# Application of Industrial Heat Pumps

IEA Industrial Energy-related Systems and Technologies Annex 13
IEA Heat Pump Programme Annex 35

## Task 1:
## Heat Pump Energy situation, Energy use, Market overview, Barriers for application

**Final Report**

**(Status: 31.05.2014)**

Prepared by the
Participants of Annex 35/13

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# 1 Summary

The world rising energy prices and environmental concern set focus on energy conservation and use of renewable energy sources.

In this context, the IEA HPP-IETS Annex 35/13 has been initiated in order to actively contribute to the reduction of energy consumption and emissions of greenhouse gases by the increased implementation of heat pumps in industry.

The heat pump markets are currently growing at a steady pace, but in many countries, however, is focused mainly on residential heat pumps for space heating and domestic hot water. While the residential market may be satisfied with standardised products and installations, most industrial heat pump applications need to be adapted to unique conditions.

The work in the Annex in task 1 starts by making an overview in the participating countries of the industrial energy situation and use, the state of the art in heat pumping and process technologies and its applications, as well as analysing business cases on the decision-making process in existing and new applications. Based upon these findings focus will be given to further work to meet the challenges in the wider application of industrial heat pumping technologies.

# 2 Introduction

Improving energy efficiency is the single most important first step toward achieving the three goals of energy policy: security of supply, environmental protection and economic growth.

Nearly a third of global energy demand and $CO_2$ emissions are attributable to industry, especially the big primary materials industries such as chemicals and petrochemicals, iron and steel, cement, paper and aluminium. Understanding how this energy is used, the national and international trends and the potential for efficiency gains, is crucial.

While impressive efficiency gains have already been achieved in the past two decades, energy use and $CO_2$ emissions in manufacturing industries could be reduced further, if best available technologies were to be applied worldwide.

Some of these additional reductions may not be economic in the short- and medium-term, but the sheer extent of the potential suggests that striving for significant improvements is a worthwhile and realistic effort. A systems approach is needed that transcends process or sector boundaries and that offers significant potential to save energy and cut $CO_2$ emissions.

Heat pumps have become increasingly important in the world as a technology to improve energy efficiency and reduce $CO_2$ emissions. They are presently widely used mainly on residential buildings for space heating and domestic hot water and are expected to spread to the industrial sector to be used for heat recovery and heat upgrading in industrial processes and for heating, cooling and air-conditioning in industrial buildings.

The introduction of heat pumps in food and beverage manufacturing factories and wood drying with operating temperature below 100 °C is in many cases considered to be easy, however, higher temperature application still require additional R&D activities for the development of high temperature heat pumps, integration of heat pumps into industrial processes and development of high temperature refrigerants.

In this context, the IEA HPP-IETS Annex 35/13 "Application of industrial Heat Pumps", a joint venture of the IEA Implementing Agreements "Industrial Energy-Related Technologies and Systems" (IETS) and "Heat Pump Programme" (HPP) has been initiated in order to actively contribute to the reduction of energy consumption and emissions of greenhouse gases by the increased implementation of heat pumps in industry.

The work in the Annex starts by making an overview in the participating countries of the industrial energy situation and use, the state of the art in heat pumping and process technologies and its applications, as well as analysing business cases on the decision-making process in existing and new applications. in the wider application of industrial heat pumping technologies.

The Task 1 Report summarized the present energy situation in general and the industrial energy use and related heat pump market subdivided into the annex 35/13 participating countries. Based upon these findings focus will be given to further work to meet the challenges for the wider application of industrial heat pumping technologies.

Table 2-1 gives an overview of general indicators worldwide, in OECD countries as well as European Annex participating countries.

Table 2-1: General indicator for 2008[1]

| | Population (million) | GDP (billion 2000 USD) | Energy production (Mtoe) | Net Imports (Mtoe) | $CO_2$ emission (Mt of $CO_2$) |
|---|---|---|---|---|---|
| **World** | 6 688 | 40 482 | 12 369 | | 29 381 |
| **OECD** | 1 190 | 30 504 | 3 864 | 1 765 | 12 630 |
| **Annex Countries Europe** | 193,2 | 5 051 | 422 | 440,3 | 1 378 |
| **France** | 64 | 1 515 | 137 | 139 | 368 |
| **Germany** | 82 | 2 095 | 134 | 211 | 803 |
| **The Netherlands** | 16,4 | 449 | 67 | 34 | 178 |
| **Sweden** | 9,3 | 297 | 33 | 20 | 46 |
| **Austria** | 8,3 | 226 | 11 | 26 | 69 |
| **Denmark** | 5,5 | 178 | 27 | -4,7 | 48 |

The following Figures present energy consumption, $CO_2$-emissions and industrial energy consumption in the 27 EU countries:

Figure 2-1 shows the final energy consumption in the EU 27 countries subdivided by energy source in 2007.

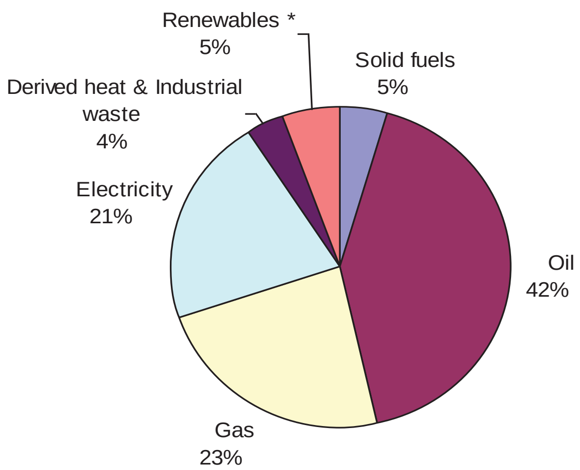



Figure 2-1: EUR27 final energy consumption by fuel 2007 (Mtoe)[2]

[1] INTERNATIONAL ENERGY AGENCY - Tracking Industrial Energy Efficiency and $CO_2$ Emissions – Energy Indicators 2007

[2] European Commission / ENERGY - EUROPE 2020 initiative - Energy Efficiency Plan 2011, Statistical pocketbook 2010

Figure 2-2 shows the final energy consumption in 2007 subdivided by sectors. 28 % of total energy consumption is used by the industry, number two after the transportation with 32 % and before the household with 25 %.

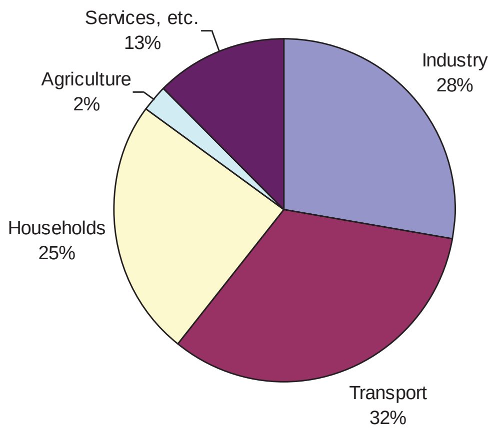



Figure 2-2: EU27 final energy consumption by sectors 2007 (Mtoe)[3]

The $CO_2$-emissions by sectors in the 27 EU countries are presented in Figure 2-3 with 22.3 % emitted by the industry.

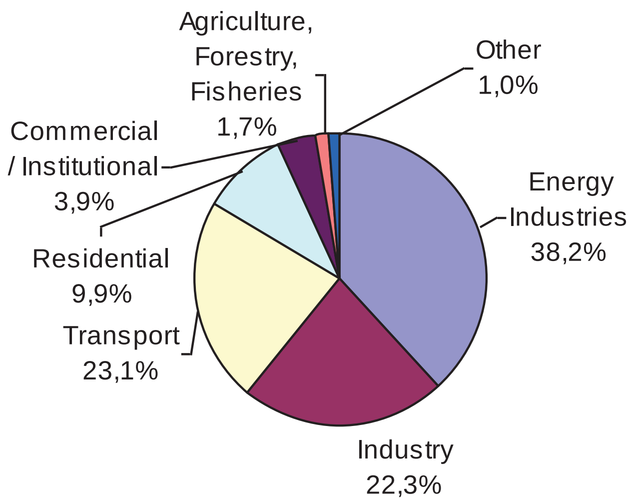



Figure 2-3: Eu27 $CO_2$ -emissions by sector 2007 (Mt)[3]

Figure 2-4 shows the European industrial final energy consumption by sectors in the 27 EU-countries, dominated by the Iron and Steel, Chemical, Non-mineral products and Paper and Printing industries.

[3] European Commission / ENERGY - EUROPE 2020 initiative - Energy Efficiency Plan 2011, Statistical pocketbook 2010

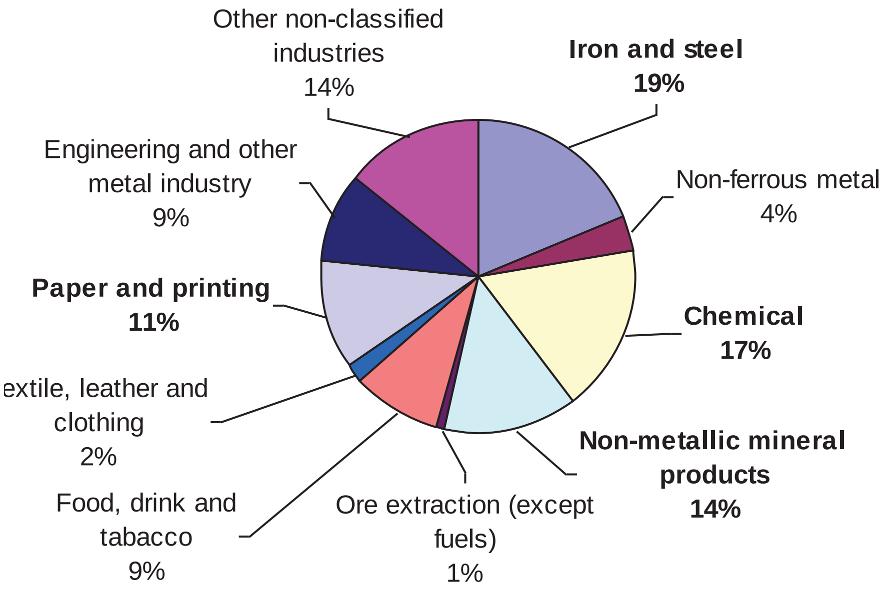
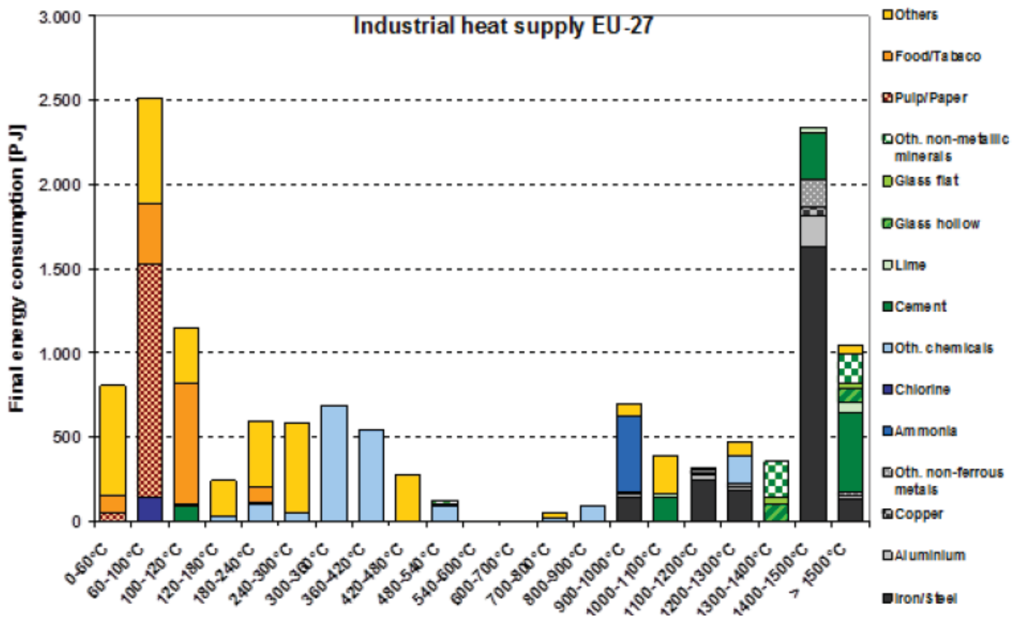



Figure 2-4: EU27 industrial final energy consumption by sectors 2008 (Mtoe)[4]




Source: SP Technical Research Institute of Sweden

Figure 2-5: EUR 27 final energy consumption by sectors as function of temperature

[4] European Commission–Eurostat -2008

# 3 Austria

## 3.1 Industrial Energy use in Austria 2009

The energy consumption in Austria has nearly doubled in the last 40 years, both in terms of combined total consumption as well as final consumption, according to Statistics Austria (2010a).

In recent years the use of renewable energy in Austria increased disproportionately due to various measures such as awareness campaigns, a variety of fundings or the creation of legal framework (Statistics Austria 2010c). A very high share of 68% of Austria's electricity supply was covered by renewable energy from hydro, wind, PV, geothermal heat and biomass. Hence, "green" electricity is in the leading position by the use of renewable energy, followed by "green" heat for district heating from biomass and geothermal energy with a share of 36%, the direct use of renewable energy from bio-heat, ambient-, geothermal- and solar-heat for heating applications with a share of 30% and biofuels[5] with a share of 7% of transport fuel. (Statistics Austria 2010c)

Despite a steady increase in the use of renewable energy sources, the bulk of Austrian energy consumption is still covered by fossil fuels such as oil and gas. This fact presents a growing problem especially as far as emissions of greenhouse gases and the security of the Austrian energy supply is concerned, as 70% of these fossil fuels have to be imported from foreign countries. Austria's dependency on foreign energy supplies amounted 64.8% in 2009 (EU average 2007 is 53.1%) and this share is steadily increasing. (Statistics Austria, 2010a)

The final energy balance split in energy carriers in Austria is shown in Table 3-1 and Figure 3-1. In 2009, 39% of the overall final energy demand in Austria (1057 PJ) was covered by oil and 17% by gas, as shown in Figure 3-1 and Table 3-1 (Statistic Austria, 2010b). Thus, the reduction of this high dependency on these fossil fuels should be focused in Austria. Keeping in mind the $CO_2$-emission and that only around 13% of the crude oil demand and 20% of the gas consumption are covered from Austrian sources, this offers a high ecological and economical potential (Statistic Austria, 2010a).

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[5] biodiesel and bioethanol

Table 3-1: Austria's final energy balance per energy carriers in 2009 (Statistic Austria, 2010b)

| Energy carrier | [PJ] |
|---|---|
| Oil[6] | 423 |
| Gas[7] | 175 |
| Coal[8] | 22 |
| Electricity | 208 |
| District Heat | 64 |
| Renewable[9] | 166 |
| Total | 1057 |

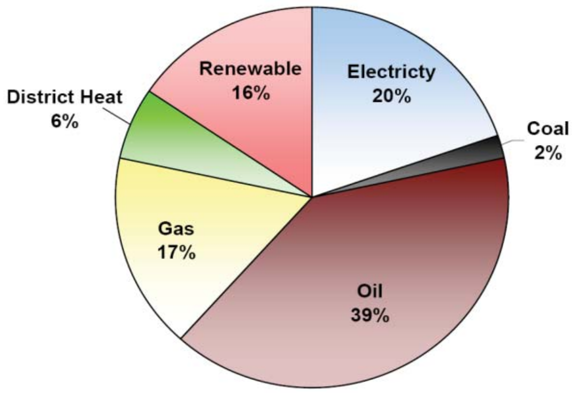


Figure 3-1: Austria's final energy balance per energy carrier in 2009 in percentage (Data based according to Statistics Austria, 2010b)

The Austria's energy demand can be classified in three main sectors:

- industry,
- transport and
- miscellaneous.

The industry sector includes the entire producing and manufacturing area in Austria. The transport sector is composed of the internal navigation, air-, rail- and road-transport as well as pipeline transport. Miscellaneous contains the aggregated domestic energy demand, including commercial and public services as well as agriculture.

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6 Oil includes: crude oil, refinery feedstock, gasoline, kerosene, fuel oil, other oil products and refinery gas (Statistics Austria, 2010b)

7 Gas includes natural gas and gasworks gases (Statistics Austria, 2010b)

8 Coal includes hard coal, lignite, BKB, peat, coke, blast furnace gas and coke oven gas (Statistics Austria, 2010b)

9 Renewable includes all energy carriers as waste, fuel-wood, bio-fuels, ambient-heat, hydro- and wind-power and PV (Statistics Austria, 2010b)

Table 3-2 represents the distribution of the final energy use across the different sectors. As shown in Figure 3-2, the final energy use in Austria is approx. uniformly distributed to the three main sectors. With a share of 29% of Austria's final energy demand, the industry offers the possibility to reduce the whole energy demand and lower the $CO_2$-emissions significantly.

