directives that they needed to stop all handling of equipment with 'freons' (refrigerants hazardous to the ozone layer) they were forced to stop retailing Eufor's direct expansion heat pumps and also quit all other collaborations with Eufor. Within a few years the GSHP value networks managed to completely outcompete the direct expansion heat pumps from the Swedish market, partly by influencing the normative rules among their installers that direct expansion heat pumps failed more frequently than other heat pumps.

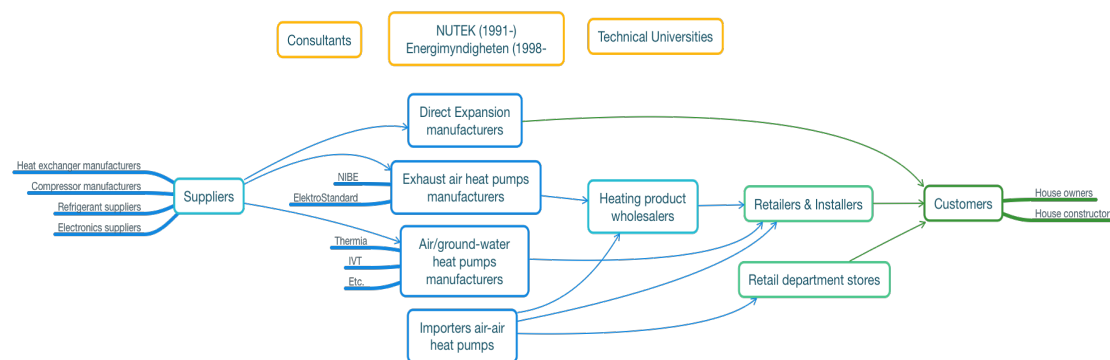


Figure 5. Heat pump value network in Sweden in the mid 1990s

In the 1980s over 100 large heat pumps had been installed in district heating facilities in different municipalities all over Sweden. But as the market for small heat pumps increases in the late 1990s and early 2000s and started to threaten the expansion of district heating the district heating companies view on heat pumps switched (see e.g. Sköldberg et al. 2006; Barth et al. 2014; RO 2012).

Value network reconfiguration again with international expansion

The heat pump market boosted between 1995 and 1997, without any subsidy. Heat pump subsidies were reintroduced first in 1998, and until 2008 heat pump market subsidies were given on and off. When the Swedish home market showed signs of saturation in the 2000s the Swedish manufacturers increased their focus on international markets (Forsén 2008). At 2003 Swedish heat pump exports were at 172 million SEK, five years later the value of exports had risen to 1,2 billion SEK (roughly corresponding to 120 million €).

In 2005 international companies Bosch and Danfoss acquired the Swedish heat pump manufacturers IVT and Thermia. Only NIBE, which was the only large Swedish heat pump manufacturer which had not chosen to skip the wholesale-step in their distribution network, remained with Swedish ownership. Still all four of the large heat pump manufacturers (NIBE, Thermia, IVT and CTC) remained with their production facilities, and even increased the production capacity, in Sweden. The competence concerning heat pump development was high in Sweden and according to NIBE's CEO Gert-Eric Lindqvist there is an

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advantage having production and development in close relation to each other (Weibul 2014). While Swedish manufacturers have been able to get a foothold in other nations the big heat pump manufacturers in Europe (e.g. Viessmann, Stiebel Eltron and Vaillant) have not been successful in penetrating the Swedish heat pump market.

In latter years energy companies has once again showed increasing interest in heat pumps, now due to the benefits of storing energy in hot water using heat pumps that balance production from renewable energy sources (Vattenfall 2011; Vattenfall Europe Wärme 2012).