Table 3-2: Distribution of the Austria's final energy use in 2009 across the main sectors (Statistics Austria, 2010b)

| Sector | Final energy use [PJ] |
|---|---|
| Industry | 308 |
| Transport | 357 |
| Miscellaneous | 392 |
| Total | 1057 |

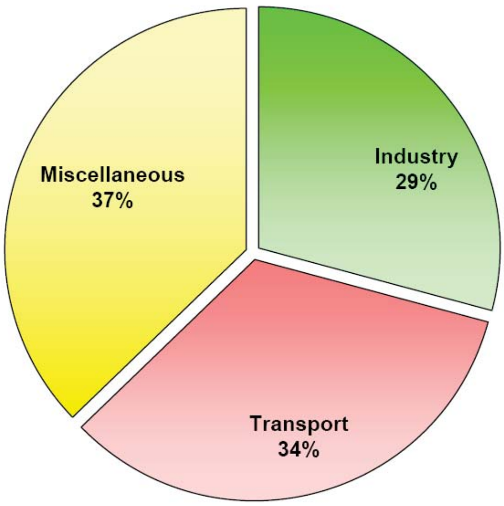


Figure 3-2: Distribution of the final energy use in Austria in 2009 across the main sectors in percentage (Data based to Statistics Austria, 2010b)

### 3.1.1 Energy use in the manufacturing industry

The balance of the different energy carriers in the Austrian industry is shown in Table 3-3. The most energy intensive industrial sector in Austria is the pulp, paper and print industry, followed by the non-metallic minerals processing and the iron and steel industry, as shown in Figure 3-3. Other industrial sectors with a high energy demand are found in the chemical and petrochemical industries. The Austrian manufacturing industry used about 308 PJ of final energy in 2009.

Table 3-3: Distribution of energy carriers in each industrial sector in Austria 2009 (Data according to Statistics Austria, 2010b – values for final energy consumption)

| **Austrian Industry Sectors** | **Electri-city** | **Coal[10]** | **Oil[11]** | **Gas[12]** | **District Heat** | **Rene-wab-le[13]** | **Total** |
|---|---|---|---|---|---|---|---|
| | [PJ] | [PJ] | [PJ] | [PJ] | [PJ] | [PJ] | [PJ] |
| Iron and Steel | 13,2 | 8,2 | 2,2 | 16,3 | 0,2 | 0,6 | **40,6** |
| Chemical and Petrochemical | 13,4 | 0,5 | 0,6 | 14,6 | 2,1 | 6,5 | **37,7** |
| Non-ferrous Metals | 3,0 | 0,2 | 0,3 | 4,2 | 0,1 | 0,0 | **7,7** |
| Nonmetallic Minerals | 7,4 | 6,6 | 3,3 | 13,3 | 0,0 | 10,5 | **41,1** |
| Transport Equipment | 2,7 | 0,0 | 0,2 | 1,4 | 1,4 | 0,0 | **5,7** |
| Machinery | 11,5 | 0,0 | 1,5 | 7,4 | 1,1 | 0,7 | **22,1** |
| Mining and Quarrying | 2,5 | 0,0 | 0,4 | 1,6 | 0,0 | 0,0 | **4,5** |
| Food Tobacco and Beverages | 6,8 | 0,1 | 2,3 | 11,4 | 1,2 | 0,5 | **22,4** |
| Pulp, Paper and Print | 16,1 | 2,6 | 0,9 | 22,0 | 0,7 | 21,3 | **63,7** |
| Wood and Wood Products | 6,0 | 0,0 | 0,2 | 2,8 | 2,1 | 14,8 | **25,8** |
| Construction Industry | 2,5 | 0,0 | 16,0 | 1,7 | 0,5 | 1,9 | **22,6** |
| Textiles and Leather | 1,8 | 0,0 | 0,3 | 1,9 | 0,0 | 0,0 | **4,1** |
| Miscellaneous Industries | 5,4 | 0,0 | 0,4 | 1,8 | 0,5 | 1,5 | **9,7** |
| **Total** | **92,1** | **18,2** | **28,5** | **100,6** | **9,9** | **58,4** | **307,7** |

According to Figure 3-3 and Table 3-3 gas and electricity are obviously very important energy carriers in the Austrian industry, due to the fact, that both are used in every industrial sector. Particularly, 22 PJ of the pulp, paper and print industry's energy demand is covered only by gas. The share of renewable energy use is very high in some industrial sectors, e.g. 57% in the wood working industry or 33.5% in the pulp paper and print industry, as shown in Figure 3-3. However, there is still a need to reduce the gas demand in nearly all industrial sectors.

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10 Coal includes hard coal, lignite, BKB, peat, coke, blast furnace gas and coke oven gas (Statistics Austria, 2010b)

11 Oil includes: crude oil, refinery feedstocks, gasoline, kerosene, fuel oil, other oil products and refinery gas (Statistics Austria, 2010b)

12 Gas includes natural gas and gasworks gases (Statistics Austria, 2010b)

13 Renewable includes all energy carriers as waste, fuel-wood, bio-fuels, ambient-heat, hydro- and wind-power and PV (Statistics Austria, 2010b)

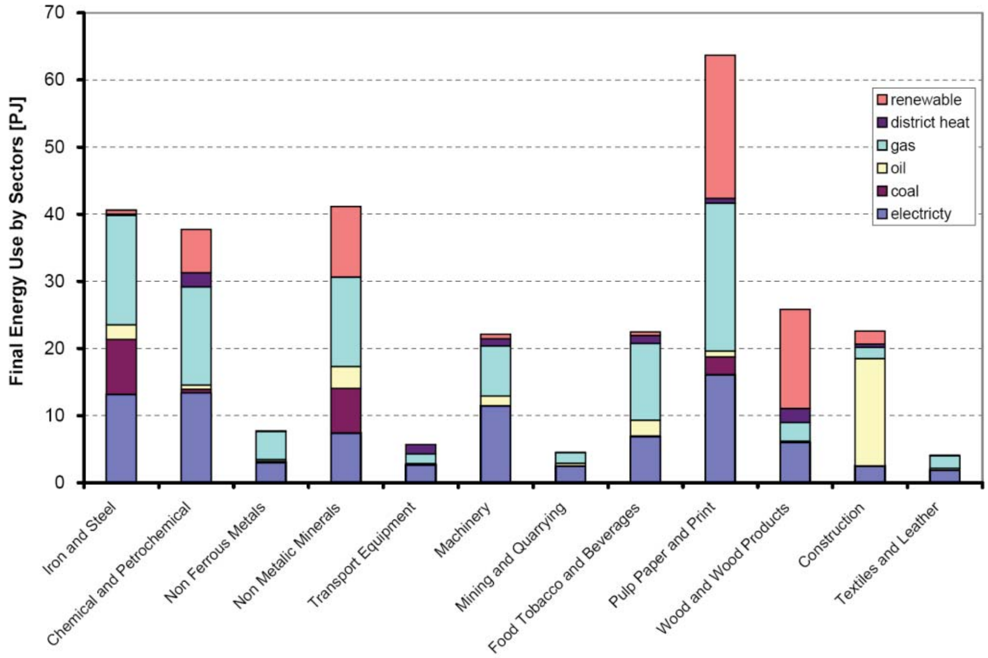


Figure 3-3: Distribution of energy carriers in each industrial sector in Austria 009 (Data according to Statistics Austria, 2010b – values for final energy consumption)

As shown in Figure 3-4, gas is still the most used energy carrier for the Austrian industry and covers 33% of the overall final energy demand, closely followed by electricity with a share of 30%. 48% of the overall final energy consumption in the industry has been covered by gas, oil and coal and only 19% by renewable energy. The problems caused by the extensive use of fossil fuels are the import- and price-dependence from foreign countries as well as $CO_2$-emissions, as mentioned before. In order to improve this situation, the application of industrial heat pumps offers the possibility to substitute a part of the fossil energy use by upgrading waste heat to process heat.

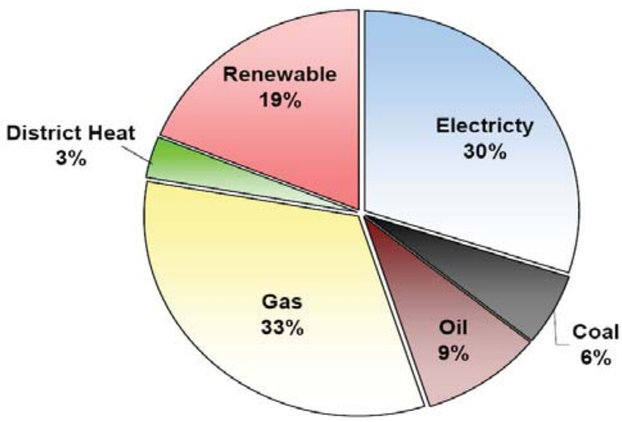


Figure 3-4: Final energy balance of the different energy carriers in Austrian Industry, 2009 in percentage (Data according to Statistics Austria, 2010b)

### 3.1.2 Heat demand of Austrian Industry

In order to determine the heat demand based on the overall final energy consumption of the Austrian industry, a share of 74% has been assumed for Austria for the year 2002 according to Vanonni et al. (2008). Assuming that this share has not changed from 2002 to 2009, the heat demand in the Austrian industry amounts to 228 PJ in 2009, based on the overall final energy consumption in the Austrian industry of 308 PJ according to Statistics Austria, 2010b. Even if this share would be a little bit lower, the heat demand represents the bulk of all energy functions in the Austrian industry.

### 3.1.3 References

STATISTICS AUSTRIA, 2010a: AUSTRIA-Data-Figures-Facts 10/11, 6th edition, Statistics Austria - Federal Institution under Public Law, Vienna 2010, ISBN 978-3-902703-66-8

STATISTICS AUSTRIA, 2010b: Energy balances for Austria - 1970-2009, Statistics Austria - Federal Institution under Public Law, Vienna 2010, http://www.statistik.at/web_en/static/energy_balances_1970_to_2009_detailed_information_029791.xls (04.03.2011)

STATISTICS AUSTRIA, 2010c: Energy balances (Homepage text), Statistics Austria - Federal Institution under Public Law, Vienna 2010, http://www.statistik.at/web_en/statistics/energy_environment/energy/energy_balances/index.html (04.03.2011)

Vanonni, C., Battisti, R., Drigo, S., 2008: Potential for Solar Heat in Industrial Processes, IEA Solar Heating and Cooling Executive Committee of the International Energy Agency

## 3.2 Market overview

### 3.2.1 Austrian Industry

Austria is declared as an industrial country, even though the service sector takes the biggest share of the Austrian economic performance. The reason for this is that it is difficult to make a clear distinction between production and service in Austria. To permit an international comparison this two segments are considered together in the category "Production of goods". According to Austria 2006 (2006) it can be concluded that the industry remains the principal driver of economic activities and development in Austria. (Austria 2006, 2006)

Many small and medium-sized enterprises characterize the Austrian industry landscape. In 2006, approximately 40% of all companies of Austria had less than 10 employees, about 80% had less than 100, and only 1.4% of all companies had more than 1,000 employees. (Austria 2006, 2006)

Based on the share of industry in the gross value added, Austria has one of the world's largest industrial sectors in 2003. Following branches have traditionally accounted for the largest share of Austria's production overall: mechanical engineering and steel work, the motor vehicle trade, the chemical, electrical and electronics industries. Nevertheless, there are new fields in which Austrian companies have also performed well, as material engineering and surface coatings, IT, biotechnology and medical technology, as well as hydraulic engineering and environmental technology, in recent years. (Austria 2006, 2006).

The Austrian industry can be classified according to Federation of Austrian Industries (IV, 2010) in following sectors (Table 3-4):

Table 3-4: Sectors of the Austrian Industry [Data according to IV, 2010]

| Industrial sectors in Austria |
|---|
| Foundry Industry |
| Non-ferrous Metal Manufacture |
| Leather production Industry |
| Leather processing Industry |
| Electro and Electronic Industry |
| Wood-working Industry |
| Chemical Industry |
| Automotive Engineering |
| Food & Drug industry |
| Petrol Industry |
| Glass Industry |
| Nonmetallic minerals and ceramic industry |
| Paper & board processing industry |
| Paper manufacturing industry |
| Apparel Industry |
| Textile industry |
| Music and Film Industry |
| Machinery and Metalwork Industry |
| Building industry |
| Mining |
| Gas- and heat supply companies |

### 3.2.2 Process temperatures in the Austrian Industry

An estimation of the distribution of the heat demand at different temperature levels for the Austrian industry was made from the available data in Figure 3-5. For the estimation, the total final energy consumption from the table “Distribution of energy carriers in each industrial sector in Austria 2009”[14] was used with an assumption, that the share of the heat demand is equal for all sectors, since no detailed data were found. For the distribution of the heat demand at different temperature levels over different industrial sectors, figures from Euroheat & Power (2006) from 2003 for EU 27 plus Turkey, Croatia, Iceland, Norway and Switzerland were used. Not all industrial branches from the above

[14] Table 3 from the Austrian Team Report - IEA HPP-IETS Annex 13 / 35 -Application of Industrial Heat Pumps; Task 1 – Part1

mentioned table were considered, since for a number of them no figures were available. However, the industries considered account for about 80% of the total final energy consumption.

Figure 3-5 shows, that almost half (47%) of the heat energy demand in Austria is at temperatures over 400°C. About a quarter (27%) of the heat demand is at temperatures from 100°C to 400°C and a quarter (26%) at temperatures below 100°C.

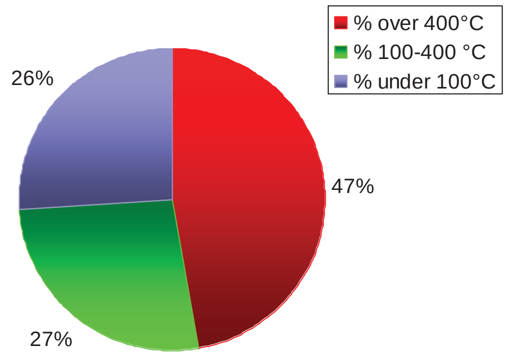


Figure 3-5: Estimation of the cumulative industrial heat demand by temperature level for selected Austrian industry branches[15] (Data according to Euroheat & Power, 2006)

The application of IHP for industrial waste heat utilization is reasonable up to 100°C or even above depending on the heat pump technology applied. This means, that the theoretical potential for the application of IHPs is about 30-40% of the overall heat demand in the industry according to the required temperature levels, including industries not considered in Figure 3-5.

In order to determine the realizable potential for the application of IHPs, it should be mentioned, that each industrial sector and each production process itself have to be regarded in detail. The operating range of thermal solar heating plants is similar to the temperature levels for the application of Industrial Heat Pumps. Various reports about the solar heating application in the industry are available in literature and have been collected to get necessary information about the process temperatures of the most significant processes in each industrial sector, which are listed in Table 3-5. As one can see in Table 3-5, there exist several different processes in the Austrian industry, which are theoretically suitable to cover their head demand by the application of IHPs.

[15] The following industry branches were not considered compared to the table 3 from the Austrian Team Report - IEA HPP-IETS Annex 13 / 35 -Application of Industrial Heat Pumps; Task 1 – Part1 "Distribution of energy carriers in each industrial sector in Austria 2009": Wood and wood products, construction industry, textiles and leather and miscellaneous.

Table 3-5: Industry sectors and processes including appropriate temperature levels for heating applications (Data according to Brunner et al., 2007, Slawitsch et al., 2007, Weiss, 2005 and Solarwärme, 2011)

| Sector | Example for temperature levels of thermal processes |
|---|---|
| Food | • Preheating of substances (20-60°C),<br>• Pasteurizing/Sterilization (70-120°C)<br>• Boiling (100-240°C)<br>• Distillation (40-100°C)<br>• Drying (40-250°C)<br>• Vaporizing (40-170°C)<br>• Washing(30-60°C)<br>• Substance concentration (60-70°C)<br>• Baking (160-260°C)<br>• Cleaning the facility (30-70°C)<br>• Space heating of the production hall (20°C)<br>• Cooling (-18-20°C) |
| Metal | • Galvanic (20-100°C)<br>• Washing (30-60°C)<br>• Drying ( 60-90°C)<br>• Cleaning the facility (30-70°C)<br>• Space heating of the production hall (20°C) |
| Paper and board | • Preheating of substances (40-80°C)<br>• Boiling (160°C)<br>• Drying (110-240°C)<br>• Cleaning the facility (30-70°C)<br>• Space heating of the production hall (20°C) |
| Textile | • Coloring (40-130°C)<br>• Laundering (40-100°C)<br>• Bleaching (60-100°C)<br>• Cleaning the facility (30-70°C)<br>• Space heating of the production hall (20°C) |
| Chemistry | • Preheating of substances (~60°C)<br>• Boiling (95-105°C)<br>• Distillation (110-300°C)<br>• Thermoforming (130-160°C)<br>• Substance concentration (125-130°C)<br>• Cleaning the facility (30-70°C)<br>• Space heating of the production hall (20°C)<br>• Cooling (5-15°C) |
| Wood | • Drying (50-80°C)<br>• Squeezing (120-180°C)<br>• Staining (50-80°C) |

Table 3-6 contains the results of a review about the required temperature levels for cooling demand in the Austrian industry in the different sectors. Particularly the sectors food and chemistry require bride temperature ranges for their cooling demand, down to -50°C. A high cooling demand signifies a theoretically high potential for waste heat utilization according to the temporary simultaneity with the heat demand.

Table 3-6: Required temperature levels for the cooling demand in Austrian Industry sectors (Data according to ETA ENERGIEBERATUNG, 2008)

| **Sector** | **Temperature levels for cooling applications** |
|---|---|
| Food | -50 – 6°C |
| Plastics | 6°C |
| Metal | 6°C |
| Chemistry | -50 – 6°C |
| Brewery | -10°c |
| Dairy | -10 – 0°C |
| Store | -30 – 6°C |

### 3.2.3 Overview of the Austrian industrial heat pump market

In order to give an overview of the Austrian industrial heat pump[16] market a simple online-search was performed. In the course of the online-search only a few reports of IHP applications were located, which are mostly referenced by Austrian heat pump manufactures themselves. But up to now there are not any figures of already installed industrial heat pump plants in Austria or outsells available.
However, this online-search gives an overview of Austrian IHP suppliers. The Austrian IHP market includes open cycle heat pump technologies (MVR) as well as closed heat pump technologies (compression heat pumps and sorption heat pumps). Several Austrian heat pump manufactures produce compression heat pumps for industrial applications even in series. These heat pumps are nowadays assembled for the cooling and heating in residential buildings, industrial premises, hotels, office buildings and recreational facilities and for the utilization of industrial waste heat. These heat pumps have the capability to achieve heat sink temperatures up to 65°C and are designed for heating capacity up to 700 kW, most of them using R134a as refrigerant.
Generally, it can be concluded that, the utilisation rate of IHP applications in Austria is still low. However, the Austrian industry features a relative high theoretical potential of IHP application and according to IZW (2009) the market of industrial heat pumps is rapidly growing in Austria. Especially in the field of large plants the demand rises sharply.

### 3.2.4 Energy prices

A rise of the energy prices is not limited to certain regions. It is worldwide observable and goes along with the demand of energy. The energy demand of Austria shows an

[16] Industrial heat pumps within this annex are defined as heat pumps in the medium and high power ranges which can be used not only for heat recovery in industrial processes, but also for heating, cooling and air-conditioning in residential, commercial and industrial buildings. The power range for the refrigerating capacity of industrial heat pumps settles between 50 and 150 kW for medium power systems and between 150kW to several MW for high power systems. This heat can deliver heat at temperatures of 100 °C and more.

increasing trend over the past decades. Together with the energy demand, the prices for the conventional energy carriers show a generally increasing trend. Table 3-7 shows the energy prices for the most common conventional energy carriers for the Austrian industry. Due to the trend of the energy prices of the conventional energy sources, it can be assumed that the usage of heat pumps gets more interesting and profitable.

Table 3-7: Energy prices (incl. VAT) for the Austrian industry from 2003 to 2009 (Data according to Austrian Energy Agency, 2010 for natural gas and Statistics Austria, 2011 for other energy carriers)

| Final consumer prices for industry (incl. taxes) | | | | | | |
|---|---|---|---|---|---|---|
| Year | Black coal [€/MWh] | Natural gas * [€/MWh] | Heavy fuel oil [€/MWh] | Gas oil [€/MWh] | Fuel oil [€/MWh] | Electricity [€/MWh] |
| **2003** | 9,25 | 20,94 | 19,87 | 28,31 | 58,05 | -- |
| **2004** | 16,45 | 20,52 | 21,40 | 32,17 | 61,11 | 92,52 |
| **2005** | 17,16 | 22,11 | 28,49 | 39,05 | 66,20 | 81,90 |
| **2006** | 17,24 | 29,53 | 33,41 | 44,99 | 72,31 | 87,00 |
| **2007** | 17,69 | 30,87 | 34,67 | 47,31 | 73,33 | 98,00 |
| **2008** | 20,36 | -- | 45,98 | 43,66 | 78,42 | 105,43 |
| **2009** | 20,89 | -- | 35,14 | 31,06 | 60,98 | -- |

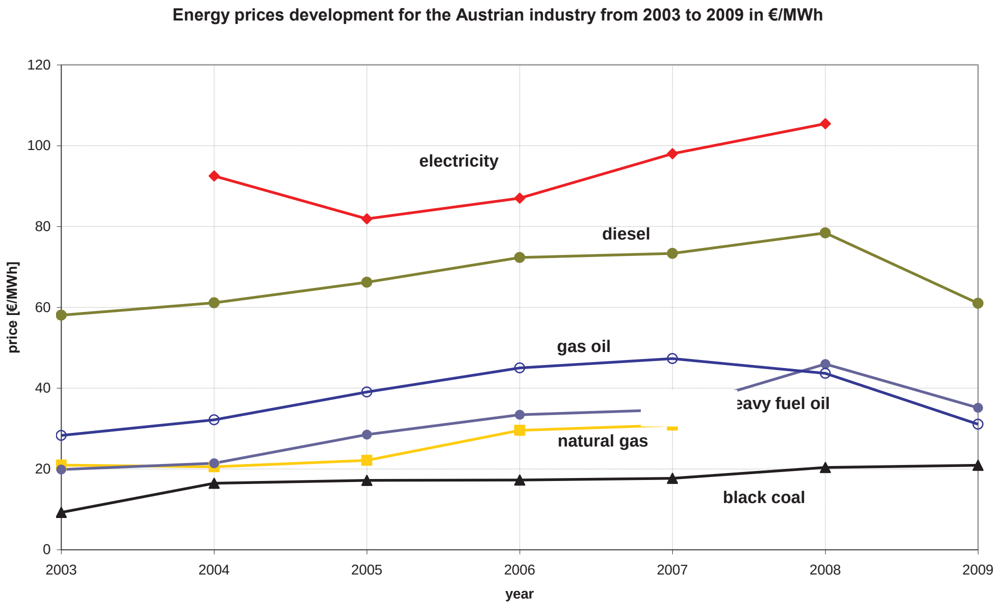


Figure 3-6: Development of energy prices (incl. VAT) for the Austrian industry from 2003 to 2009 (Data according to Austrian Energy Agency, 2010 for natural gas and Statistics Austria, 2011 for other energy carriers)

It can be seen from Figure 3-6 that, due to the global economic crisis, all energy prices, except for black coal, decreased after 2008. For 2003 and 2009 there is no data available for the electricity price. The prices of natural gas for commercial usage for 2008 and 2009 are also missing in the used sources. The prices shown are not inflation-adjusted.

### 3.2.5 Legal documents

This chapter gives an overview of standards as well as funding guidelines in Austria concerning the application of IHPs.

**National and European Standards**
The following standards are relevant in Austria for an application of an industrial heat pump plant:

- **OENORM EN 378-1** (2008-06-01) "Refrigerating systems and heat pumps - Safety and environmental requirements - Part 1: Basic requirements, definitions, classification and selection criteria"
- **OENORM EN 378-2** (2008-06-01) "Refrigerating systems and heat pumps - Safety and environmental requirements - Part 2: Design, construction, testing, marking and documentation"
- **OENORM EN 378-3** (2008-06-01) "Refrigerating systems and heat pumps - Safety and environmental requirements - Part 3: Installation site and personal protection"
- **OENORM EN 378-4** (2008-06-01) "Refrigerating systems and heat pumps - Safety and environmental requirements - Part 4: Operation, maintenance, repair and recovery"
- **OENORM EN 12263** (1999-01-01) "Refrigerating systems and heat pumps - Safety switching devices for limiting the pressure - Requirements and tests"
- **OENORM EN 12284** (2004-01-01) "Refrigerating systems and heat pumps - Valves - Requirements, testing and marking"
- **OENORM EN 12309-1** (1999-10-01) "Gas-fired absorption and adsorption air-conditioning and/or heat pump appliances with a net heat input not exceeding 70 kW - Part 1: Safety"
- **OENORM EN 12309-2** (2000-04-01) "Gas-fired absorption and adsorption air-conditioning and/or heat pump appliances with a net heat input not exceeding 70 kW - Part 2: Rational use of energy"
- **OENORM EN 13313** (2002-06-01) "Refrigerating systems and heat pumps - Competence of personnel"
- **OENORM EN 14276-1** (2006-11-01) "Pressure equipment for refrigerating systems and heat pumps - Part 1: Vessels - General requirements"
- **OENORM EN 14276-2** (2007-08-01) "Pressure equipment for refrigerating systems and heat pumps - Part 2: Piping - General requirements"
- **OENORM EN 14511-1** (2004-08-01) "Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors - Heating mode - Part 1: Terms, definitions and designations"
- **OENORM EN 15316-4-2** (2005-12-01) "Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies - Part 4-2: Space heating generation systems, heat pump systems"
- **OENORM EN 15450** (2008-01-01) "Heating systems in buildings - Design of heat pump heating systems"
- **OENORM EN 15834** (2008-09-01) "Refrigerating systems and heat pumps - Qualification of tightness of components and joints"
- **OENORM H6021** (2003) **"**Ventilation equipment – Keeping of cleanness and hygiene"
- **OENORM H6020-2** (2007) "Ventilation equipment in clinics and hospitals – operation, maintenance, technical and hygienic control"

- **OENORM H6021** (2003) “Ventilation equipment – Keeping of cleanness and hygiene“
- **OENORM H6020-2** (2007) “Ventilation equipment in clinics and hospitals – operation, maintenance, technical and hygienic control“
- **OENORM B5019** (2007) “Hygienic design, operation, maintenance, reconstruction and supervision of drinking water equipment”

### 3.2.6 Funding of industrial heat pumps in Austria

National grants for the installation of an IHP can significantly reduce the payback period and consequently take an influence on the decision to invest. The Kommunalkredit Public Consulting (KPC) banking institution manages the national grant system in Austria. According to KPC (2011a) several guidelines cover the grant regulations for IHP applications:

- Heat pumps < 400kW$_{th}$ (KPC, 2011b)
  Specifications: water/brine or water/water heat pump: COP>4
  air/water heat pump: COP>3,5
  Grant ratio: max. 30% of environmentally relevant investment costs

- Heat pumps > 400kW$_{th}$ (KPC, 2011c)
  Specifications: water/brine or water/water heat pump: COP>4
  air/water heat pump: COP>3,5
  Grant ratio: max. 15% of environmentally relevant investment costs

- Efficient energy use – process-oriented measures (KPC, 2011d):
  Specifications: industrial waste heat utilisation
  Grant ratio: max. 30% of environmentally relevant investment costs

Furthermore it is possible to apply for additional regional grants according to the different federal systems in Austria.

## 3.3 Barriers for applications

At present no detailed information about market barriers of IHPs in Austria are found. In the course of this Annex more detailed information’s about the barriers will be ascertained form the Austrian industry. Therefore, a questionnaire was set up in order to gather and evaluate stake holder opinions, which shall be included within the final Annex report. However, from a preliminary evaluation following barriers possibly play a major role in the Austrian IHP market:

- Despite the national grant regulations for industrial heat pump applications, the economical point of view seems to be one of the most deciding barriers, which can hind the full market success in Austria. Austrian industrial companies claim for very short payback periods. It is estimated that the payback periods should be less than three years.
- Additionally, so far the confidence in the Austria’s industrial companies in the IHP-technology is not given regarding to the less experience and knowledge. So it seems to be necessary to promote the IHP-technology to the Austria’s industrial compa-

nies, e.g. by referencing to best practise cases. Because up to now only a limited number of installations is available, it seems to be necessary to refer to foreign demonstration and good practise cases at the beginning.

- From the technical point of view one barrier can be identified regarding to the temperature limits of most commercially available heat pumping units. Many applications are limited to heat sink temperatures below 65°C but as the study of the "Process temperatures in the Austrian Industry" shows, the theoretical potential for the application range of IHP increases significantly by developing energy efficient heat pumps for heat sink temperatures up to 100°C.

To come up to their ecological potential, IHPs have to be commercial attractive on the market. The business success of IHPs depends on the profitability as well as on a flawless performance of the plants, which guarantee the confidence of the customers. The development of heat pump technologies for temperatures up to 100°C offers a greater application field. Also the dissemination of the advantages of IHP applications can promote the commercial success of IHPs.

## 3.4 Literature

Austria 2006, 2006: Sectors of the Austrian economy, industry, homepage of the Austria 2006 – presidency of the European Union, http://www.eu2006.at/de/Austria/Overview/sectors.html (23.02.2010)

Austrian Energy Agency, 2010: Endverbraucherpreise für die Industrie: Elektrizität, Erdgas, Heizöl. - http://www.energyagency.at/energien-in-zahlen/energiepreise/endverbraucherpreise/industrie.html (02.03.2010)

Biermayer, P., Weiss, W., Bergmann, I., Glück, N., Stukelj, S., Fechner, H., 2008: Erneuerbare Energie in Österreich – Marktentwicklung 2008, Photovoltaik, Solarthermie und Wärmepumpen, Erhebung für die Internationale Energie Agentur (IEA), Bundesministerium für Verkehr, Innovation und Technologie

Brunner, C., Slawitschek, B., Giannakopoulou, K., Trinkaus, P., Schnitzer, H., Weiss, W., Schröttner, S., Reif, B., 2007: STYRIAN PROMISE (Produzieren mit Solarer Energie) – Initiative zur Nutzung von Energieeffizienz und Erneuerbaren Energien (Solare Prozesswärme) in steirischen Betrieben. Endbericht, Joanneum Research Forschungsgesellschaft mbH, Institut für Nachhaltige Techniken und Systeme - JOINTS

Döberl, R., 2003: Verbote von Stoffen, die zum Abbau der Ozonschicht führen (FCKW, HFWKW, Halogene, Trichlorethan, Tetrachlorkohlenstoff), WKO Wirtschaftskammern Österreich

Eta Energieberatung, 2008: Carmen Fachgespräche „Kälte aus Wärme". http://www.carmen-ev.de/dt/hintergrund/vortraege/fg_biogas/1_06_Sch%E4fer.pdf - (11.02.2010)

Euroheat & Power, 2006: Final Report of the Project ECOHEAT COOL, Work Package 1 - The European Heat Market. http://www.euroheat.org/Files/Filer/ecoheatcool/documents/Ecoheatcool_WP1_Web.pdf

IV (Federation of Austrian Industries), 2010: Fachverbandausschüsse der Bundessparte Industrie. http://www.voei.at/industrieliste?PHPSESSID=64872190732c14e390656e052481b0a6 (04.03.2011)

IZW (Informationszentrum Wärmepumpen + Kältetechnik), 2009: Österreich: Wärme-pumpen - http://www.hp-summit.de/de/presse/laenderberichte/876f609b-3a02-4f72-9a6f-9b79ccb71b15/ (29.03.2011)

KPC , 2011a: Kommunalkredit Public Consulting GmbH -Umweltförderung im In-land/Förderungsrichtlinien 2009; http://www.publicconsulting.at/kpc/de/home/ (25.03.2011)

KPC, 2011b: Kommunalkredit Public Consulting GmbH -Umweltförderung im In-land/Förderungsrichtlinien 2009 http://www.publicconsulting.at/kpc/de/home/umweltfrderung/fr_betriebe/energieeffizienz/wrmepumpen_bis_400kw_thermisch/(25.03.2011)

KPC, 2011c: Kommunalkredit Public Consulting GmbH -Umweltförderung im In-land/Förderungsrichtlinien 2009 http://www.publicconsulting.at/kpc/de/home/umweltfrderung/fr_betriebe/energieeffizienz/wrmepumpen_ab_400kw_thermisch/ (25.03.2011)

KPC, 2011d: Kommunalkredit Public Consulting GmbH -Umweltförderung im In-land/Förderungsrichtlinien 2009 http://www.publicconsulting.at/kpc/de/home/umweltfrderung/fr_betriebe/energieeffizienz/effiziente_energienutzung__prozessorientierte_manahmen/ (25.03.2011)

Republik Österreich Parlament, 2010: Fluorierte Treibhausgase- Gesetz 2009 – Vorblatt und Erläuterungen (222 der Beilagen XXIV.GP). http://www.parlament.gv.at/LI/EW/show.psp?p_display_i=&x=1&p_instanz_i=PD&p_alles_i=alles&p_request_i=EinfacheSuche&p_gp_i=XXIV&p_search_string_i=verordnung+hfkw (12.03.2010)

Slawitsch, B., Brunner, C., Giannakopoulou, K., Trinkhaus, P., Reif, B.: 2007: Solare Pro-zesswärme: Einsatzbereiche und Herausforderungen für die Solarindustrie, IEA SHC Task 33 Solarwärme für die Industrie, Tagungsunterlagen, AEE – Institut für Nachhaltige Technologien

Statistics Austria, 2011: Jahresdurchschnittspreise und –steuern für die wichtigsten Energieträger; http://www.statistik.at/web_de/statistiken/energie_und_umwelt/energie/preise_steuern/index.html; (28.03.2011)

Solarwärme, 2011: Sun and Energy, Process heat; http://www.solarwaerme.at/Sonne-und-Energie/Prozesswaerme/; (29.03.2011)

Weiss, W., 2005: Solarwärme für industrielle Prozesse, energytech.at AUSTRAhttp://www.noest.or.at/intern/dokumente/193_Endbericht_Styrian_Promise.pdf (28.03.2011)

# 4 Canada

## 4.1 Industrial Energy use

### 4.1.1 Energy production in Canada

The energy industry contributes significantly to the Canadian economy, despite the global economic volatility and instable prices of fossil fuels observed since 2008. It accounts for 7% of Canada's gross domestic product and employs 2% of the Canadian labour force. In 2008, petroleum (including crude oil and natural gas liquids, upgraded and non-upgraded bitumen, and condensate) accounts for 39.4% and natural gas for 35.14% of domestic energy production, nuclear energy accounts for 6.13%, hydroelectricity for 7.49%, coal for 8.23% and wind for 0.07% (see Figure 4-1).

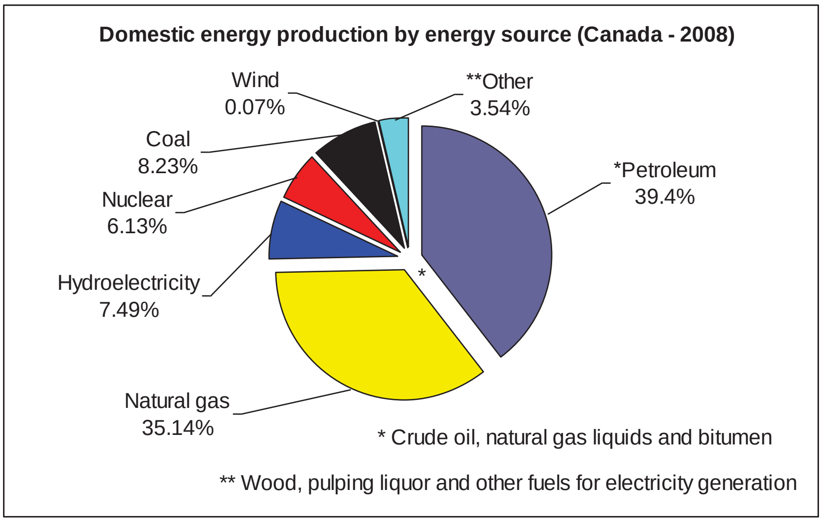


Figure 4-1: Domestic energy production by energy source – Canada 2008

### 4.1.2 Energy use in Canada

Canada is one of the largest consumer of energy on a per person basis in the world, consuming almost 200 GJ per capita, the equivalent of each Canadian resident using more than 5,000 litres of crude oil per year. This is approximately twice the per capita energy consumption seen in other OECD countries. 2008 total secondary energy demand (end use demand) was of approximately 11,000 PJ It is the energy used by the final consumer and represents residential (13.75%), commercial (14.04%), transportation (24.57%) and industrial (47.66%) energy demands (see Figure 4-2)

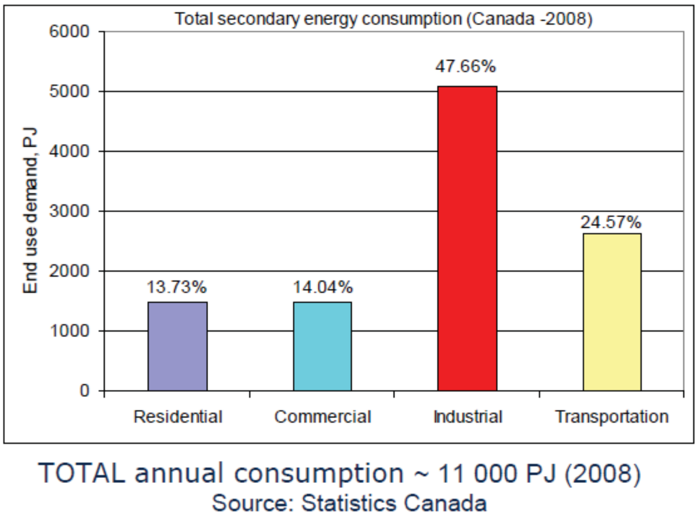


Figure 4-2: Total secondary energy consumption

### 4.1.3 Energy use in industry

The energy use of 14 sub-sectors of eight major Canadian manufacturing industries accounts for about 1.7 million TJ representing 65.3% of the total energy use of all Canadian manufacturing industries (2.6 million TJ). Compared to the total energy consumption, the pulp and paper sector consumes 27.6%, primary metals industries, 16% and the petroleum sector, 13.7%. Wood (3%) and food (1.2%) industries are relatively small energy consumers compared to the previous mentioned large industrial consumers (see Figure 4-3).

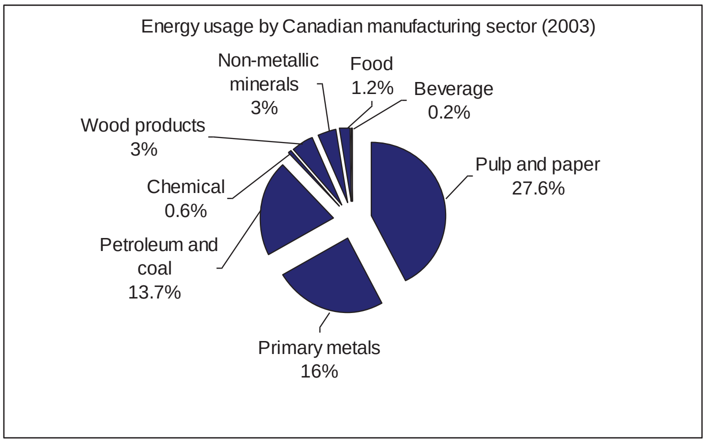


Figure 4-3: Energy use by Canadian manufacturing sectors (2003)

### 4.1.4 Waste heat in manufacturing industry

About 71% of the input energy is related to the environment via four classes of identifiable waste heat streams. Liquid cooling losses represent the largest class of thermal losses (553 PJ), closely followed by stack losses (524 PJ). Steam losses account for 306 PJ, and energy lost in process gases represents 290 PJ. It should be noted that “other losses” accounting for 611 PJ. However, these are normally in a form that is difficult to quantify or capture, such as radiated low-grade heat from equipment. The Figure below indicates the waste heat in 14 sub-sectors of eight major Canadian manufacturing industries:

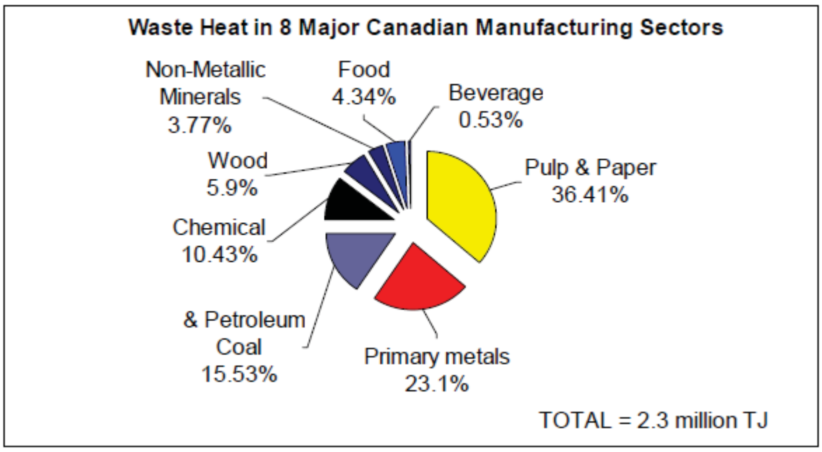


Figure 4-4: Waste Heat in 8 major Canadian Manufacturing Sectors

It shows the percentage of the total industrial waste heat that each industry sub-sector represents as a percentage of all manufacturing sector. In this Figure, not all sub-sectors of each manufacturing sector have been included. Thus, together, the selected 14 sub-sectors represent 65.3% of the manufacturing consumption, while the eight sectors account for 91.3% of the manufacturing energy usage.

More information: [1]

## 4.2 Market of industrial heat pumps

### 1994 Market Assessment

In 1994, a Canadian market assessment study [1] has investigated the industrial heat pump (IHP) potential in industries already using such heat recovery devices, as well as in processes where IHP use has been limited or non-existent. The industrial sectors already using industrial heat pumps were lumber drying, food processing (poultry, milk and cheese processing), pulp and paper production, metallurgical (iron and steel blast furnaces) and chemical production, and brewing. At that time (year end 1993), 14 chosen processes contained more than 1,900 individual plants and accounted 35% of the total Canadian industrial process heating load (Table 4-1). About 320 (17%) of these plants used industrial heat pumps. However, more than 90% (or 295 units) were found in one industry, lumber drying. In terms of current penetration, liquor distilling showed the highest level of industrial heat pumps use. The next highest levels were found in lumber drying (27%), cheese production (6%) and poultry processing (5%).

Across the 14 processes analyzed in 1994, the cumulative market penetration of industrial heat pumps under maximum scenario was estimated to be 9% by 2010 with 225 units projected to be installed. Of the total, electric closed-cycle systems were estimated to account for 70% of the potential installations, followed by mechanical vapor recompression at 19% [1].

Projected penetration under the average scenario was estimated at over 25% for four industrial processes: chlorine/soda, newsprint, pulp and specialty paper productions

For the 14 industrial processes combined, the potential to reduce industrial process heat consumption was estimated at between 5 500 – 14 600 TJ/year by 2010. Five processes were estimated to account for some 88% of the total savings: chlorine/soda production (63%), petroleum refining (7%), iron and steel blast furnaces (7%), specialty paper production (6%) and pulp production (5%) [1].

Table 4-1: Summary of 1994 industrial heat pump application in Canada [?]

| Process | Number of plants | Number of IHP |
|---|---|---|
| Lumber drying | 1087 | 295 |
| Liquor distilling | 24 | 8 |
| Cheese production | 108 | 7 |
| Poultry processing | 119 | 6 |
| Pulp production | 39 | 2 |
| Milk production | 179 | 2 |
| Newsprint production | 42 | 2 |
| Iron and steel | 23 | 0 |
| Sugar refining | 8 | 0 |
| Specialty paper | 28 | 0 |
| Petroleum refining | 33 | 0 |
| Chlorine/soda production | 16 | 0 |
| Textile | 192 | 0 |
| BTX production | 9 | 0 |
| TOTAL | 1 907 | 322 (17%) |

Depending on the process, the potential level of energy savings per process ranged between less than 1% to 16%, with the highest levels estimated in chlorine/soda, cheese and poultry productions, and liquor distilling.

In Canada, industrial heat pumps would be reducing natural gas-based process heating energy consumption in many processes. Therefore, while they would reduce plant- and national-level emissions of all fossil-fuel based pollutants, the primary benefit would be reduced $CO_2$ emissions, followed by lesser reductions in SO and NOx emissions. The greatest environmental benefits from IHP use can be in processes that rely most heavily on oil and coal process heating, as pulp and paper, iron and steel, and petroleum refining [1].

During the spring 2011, a partial market assessment study of the Canadian industrial heat pump market has been performed. In order to estimate the number of industrial heat pumps existing in four Canadian provinces at the end of 2010, a simplified questionnaire has been send to several plants in some industrial sectors shown in Table 4-2. The scope was to identify the actual state and new trends of this industrial market.

Table 4-2: Industrial sectors targeted (2011)

| Example of targeted industrial sectors |
|---|
| Lumber drying |
| Milk production |
| Cheese production |
| Poultry processing |
| Sugar refining |
| Pulp production |
| Textile |
| Petroleum refining |

The majority of questioned plants was in Québec (eastern Canada), Ontario (central Canada) and British Columbia (western Canada), respectively. 22 plants have been identified in Manitoba (central Canada). The number of plants having responding to the questionnaire is shown in Table 4-3 by Canadian province.

Table 4-3: Number of plants that have responded to the questionnaire (2011)

| Canadian province | Number of plants |
|---|---|
| Québec | 132 |
| Ontario | 94 |
| British Columbia | 91 |
| Manitoba | 22 |
| **TOTAL** | **339** |

The number of plants with industrial heat pumps is indicated in Table 4-4. It can be seeing that only 7.67% of questioned plants use one or more industrial heat pumps for process and/or waste heat recovery.

Table 4-4: Number of industrial heat pump installed

| Number of IHPs | Number of plants | % |
|---|---|---|
| Any | 313 | 92.33 |
| 1 | 8 | 2.35 |
| 2 | 6 | 1.76 |
| 3 | 2 | 0.59 |
| 4 | 3 | 0.88 |
| 5 | 2 | 0.59 |
| 6 | 3 | 0.88 |
| 7 | 0 | 0.00 |
| 8 | 1 | 0.29 |
| 9 | 1 | 0.29 |
| **TOTAL** | **339** | **100** |

Table 4-5 shows the number of installed heat pump by industrial process. It can be seeing that 31% of them are installed in drying processes, 27% for waste heat recovery and 8% in evaporation processes.

Table 4-5: Number of installed heat pump by industrial process

| Drying | | Evaporation | | Waste heat recovery | | Others* | | Total |
|---|---|---|---|---|---|---|---|---|
| # | % | # | % | # | % | # | % | |
| 8 | 31 | 2 | 8 | 7 | 27 | 9 | 35 | 26 |

* Others: process thermal recovery; exhausted heat recovery

Table 4-6 indicates the number of heat pumps, primary energy used as driving energy and the year of installation. The most common new installed industrial heat pumps are based on electrical closed-vapor compression cycles used especially in drying, waste heat recovery and evaporation processes. It can be also seeing that 76.9% of the industrial heat pumps have been installed after 1994, and that 92.3% of installed heat pumps use the electricity as primary energy and only 7.7% the natural gas. That means that the number of new IHPs installed between 1994 and 2010 was of 1.25/year among the 339 plants questioned.

Table 4-6: Type and date of installed industrial heat pumps

| Type* | Number | Primary energy | | Year of installation | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| - | - | Electricity | Natural gas | - | - | - | - | - | - |
| W/W | 6 | 6 | 0 | 1976 | 2000 | 2*2009 | 2 *n/a | | |
| W/A | 2 | 2 | 0 | 1997 | 2004 | | | | |
| A/A | 7 | 6 | 1 | 1984 | 1992 | 2000 | 2001 | 2007 | 2009 |
| A/W | 1 | 1 | 0 | 1985 | | | | | |
| Lumber drying | 3 | 3 | 0 | 1979 | 1989 | 2000 | | | |
| MVR | 3 | 2 | 1 | 1985 | 2000 | 2001 | | | |
| Other | 4 | 4 | 0 | 2*2005 | 2*n/a | 2010 | | | |
| **Total** | **26** | **24** | **2** | - | - | - | - | - | - |

* W/W: water-to-water; W/A: water-to air; A/A: air-to-air; A/W: air-to-water; MVR: mechanical vapor

The installed capacities of heat pumps listed in Table 4-6 vary between 4 to 300 tons (14 and 1050 kW) of installed cooling capacity. The compressor nominal capacity of a mechanical vapor recompression system installed in 2001 was of 257 kW.

## 4.3 Barriers for applications

Despite of several benefits of industrial heat pumps, as reduced energy consumption and increased capacity of heating systems, the number of this equipment installed to date is relatively low compared to the number of existing technically and economically viable opportunities. Among other reasons can be mentioned the lack of knowledge and experience with heat pump technology. Historically, technical barriers were mainly related to the availability of reliable heat pump components and the use of heat generated. Economical barriers were related to low prices of natural gas and oil versus high electricity prices. Finally, as a legal barrier, many incentives were based on product quality and/or environmental concerns *rather* than economic.

## 4.4 Literature

[1] IEA HPP Annex 21: Industrial Heat Pumps - Experiences, Potential and Global Environmental Benefits, IEA Heat Pump Centre,
Report No. HPP-AN21-1, April 1995

# 5 Denmark

## 5.1 Energy use in the Denmark in 2009

In 2009 Denmark had an energy consumption of 808.9 PJ, and it has been falling since 2007. From 2008 to 2009 the consumption fell by 4.0 % from 843 PJ in 2008. The share of renewable energy is 19.7 %. The electricity production based on renewable energy is 27.4 % of which wind power contributed with 18.3 %.

Table 5-1: Energy consumption in 2009

| **Energy carrier** | **PJ** |
|---|---|
| Oil | 315.6 |
| Natural gas | 165.3 |
| Coal | 168.7 |
| Electricity | 1.2 |
| Waste heat | 15.9 |
| Renewable | 142 |
| District heat | 0.2 |
| **Total** | **808.9** |

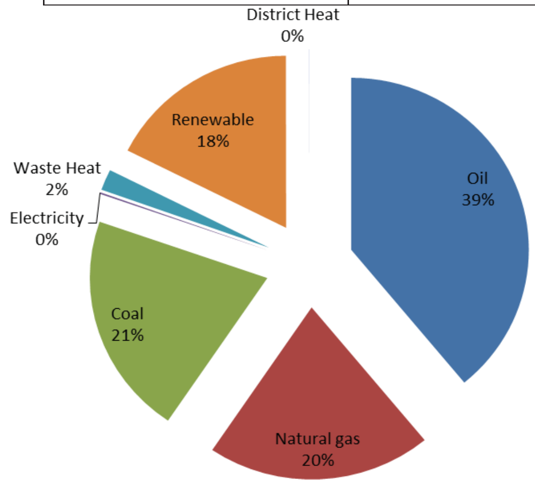


Figure 5-1: Final energy demand in Denmark in 2009 for different energy carriers [PJ]

The table depicts the net balance per energy carrier. The term ‘Electricity and District Heat’ does not refer to the electricity and district heat use but to the net result of import and export of electricity and district heat.

The following table presents the distribution of the total energy use across the different sectors. The energy use of energy companies relates to the conversion losses that occur during for example the production of electricity from natural gas or coal.

Table 5-2: -Energy use across sectors

| Sector | PJ |
|---|---|
| Energy companies | 146.6 |
| Refining sector | 44.9 |
| Manufacturing industry | 136.3 |
| Transport | 209.3 |
| Residential | 188.8 |
| Commercial | 83 |
| **Total** | **808.9** |

In this context the maufacturing industry comprises the following sectors: agriculture, forestry, gardening and fishing, the manufacturing industry and the building and construction sector.

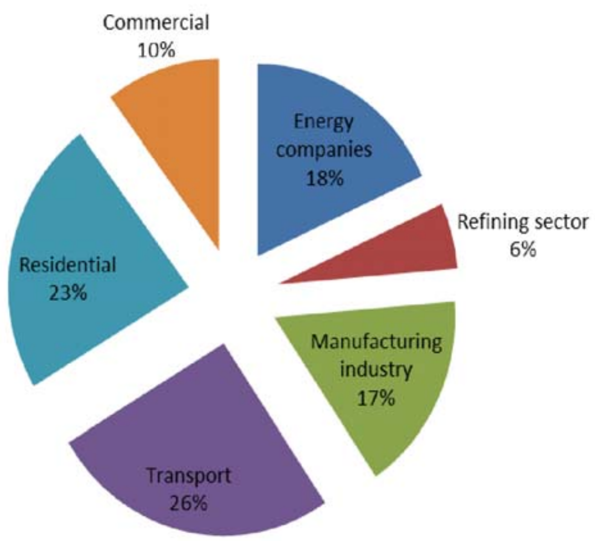


Figure 5-2: Final energy use in Denmark in 2009 for different sectors [PJ]

## 5.2 Energy Use in the Manufacturing Industry

The industrial energy use has been analyzed in a project from 2008 – the numbers used in this survey are from 2006. The Danish manufacturing industry used 127.2 PJ in 2006, within agriculture and fishing the consumption was 44.0 PJ, whereas the private trade and service sector used 47.6 PJ. In total, within the manufacturing industry and the trade and service sector was used 218.8 PJ.

This survey focuses on the manufacturing industry, since here is the greatest potential for large heat pumps and high temperature heat pumps.

Table 5-3: Energy use in the Danish manufacturing industry based on energy carriers in 2006 [PJ]. Wiegand og mågøe

| Energy carrier | PJ |
|---|---|
| Oil | 21.4 |
| Natural gas | 48.8 |
| Coal, wood, straw | 13.9 |
| Electricity | 35.8 |
| Miscellaneous | 7.1 |
| Total | 127.2 |

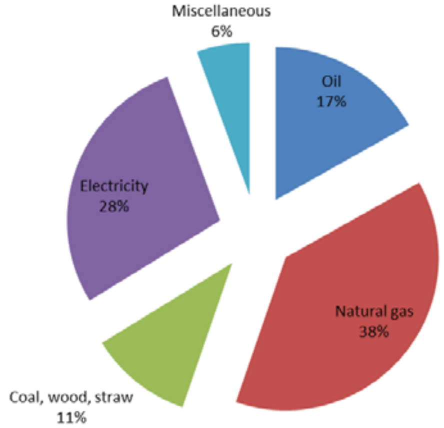


Figure 5-3: Share of industrial energy use within the different sectors

Table 5-4: Energy use in the Danish manufacturing industry based on sector and carrier

| Industry sectors | Coal | Rene-wable | Oil | Gas | Electri-city | District heating | Total | Share |
|---|---|---|---|---|---|---|---|---|
| | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | % |
| Mining and quarrying | 165.1 | 89.6 | 1658.0 | 1480.7 | 300.0 | 2.7 | 3696.0 | **2.91** |
| Food, beverages and tobacco | 2114.8 | 431.5 | 6997.2 | 12604.0 | 9021.0 | 1412.9 | 32581.4 | **25.66** |
| Textile and leather | 0 | 7.8 | 84.9 | 680.7 | 601.4 | 131.7 | 1506.5 | **1.19** |
| Wood and wood products | 0 | 2492.7 | 770.2 | 662.9 | 2481.0 | 650.0 | 7056.9 | **5.56** |
| Pulp, paper and print | 0 | 46.1 | 273.4 | 3026.5 | 2626.5 | 682.8 | 6655.3 | **5.24** |
| Chemicals, medicine industry | 563.8 | 3.4 | 1885.0 | 18016.0 | 5730.8 | 1986.8 | 27986.4 | **22.04** |
| Plastic and rubber industry | 0 | 17.463 | 256.0 | 1505.0 | 2551.8 | 154.1 | 4484.3 | **3.53** |
| Metal and machinery | 0 | 83.0 | 2034.4 | 5634.5 | 6782.3 | 1374.8 | 15909.0 | **12.53** |
| Other industries | 0 | 66.4 | 306.6 | 1044.8 | 2521.4 | 671.5 | 4610.6 | **3.63** |
| Non metallic | 0 | 0 | 14 | 1312.7 | 667.4 | 16.7 | 2010.9 | **1.58** |
| Construction indus-try | 10670.0 | 1208.1 | 1687.9 | 4323.1 | 2530.4 | 65.3 | 20484.8 | **16.13** |
| **Total** | **13513.7** | **4446.0** | **15967.5** | **50290.7** | **35814.0** | **7149.2** | **126982.0** | **100.00** |
| **%** | **10.64** | **3.50** | **12.57** | **39.60** | **28.20** | **5.63** | **100** | |

The food, beverage and tobacco industries use 25.7% of the industrial energy, whereas the medical and chemical industries use 22 %. Gas is the largest energy source in the industry and constitutes 39.6 % of the energy demand.

Table 5-5: Industrial energy use regarding sectors and application

| **Temperature** | **Final applications** | **Fuel/FjV** | **Electricity** | **Totals** | **Share %** |
|---|---|---|---|---|---|
| | | [PJ] | [PJ] | [PJ] | [%] |
| <70 | Boiler and pipe losses | 7867 | 0 | 7867 | 6.185575 |
| 0-120 | Preheating and boiling | 24592 | 496 | 25088 | 19.72591 |
| 40-250 | Drying | 15551 | 689 | 16240 | 12.769 |
| 40-170 | Evaporation and concentra-tion | 5759 | 0 | 5759 | 4.528121 |
| 40-100 | Destillation | 3755 | 0 | 3755 | 2.952439 |
| 300-1000 | Burning/Sintering | 12444 | 24 | 12468 | 9.803197 |
| 300-1000 | Melting/Casting | 2827 | 2458 | 5285 | 4.15543 |
| 70 | Heat up to 150 °C | 345 | 10 | 355 | 0.279125 |
| 150< | Heat above 150 °C | 1187 | 94 | 1281 | 1.00721 |
| NR | Transport | 605 | 0 | 605 | 0.475693 |
| NR | Lightning | 0 | 2758 | 2758 | 2.168529 |
| NR | Pumping | 0 | 3665 | 3665 | 2.881674 |
| NR | Refrigeration/freezing | 0 | 3053 | 3053 | 2.400478 |
| NR | Fans and blowers | 0 | 6387 | 6387 | 5.021898 |
| NR | Compressed air and process air | 0 | 4093 | 4093 | 3.218197 |
| NR | Size reduction | 0 | 1599 | 1599 | 1.257243 |
| NR | Stirring | 0 | 709 | 709 | 0.557464 |
| NR | Other electrical motors | 0 | 8545 | 8545 | 6.718665 |
| NR | Computers and electronics | 0 | 474 | 474 | 0.372691 |
| NR | Other electrical users | 0 | 345 | 345 | 0.271263 |
| 50 | Space heating | 16436 | 416 | 16852 | 13.2502 |
| | **Totals** | **91367** | **35815** | **127183** | **100** |

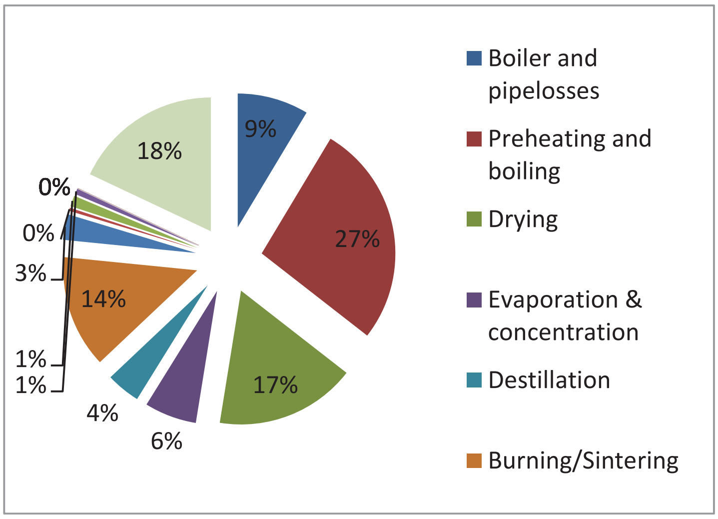


Figure 5-4: Energy use in the Danish manufacturing industry based on processes

Table 5-6: Energy use in the Danish manufacturing industry based on sectors and processes

| Use | Mi-ning | Food | Tex-tile | Wood | Pulp and paper | Che-micals | Plastic and rubber | Metal | Other | Non metal-lic | Con-struc-tion | Total | Share |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | [TJ] | % |
| Boiler and pipe losses | 356 | 3136 | 137 | 751 | 393 | 1557 | 341 | 837 | 224 | 27 | 296 | 8056 | 6.3 |
| Preheating and boiling | 235 | 7011 | 418 | 168 | 199 | 14032 | 202 | 1756 | 97 | 26 | 1015 | 25159 | 19.8 |
| Drying | 466 | 5747 | 186 | 1615 | 2080 | 1190 | 232 | 1035 | 115 | 40 | 2920 | 15626 | 12.3 |
| Evaporation & concen-tration | 2033 | 4025 | 0 | 0 | 0 | 478 | 0 | 0 | 0 | 0 | 0 | 6536 | 5.1 |
| Destillation | 0 | 567 | 0 | 0 | 0 | 3188 | 0 | 0 | 0 | 0 | 0 | 3755 | 3.0 |
| Burning/ sintering | 165 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 0 | 6 | 11930 | 12128 | 9.5 |
| Melting/ casting | 0 | 0 | 0 | 0 | 0 | 11 | 1184 | 1682 | 349 | 1154 | 905 | 5285 | 4.2 |
| Heat up to 150 °C | 0 | 94 | 32 | 39 | 0 | 190 | 0 | 0 | 0 | 0 | 0 | 355 | 0.3 |
| Heat above 150 °C | 0 | 586 | 0 | 58 | 0 | 0 | 0 | 281 | 0 | 128 | 220 | 1273 | 1.0 |
| Transport | 96 | 144 | 3 | 109 | 51 | 10 | 30 | 91 | 33 | 5 | 33 | 605 | 0.5 |
| Lightning | 9 | 571 | 78 | 201 | 295 | 212 | 194 | 799 | 294 | 33 | 72 | 2758 | 2.2 |
| Pumping | 81 | 1315 | 41 | 61 | 320 | 1447 | 84 | 175 | 38 | 33 | 69 | 3665 | 2.9 |
| Refrigeration / freezing | 0 | 2016 | 2 | 0 | 65 | 623 | 241 | 55 | 51 | 0 | 0 | 3053 | 2.4 |
| Fans and blowers | 75 | 1566 | 84 | 964 | 409 | 567 | 291 | 1127 | 486 | 140 | 677 | 6387 | 5.0 |
| Compressed air and process air | 18 | 596 | 61 | 386 | 186 | 1343 | 222 | 779 | 276 | 127 | 98 | 4093 | 3.2 |
| Size reduc-tion | 45 | 290 | 0 | 47 | 194 | 53 | 65 | 2 | 18 | 7 | 879 | 1599 | 1.3 |
| Stirring | 0 | 114 | 0 | 0 | 54 | 481 | 42 | 0 | 0 | 0 | 19 | 709 | 0.6 |
| Other elec-trical motors | 69 | 2212 | 235 | 623 | 824 | 635 | 289 | 2096 | 809 | 120 | 631 | 8545 | 6.7 |
| Computers and elec-tronics | 0 | 62 | 1 | 39 | 215 | 14 | 33 | 53 | 58 | 0 | 0 | 474 | 0.4 |
| Other elec-trical users | 0 | 0 | 0 | 0 | 0 | 0 | 25 | 298 | 22 | 0 | 0 | 345 | 0.3 |
| Space heat-ing | 47 | 2540 | 227 | 1996 | 1371 | 2154 | 1010 | 4816 | 1741 | 164 | 712 | 16777 | 13.2 |
| Totals | 3696 | 32591 | 1506 | 7057 | 6655 | 28186 | 4484 | 15909 | 4611 | 2011 | 20477 | 127183 | |
| | 2.9 | 25.6 | 1.2 | 5.5 | 5.2 | 22.2 | 3.5 | 12.5 | 3.6 | 1.6 | 16.1 | 100.0 | |

## 5.3 Market Survey

Industrial demography:

From a conversional point of view, the foodstuff, metal and machine industries constitute the largest sectors within the Danish manufacturing industry. However, the chemical and medical industry exceeds the metal industry as regards use of energy. As for implementation of heat pumps, the foodstuff, chemical and medical industries are the most essential consumers of energy.

The extension of heat pumps is not huge in the Danish industry.

Challenges:

Profitability: The most important challenge is the rather low economic advantage by establishing heat pumps.

Focus on reutilization for heating: Furthermore, at great part of the focus has been on the reutilization of heat from the industry for the heating of rooms, and in this case the Danish energy tax system is a big challenge.

Knowledge: Lack of knowledge and experiences also constitutes a challenge in the industry.

## 5.4 Literature

1: Energistatestik 2009, Energistyrelsen (Danish Energy Agency), ISBN 978-87-7844-872-9

2: Kortlægning af erhvervslivets energiforbrug, November 2008, Energistyrelsen (Danish Energy Agency). Elaborated by: Dansk Energianalyse A/S; Viegand og Maagøe A/S

# 6 France

## 6.1 Energy in France[17]

2007 France used 154 Mtoe of Energy. The final energy consumption by fuel has been: 45% oil, 24% electricity, 20% gas and 7% renewable. The gross electricity generation was 570 TWh (2007): 77% nuclear, 12% renewable, 4% coal. The price of electricity for the industry has been 2008 one of the cheapest of Europe (6.15 € per 100 kWh).

The industry represented 2007 22% of the final energy consumption (33% transport, 27% household, 16% services and 2% agriculture).

The $CO_2$ emission of the French industry has been 2007 95.5 Mt of $CO_2$. The industry represented 24% of these emissions (34% transport, 17% energy industry, 14% residential).

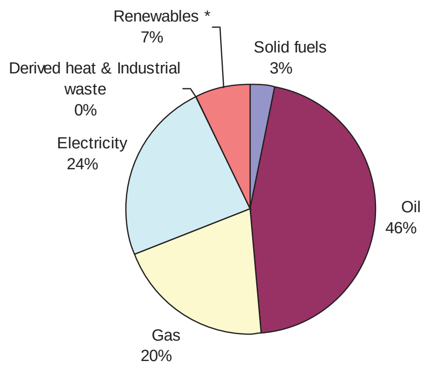


Figure 6-1: France final energy consumption by fuel 2007 (Mtoe)[18]

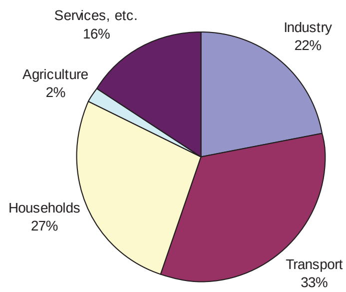


Figure 6-2: France final energy consumption by sectors 2007 (Mtoe)

[17] COMMISSARIAT GÉNÉRAL AU DÉVELOPPEMENT DURABLE - Chiffres clés de l'énergie – October 2010

[18] European Commission / ENERGY - EUROPE 2020 initiative - Energy Efficiency Plan 2011, Statistical pocketbook 2010

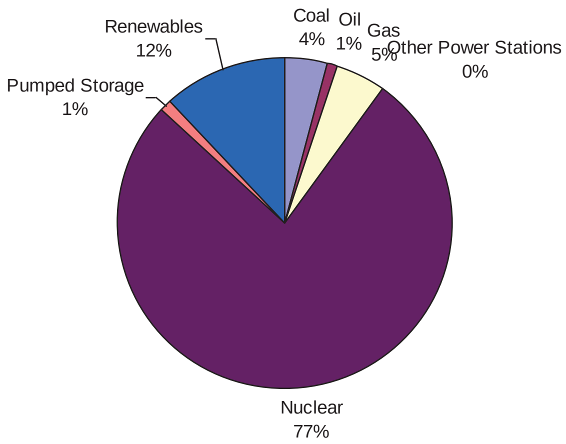


Figure 6-3: France Gross electricity generation 2007 (in TWh)

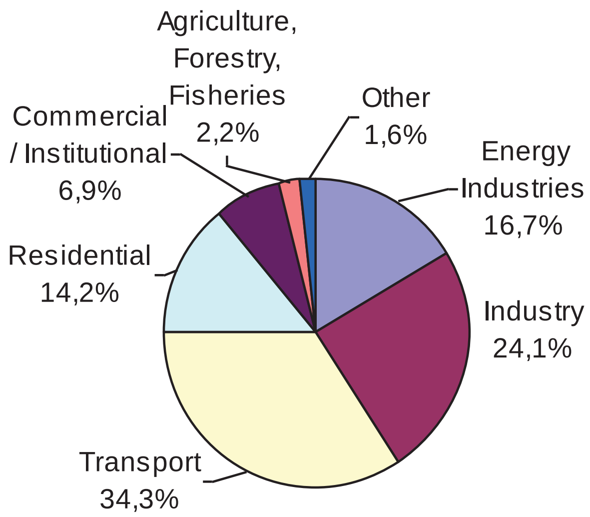


Figure 6-4: France $CO_2$ Emissions by sector 2007 (Mt)

### 6.1.1 Energy in French Industry

The industry represents 25% of the greenhouse gas emissions (24% of the total $CO_2$ emissions, 78% of $SO_2$, 44% of COV, 25% of NOx). The $CO_2$ emissions represent 80% of the total greenhouse gas emissions of the French industry.

The French industry represents 15% of the GDP and of the employments (3.6 for 25 millions).

The main sectors in the French industry are in 2008: 26% chemical, 17% steel, 14% Food, 13% mineral, 12% mechanical and 10% pulp and paper (two sources are presented, ADEME and EUROSTAT, the limits of the sectors are different).

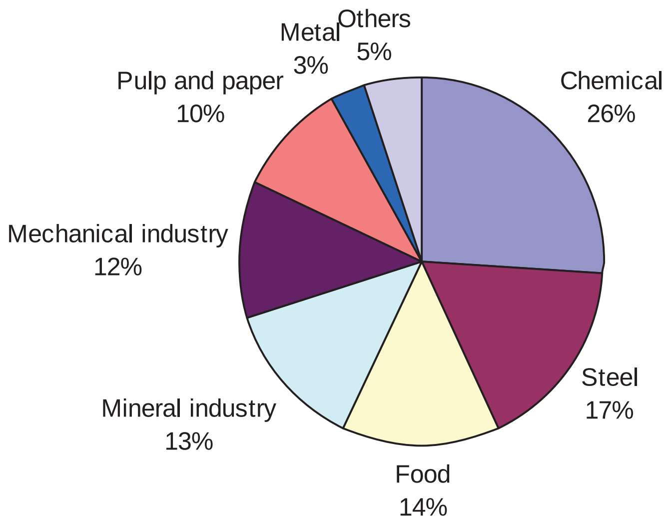


Figure 6-5: Industrial final energy consumption by sectors 2008 [19]

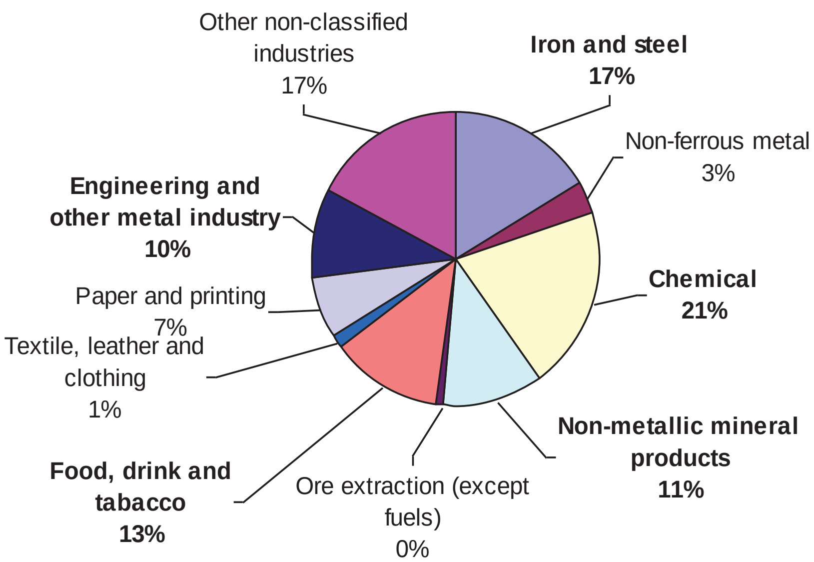


Figure 6-6: France industrial final energy consumption by sectors 2008 (Mtoe) 20

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[19] Colloque Programme Energie, Vannes - France, May 29th 2009, ADEME
[20] European Commission – Eurostat - 2008

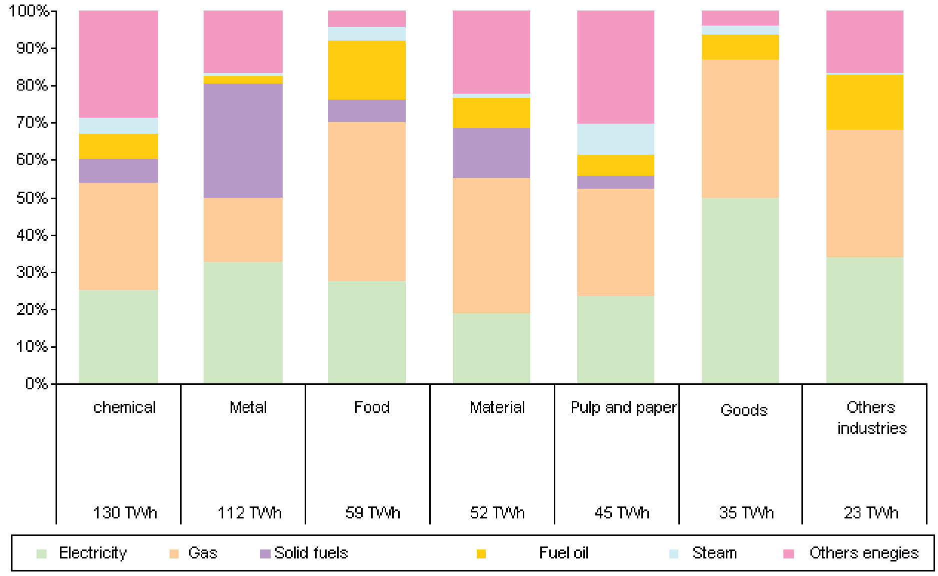


Figure 6-7: Type of energy used by industrial sectors[21]

In 2009 the energy consumption of the French industry decrease of -15.9% (-1.3% in 2008). The steel and metal industry decrease of -28.2%, the chemical industry of -10.2%, the glass industry of -15.9%, the material industry (cement, …) of -13.2% and the Pulp and paper industry of -10.1%. Only the energy consumption of food industry is stable (with +11.6% for the sugar industry).[22]

Then the electricity consumption decrease of -11% (-24% for the steel industry), the gas consumption decrease of -3.4%, fuel oil of -7.5% and coal -24% (because of the steel industry which use 70% of the coal).

The renewable energy represents 7% of the energy consumption of the industry (x2 in 10 years).

More than 70% of the energy is used to heat. In term of operation, 29% are boilers, 17% chemical reactions, 15% furnaces. The motors (motors, HVAC, Cold) represent 70% of the electrical consumption of the industry.

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[21] Sources : CEREN, SESSI, AGRESTE (2010)

[22] Bilan énergétique de la France pour 2009 (Commissariat général au développement durable - Service de l’observation et des statistiques)

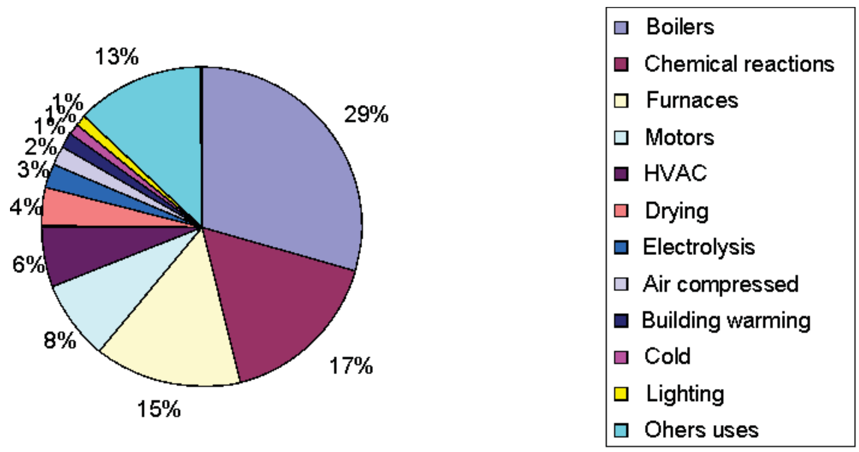


Figure 6-8: Type of uses of energy in 2007[23]

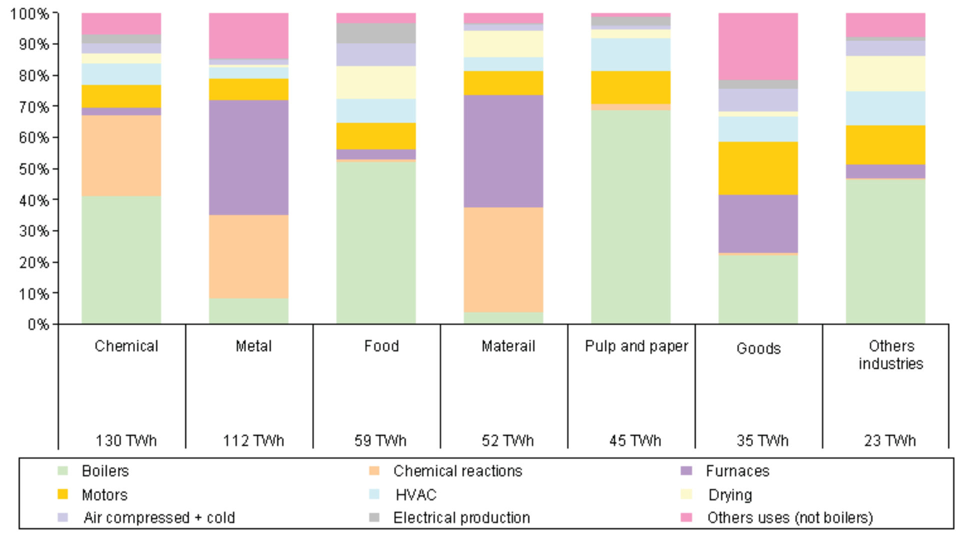


Figure 6-9: Main operations by industrial sectors[24]

### 6.1.2 Market assessment of industrial heat in France

This part describes the needs for heat sources and availability of cold sources.

French energy consumption analysis shows that the energy bill for the processes in the temperature range 0-200°C (all industrial sectors combined) is ten times higher than the energy bill for processes in the temperature range 0-70°C. Therefore, the development of energy efficient solutions for temperatures higher than 70°C (the limiting condensation temperature for existing industrial heat pumps), could increase potential energy savings on industrial processes by a factor of 10.

[23] Source RTE (Operator of the French electricity transmission system.)
[24] Sources : CEREN, SESSI, AGRESTE (2010)

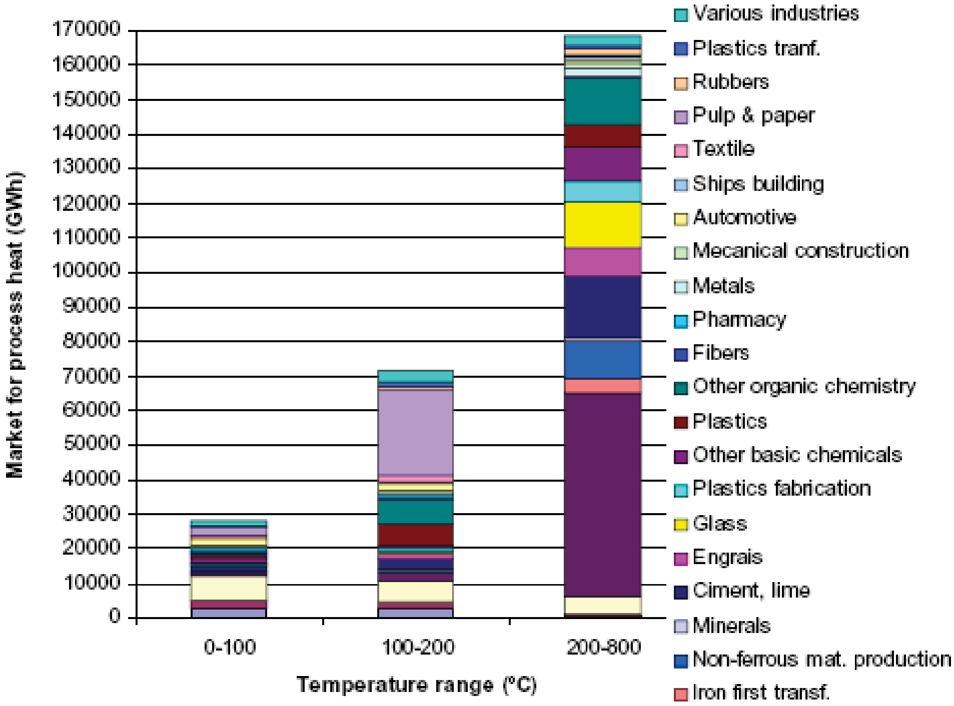


Figure 6-10: Process energy market on the 27 main industrial sectors[25]

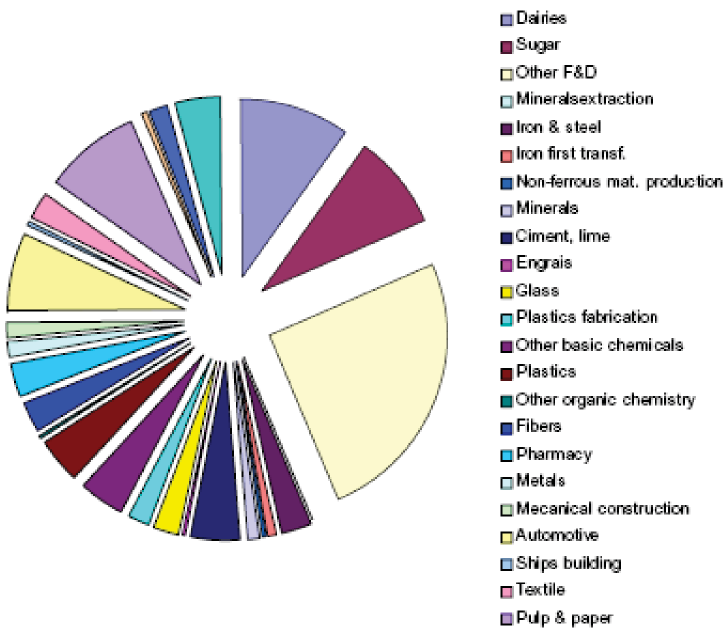


Figure 6-11: Distribution by sector of energy consumption of processes below 100°C

[25] Source : EDF-R&D (+ CEREN 2007)

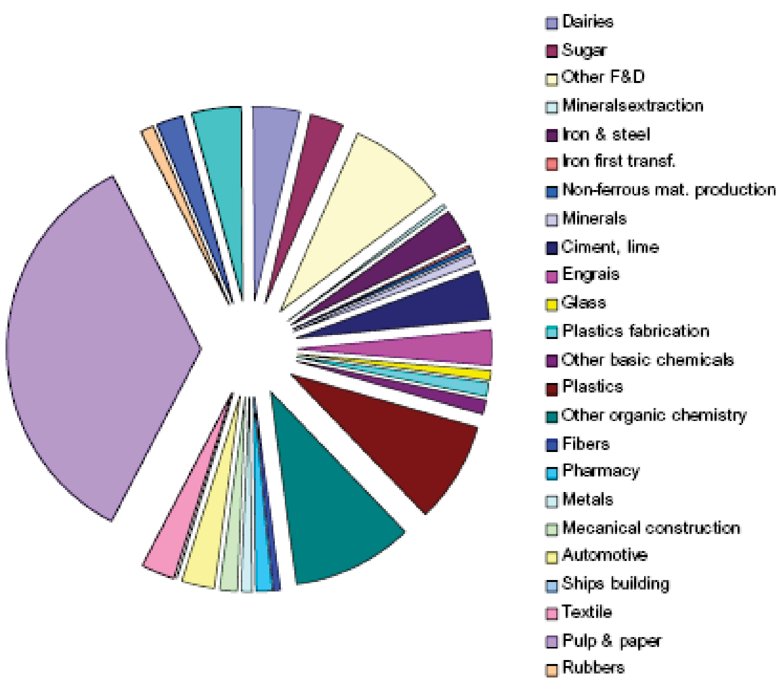


Figure 6-12: Distribution by sector of energy consumption of processes between 100°C and 200°C

By the way, the most energy consuming processes are:

- Heating of liquids and gases, very frequent between 0 and 100°C (35% of the consumption of this range) and in the food processing industry
- Drying, very frequent between 100 and 200°C (39% of the consumption in this range) and in the paper industry.

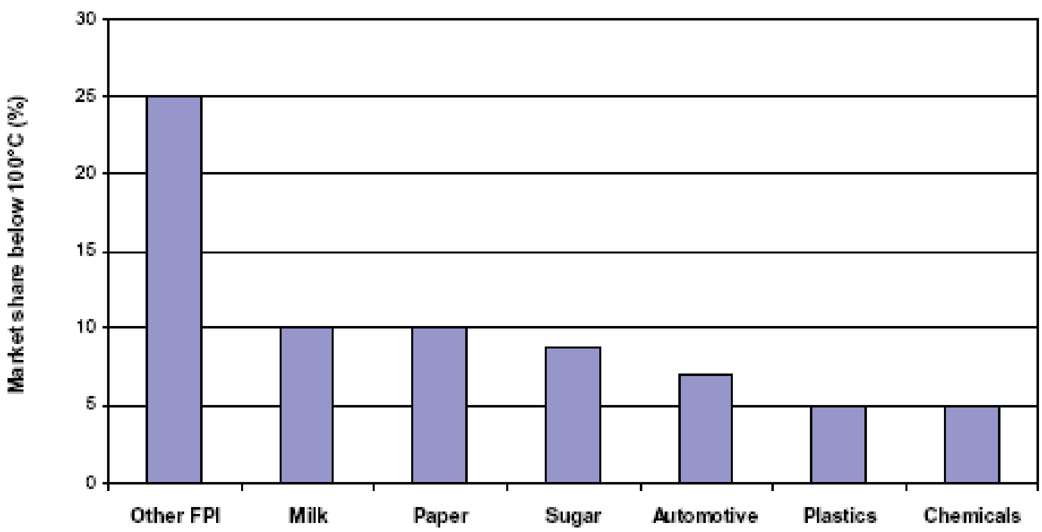


Figure 6-13: The seven sectors with the highest consumptions below 100°C

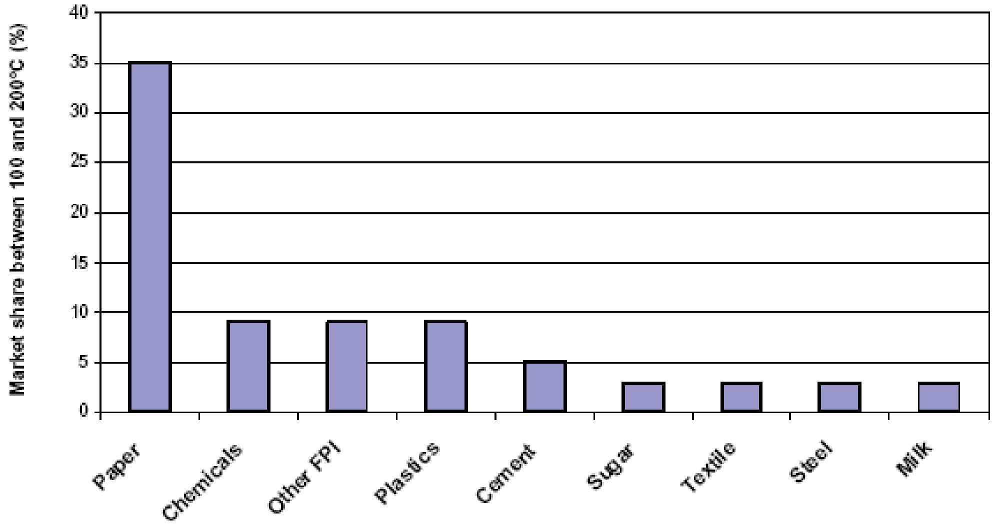


Figure 6-14: The nine main sectors for the 100°C to 200°C market

As can be seen in the figures above, in the temperature ranges 0-100°C and 100-200°C, three sectors are consuming particularly high quantities of process heat. They will be used to orientate the technological specification for a heat pump adapted to their applications:

- The food processing industry (mainly in the range 0- 100°C), including dairy and sugar;
- The basic organic chemistry industry, including manufacturing of basic plastic and elastomer materials
- The paper industry (mainly above 100°C)

These three sectors represent the respectively 64% (68%) of the total national consumption by process equipment in the temperature range 0-100°C (100-200°C).
Four other sectors consume large quantities of energy in the temperature range 100-200°C, although to a lesser extent: manufacturing of plaster, lime, cement ; automobile manufacturing ; textile industry and steelworks

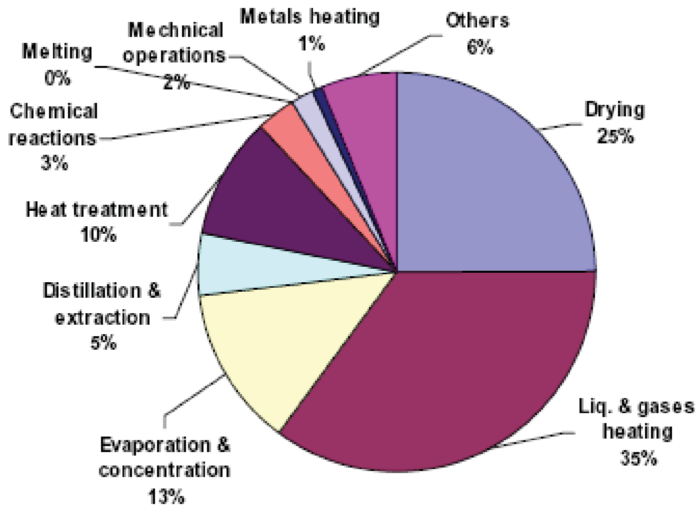


Figure 6-15: Distribution of the energy consumption on the different processes below 100°C, all sectors combined

Remarkably, each of the two temperature ranges is marked by one and possibly two major types of energy consuming operations that themselves correspond to a consumption concentration in a particular sector, despite their presence across all sectors. Thus:

- Heating of liquids accounts for 35% of energy consumption below 100°C; 47% of the energy necessary for liquid heating processes in this temperature range are consumed in the food processing industry (4.6 TWh) distributed among dairy, sugar and other food processing activities, the consumption for the dairy industry in heating of liquids being greater than consumption for all other food processing excluding sugar (see figure above).
- Drying accounts for 39% of energy consumption between 100 and 200°C; 62% of the energy necessary for drying in this temperature range is consumed in the paper sector (17 TWh), and 10% in the food processing industry (see Figure 6-16).

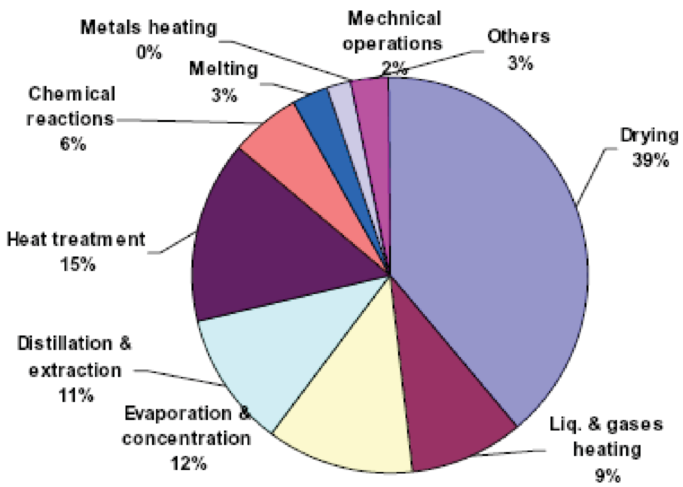

Figure 6-16: Distribution of energy consumption on the different processes between 100°C and 200°C, all sectors combined

Knowledge about consuming processes in food processing, chemicals and paper has been specified in a finer temperature range. Although the extrapolation method underestimates the number of equipment in the country and overestimates the average power per equipment, these values have validated the advantage of developing a standard heat pump for integration, substitution, make up or pre-heating for the corresponding application processes.

Key energy consuming applications for the installation of a very high temperature heat pump satisfying the two conditions (a large number of equipment and the moderate average power) are given in summary table below. Applications with a less appropriate profile composed of the number of equipment and average power, but that are still interesting due to their energy consumption have also been identified and listed in the core of this report.

It is difficult to evaluate the availability of degraded industrial heat sources that can be used by the VHT HP (Very High Temperature Heat Pump) evaporator: effluent quantities, physical and biological quality and temperatures are not well known. Nevertheless, an evaluation of the integration of a VHT HP in series on cooling units to recover heat from the cooling unit condensers, demonstrates that this solution alone could at least cover the energy consumption of the processes consuming most energy, and possibly even all process consumption, in the food processing and dairy sector.

Table 6-1: Summary of the most attractive applications of a VHT HP by temperature level

| Temperature | Application | Consumption (TWh) | Number of units in France | Average unit power (MW of heat) |
|---|---|---|---|---|
| **70 - 79°C** | Dairy, pasteurisation | 0.4 | 198 | 2.4 |
| | Dairy, cleaning water | 0.12 | 90 | 1.3 |
| | Various food processing industries (FPI), heating of liquids | 0.25 | 447 | 0.8 |
| **80 - 89°C** | Dairy, pasteurisation | 0.29 | 175 | 1.9 |
| | Dairy, cleaning water | 0.11 | 103 | 1.5 |
| | Miscellaneous FPI, heating of liquids | 0.44 | 438 | 1.6 |
| | Miscellaneous FPI, th treatment: cooking food | 0.38 | 521 | 1 |
| | Paper, drying | 0.37 | 276 | 0.8 |

| Temperature | Application | Consumption (TWh) | Number of units in France | Average unit power (MW of heat) |
|---|---|---|---|---|
| 90 - 99°C | Dairy, pasteurisation | 0.27 | 182 | 1.1 |
| | Miscellaneous FPI, heating of liquids | 0.56 | 572 | 3.5 |
| | Miscellaneous FPI, th treatment: cooking food | 0.48 | 607 | 2.2 |
| | Plastics, chemical reactions | 0.02 | 101 | 1.6 |
| 100 - 119°C | Miscellaneous FPI, th treatment: cooking food | 0.58 | 754 | 2.3 |
| | Plastics, chemical reactions | 0.16 | 80 | 4.5 |
| | Other organic chemistry, chemical reactions | 0.2 | 635 | 9 |
| 120 -139°C | Miscellaneous FPI, th treatment: cooking food | 0.58 | 483 | 2.3 |
| | Miscellaneous FPI, sterilisation, appertisation | 0.92 | 678 | 3.8 |
| | Plastics, chemical reactions: make up | 0.13 | 55 | 16 |
| | Other organic chemistry, heating of gases | 0.75 | 274 | 3.3 |
| 140 - 159°C | Paper, make up drying | 4.6 | 194 | 7.1 |
| | Other organic chemistry, make up chemical reactions | 0.83 | 1423 | 10.5 |
| 160 - 179°C | Other organic chemistry, make up chemical reactions | 1.2 | 871 | 19 |
| | Other organic chemistry, make up distillation | 1.8 | 192 | 5.5 |

## 6.2 French Market overview

Looking at the industrial heat pump market in France, we can notice two main features:

- Open cycle heart pumps, MVR, are largely developed
- Closed cycle heat pumps are more and more used by industry, but the actual market is far to be fully developed.

Concerning MVR, a great number of installations has been realized in 80's and 90's, especially in agro-food sector. Today, most of whey concentration plants and sugar plants are equipped by MVR.

Concerning closed cycle heat pumps, the situation is different. Between the end of 80's and the beginnings of 90's some heat pumps were installed, especially for drying applications. EDF internal reports showed some existing machines in breweries and lumber drying. But most part of the potential market has not been penetrated by heat pumping technology. Today, rising of fossil energies price and increasing concerns related to CO2 emissions lead industry to discover again the energy efficiency potential of heat pumps. Several machines have been sold for recent years in different sectors, and particularly in dairies where, recovering energy at chiller condenser to valorize it at higher temperatures is becoming more and more usual.

Today, heat pumps can be found in different agro-food sectors (meat, dairy, oil, brewery) but also in cosmetic industries, PC processors plants and several other sectors. Anyway, their utilization is limited to hot water production or buildings heating. Market will be fully developed once heat pumps will be directly installed on the industrial process. The potential of this development is very high.

## 6.3 Barriers for applications

Three types of barriers hinder the full development of industrial heat pump market:

1. Profitability: payback period requested by French industrial customers is less than three years. Even if French electricity price is quite low, it's not easy to reach such profitability. Heat pumps are profitable when COP is high and when they're installed on a process which works all year long. For recent years, low price non conventional gas is a real barrier on heat pumps profitability.
2. Lack of knowledge: industry doesn't know heat pumps as well as boilers. Several good references are necessary before winning customer confidence.
3. Lack of specialized engineering companies: installing a heat pump on an industrial process is not easy. Heat pump is often the heart of a more complex heat recovery system including heat exchangers, secondary hydraulic loops and storage tanks. Today in France there is no engineering company special-

ized on industrial heat pump. Several manufacturers propose heat pumps for heat recovery on chillers condensers in order to produce hot water. But societies suggesting heat pump installation directly on the industrial process are almost inexistent up to now.

The three types of barriers are strictly linked: increasing profitability means more references on industrial plants, and so a growing demand and the development of specialized engineering companies able to satisfy this demand.

# 7 Germany

## 7.1 Energy use in Germany

The primary energy consumption in Germany did not change significantly in the past twenty years. Figure 7-1 illustrates this development. The minimum in 2009 is strongly related to the financial crisis that resulted in a decrease of the German GDP by 5.1 % followed by a strong recovery in 2010 /Statistisches Bundesamt 2012/.

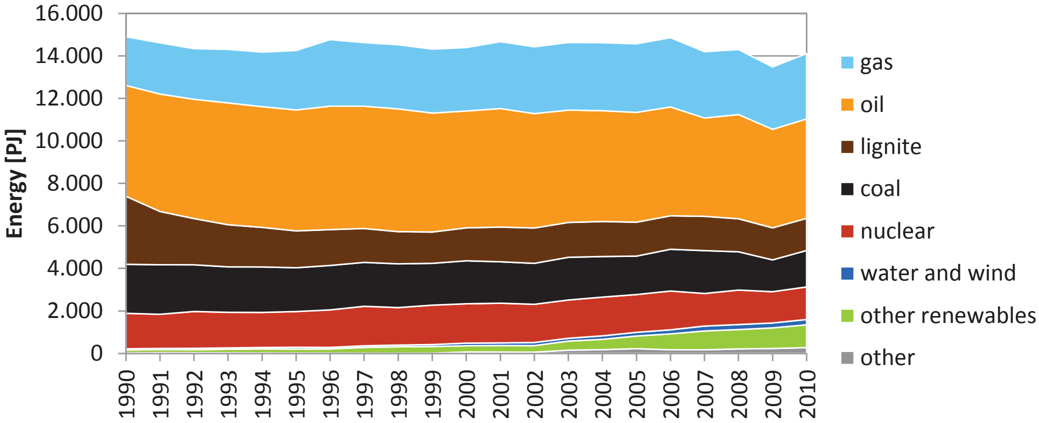


Figure 7-1: German primary energy balance per energy source /BMWi 2012/

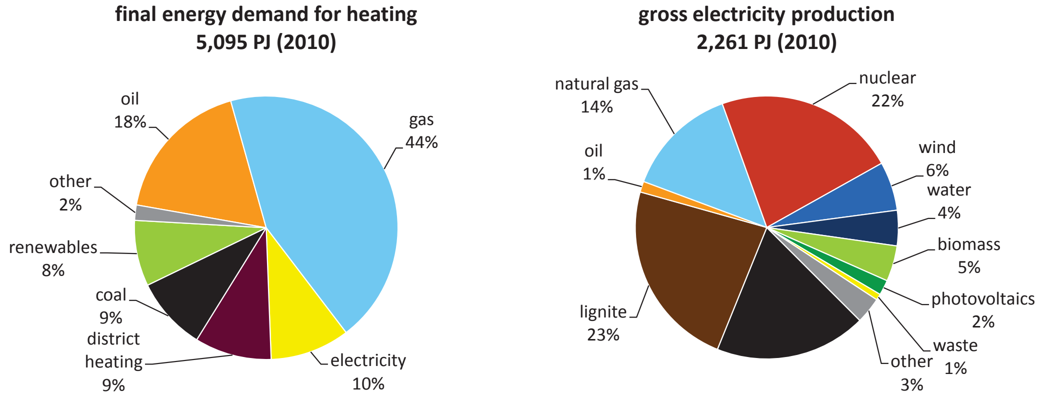


Figure 7-2: Final energy demand for heating and gross electricity by energy source in Germany /BMWi 2012/

The primary energy consumption of 14,044 PJ in 2010 was dominated by fossil energy sources. The energy mix is devided into gas (21.9 %), oil (33.3 %), lignite (10.8 %), coal (12.2 %), nuclear energy (8.8 %), water and wind energy (1.8 %), other renewables (7.6 %) and other sources (1.9 %). Figure 7-1 shows a constant increase of the renewable energy share in the last ten years.

The renewable share in final energy demand for heating has risen up to 8.1 % in 2010 but more than two thirds are covered by burning fossil fuels (Figure 7-2). In gross electricity production the share of renewable sources has risen from 7.0 % in 2000 up to

16.6 % in 2010. This led to a reduction of the specific $CO_2$ emissions from 623 g/kWh$_{el}$ to 562 g/kWh$_{el}$ /UBA 2012/.

The final energy demand in Germany can be classified in four main sectors:

- industry
- trade/services
- private households
- transport

In 2010 Germany had a final energy demand of 9,060 PJ. The shares of industry, transport and private household are of almost equal size around 28 %. Trade and services play a minor important role with a share of 15 %.

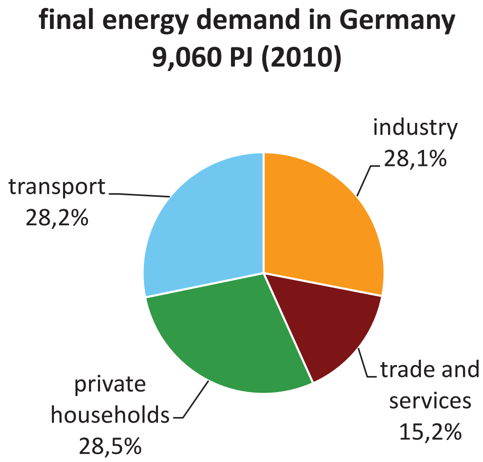


Figure 7-3: Final energy consumption in Germany by sector /BMWi 2012/

### 7.1.1 Final energy use in the German industry

After a decrease in the early 1990s, that was mainly caused by the collapsing industry in eastern Germany after the reunification, the final energy demand of the German industry developed constantly between 2,300 PJ and 2,600 PJ (Figure 7-4). The minimum reached in 2009 is to be seen as the effect of the financial crisis. During the last ten years the shares of renewable energies and district heat are increasing slightly, while the use of coal and oil is decreasing.

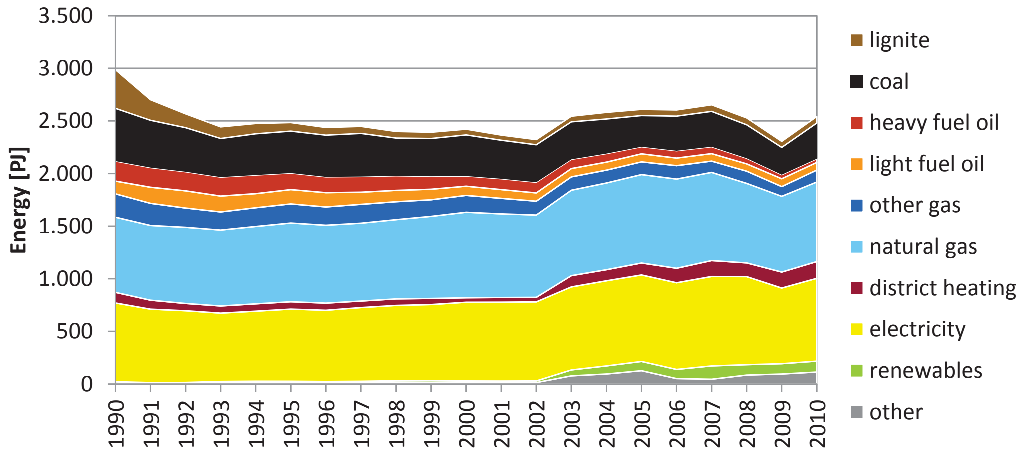


Figure 7-4: Final energy balance of the German industry from 1990 to 2010 /BMWi 2012/

In 2010 the final energy demand of the German industry has reached 2,542 PJ. The biggest share was needed in form of process heat (1,666 PJ / 65.6%), followed by mechanical energy (553 PJ / 21.7%), space heating (196 PJ / 7.7%), lighting (38 PJ / 1.5%), information and communication technology (ICT) (32 PJ / 1.3%), hot water (23 PJ / 0.9%), process cold (18 PJ / 0.7%) and climatisation (17 PJ / 0.7%). Figure 7-5 shows that heating purposes (process heat, space heating, hot water production) account for almost three quarters of the industrial final energy demand in Germany.

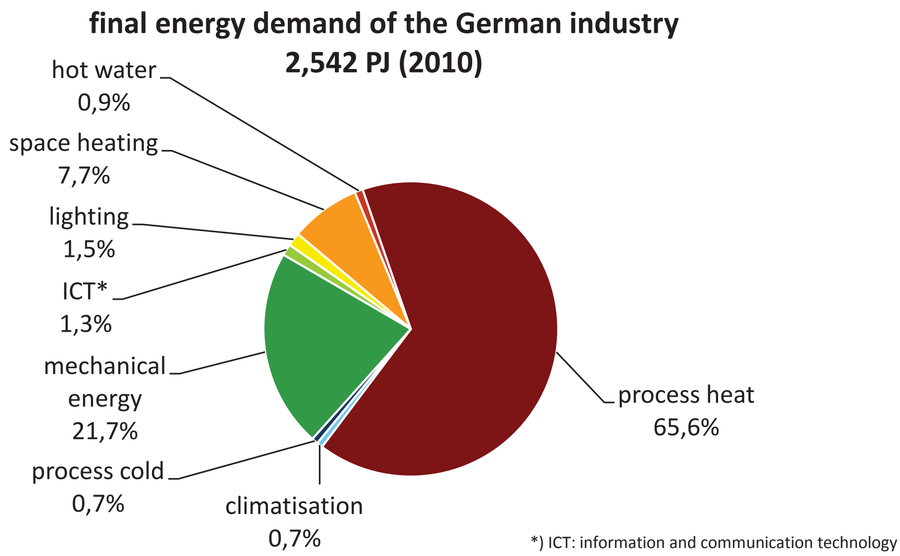


Figure 7-5: Final energy demand of the German industry in 2010 /BMWi 2012/

### 7.1.2 Heat demand of the German industry

The German industrial heat demand reached 1,883 PJ in 2010 (Figure 7-6). It was even more dominated by fossil fuels than the overall German heat demand (Figure 7-2). The most widely used energy source was gas (861 PJ / 45.7%) followed by coal (401 PJ /

21.3%), district heating (160 PJ / 8.5%), electricity (138 PJ / 7.3%), oil (126 PJ / 6.7%), renewables (104 PJ / 5.5%) and other sources (95 PJ / 5.0%). Although the renewable share in industrial heat production has risen slightly it is still far behind the share of renewable heat produced in private household sector (12.4 % in 2010).

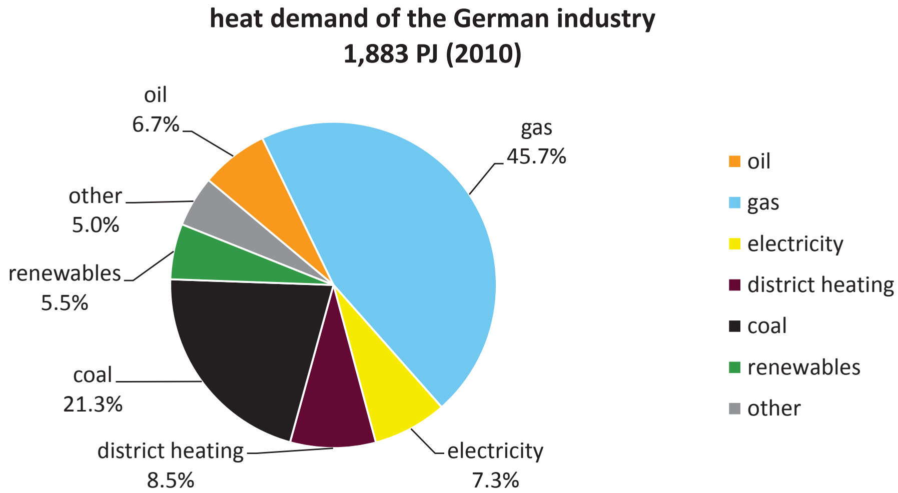


Figure 7-6: Heat demand of the German industry in 2010 by energy source /BMWi 2012/

An overview over the structure of the industrial heat demand is given in Figure 7-7. Metal production is by far the most heat consuming industrial branch followed by production of basic chemicals and food & tobacco industry. While in metal production coal is largely used for heat generation, natural gas has the biggest share in the other industrial branches.

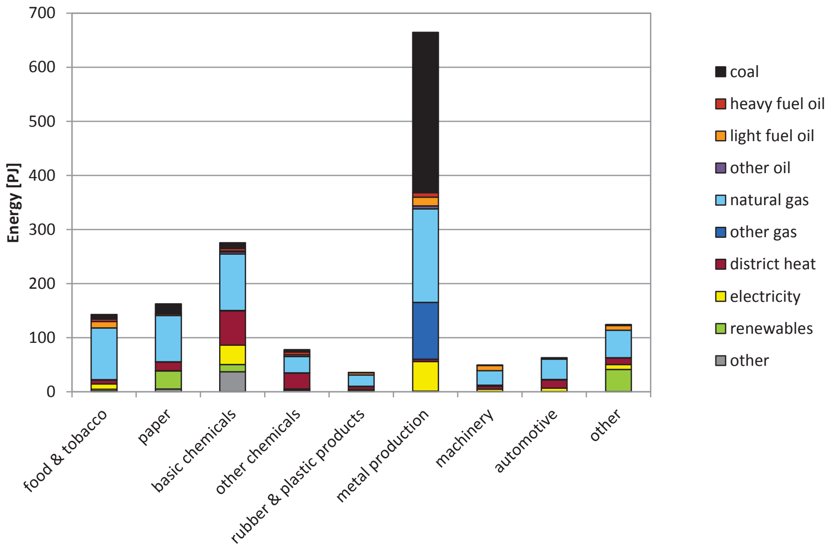


Figure 7-7: Structure of the final Energy demand for heating purposes in the German industry /AGEB 2011/

### 7.1.3 Industrial energy prices

As shown in Figure 7-4 the final energy demand in the German industry stayed quite constant over the last two decades. In contrast to this the energy prices for the industry have been slightly decreasing in the 1990s but started to rise in the year 2000.

Table 7-1: Development of energy prices for industry /BMWi 2012/

| Final consumer prices for industry | | | | |
|---|---|---|---|---|
| **year** | **heavy fuel oil** | **light fuel oil** | **natural gas** | **electricity** |
| | [ct/kWh] | [ct/kwh] | [ct/kwh] | [ct/kwh] |
| 1991 | 1.04 | 2.07 | 1.47 | 6.91 |
| 1992 | 0.94 | 1.78 | 1.38 | 6.96 |
| 1993 | 0.92 | 1.76 | 1.32 | 7.03 |
| 1994 | 0.96 | 1.60 | 1.27 | 6.82 |
| 1995 | 0.97 | 1.52 | 1.27 | 6.74 |
| 1996 | 1.07 | 1.88 | 1.29 | 6.62 |
| 1997 | 1.08 | 1.91 | 1.39 | 6.37 |
| 1998 | 0.91 | 1.50 | 1.33 | 6.05 |
| 1999 | 1.07 | 1.96 | 1.27 | 5.34 |
| 2000 | 1.72 | 3.24 | 1.69 | 4.40 |
| 2001 | 1.53 | 2.97 | 2.14 | 4.89 |
| 2002 | 1.68 | 2.71 | 1.95 | 5.15 |
| 2003 | 1.70 | 2.81 | 2.16 | 5.79 |
| 2004 | 1.59 | 3.22 | 2.12 | 6.19 |
| 2005 | 2.21 | 4.32 | 2.46 | 6.76 |
| 2006 | 2.69 | 4.85 | 2.91 | 7.51 |
| 2007 | 2.62 | 4.77 | 2.77 | 7.95 |
| 2008 | 3.59 | 6.29 | 3.36 | 8.82 |
| 2009 | 2.78 | 4.16 | 3.15 | 10.04 |
| 2010 | 3.60 | 5.33 | 2.93 | 9.71 |

Table 7-1 lists the prices for the most important energy sources from 1991 to 2010. Compared to the base-year 1991 the electricity price decreased by 36.3% until 2000 and started to rise from this year on. In 2010 the average electricity price for industry was 9.71 ct/kWh, which was 40.6% higher than in 1991. The price increase for fossil fuels (heavy fuel oil, light fuel oil and natural gas) was significantly higher. In 2010 the price for natural gas was 2.93 ct/kWh (+99.7%), for light fuel oil 5.33 ct/kWh (+157.4%) and for heavy fuel oil 3.60 ct/kWh (+244.8%). In the same period of time the average cost of living in Germany increased by 42.6 %. The detailed development is shown in Figure 7-8. As energy prices are expected to further increase in the future, the market conditions for energy efficient heating technologies will further improve. For heat pumps however the electricity/gas price ratio is an important indicator for the economic feasibility. While gas prices increased faster than electricity prices in the past 10 years this ratio lead to an advantage for electrical heat pumps. This trend could be reversed in future due to the increased production of unconventional gas. This would result in an increased installation of conventional gas burners and gas driven heat pumps.

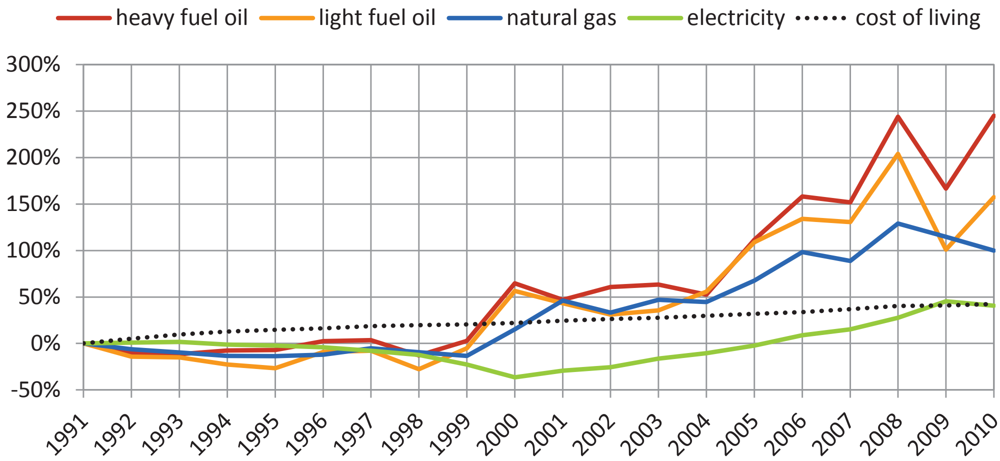


Figure 7-8: Development of energy prices for industry and general cost of living compared to the base-year 1991 /BMWi 2012/

## 7.2 Market overview Germany

### 7.2.1 German industrial sector

Although Germany is known as an industrial country with a large export of industrial products the producing sector only accounts for 24.7% (548 billion €) of the German GDP of 2,296 billion € in 2010. As shown in Figure 7-9, the service sector takes the biggest share of the German economy. Germany's export strategy and the resulting trade surplus of 128 billion € in 2010, however, are mainly driven by the producing sector.

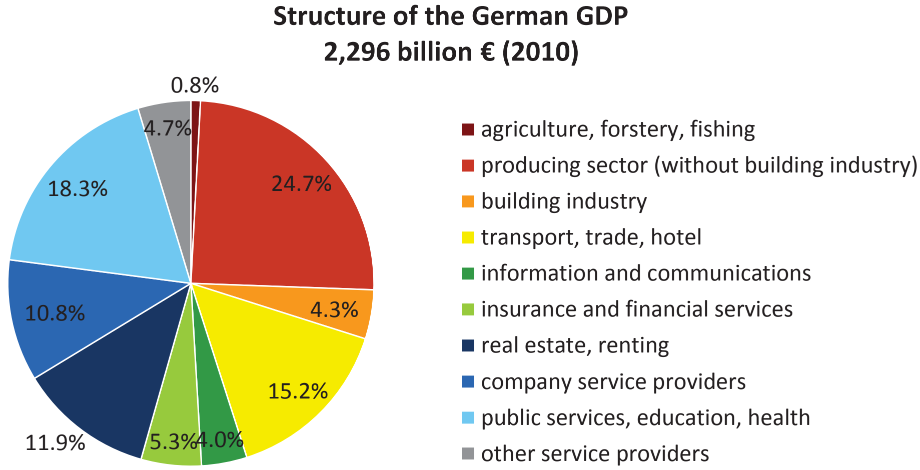


Figure 7-9: Structure of the German GDP in 2010 /Statistisches Bundesamt 2012/

The German economy is characterized by a large number of small and medium sized enterprises (SME). SMEs are defined as companies with less than 250 employees and not more than 50 million € annual turnover. All following data is taken from the year

2009, as newer statistics were not available. 99.5 % of all German enterprises fulfill the requirements of the SME definition. They account for 37.8 % of the total turnover of all German enterprises. In total SMEs employ 55.1 % of all employees in German enterprises /IfM 2011/.

## 7.3 Technical potential for the use of heat pumps in the German industry

The technical potential for industrial heat pumps in Germany can be derived by analyzing the heat demand of the most promising industrial sectors and the typically used processes.

Table 7-2 shows the technical potential broken down to industrial sectors and temperature levels. Data from this table is displayed in form of bar charts in Figure 7-10 Machinery, automotive, food and chemical industry show a high potential at lower temperatures up to 80 °C. These temperatures can be delivered by heat pumps using conventional refrigerants. The overall potential up to 80 °C amounts to 271.65 PJ/a, which equals 14.4 % of the industrial heat demand. When it comes to high temperature heat pumps, which operate at temperatures up to 140 °C, a great increase of the potential can be seen in food, paper and chemical industry. The technical potential for all industrial heating purposes up to 140 °C is 598.82 PJ/a. This is 31.8 % of the industrial heat demand and 23.6 % of the total final energy demand in the German industry. Figure 7-10 clearly shows a big potential for the use of high temperature heat pumps in food, chemical and paper industry. The mayor part of this potential is needed for pasteurization, sterilization, drying and thickening in the food industry, for dyeing fabrics and condensation of viscose fabrics in textile industry and for melting of polyethylene and the production of rubber in the chemical industry /Blesl et al. 2012/.

Table 7-2: Technical potential for industrial heat pumps in Germany /Blesl et al. 2012/

| | **hot water** | **space heating** | **PH 70 °C** | **additional PH 80 °C** | **additional PH 100 °C** | **additional PH 140 °C** |
|---|---|---|---|---|---|---|
| | PJ/a | PJ/a | PJ/a | PJ/a | PJ/a | PJ/a |
| **Food** | 7.72 | 21.19 | 8.28 | 8.11 | 15.26 | 84.64 |
| **Textiles** | 0.42 | 6.74 | 1.98 | 0.24 | 1.46 | 4.55 |
| **Wood** | 0.18 | 1.45 | 5.41 | 0.00 | 0.00 | 0.70 |
| **Paper** | 0.38 | 9.89 | 3.85 | 0.00 | 124.04 | 0.00 |
| **Printing** | 0.31 | 6.66 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Chemicals** | 1.80 | 21.92 | 8.35 | 2.21 | 11.98 | 84.53 |
| **Plastic** | 0.49 | 8.85 | 14.86 | 0.00 | 0.00 | 0.00 |
| **Machinery** | 3.25 | 49.23 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Automotive** | 2.28 | 29.70 | 7.15 | 0.00 | 0.00 | 0.03 |
| **Other** | 1.68 | 36.37 | 0.72 | 0.00 | 0.00 | 0.00 |
| **Sum** | **18.51** | **192.00** | **50.58** | **10.56** | **152.74** | **174.44** |

PH = process heat

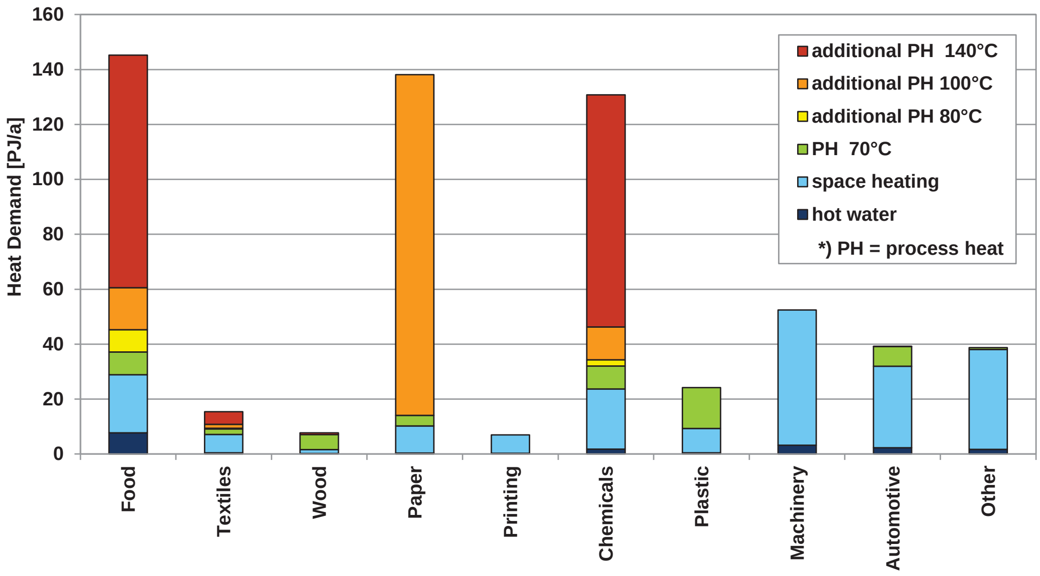


Figure 7-10: Technical potential for industrial heat pumps in Germany /Blesl et al. 2012/

## 7.4 German heat pump market

In Germany heat pumps are already widely used in the residential sector. Especially new buildings are often equipped with heat pumps. In 2010 612,500 heater units for residential heating were sold in Germany (Figure 7-11). Although gas fired boilers are still the most common heater type, heat pumps are increasing their market share. This lead to 51,000 sold heat pumps in 2010 and 57,000 in 2011. Half of them used ambient air as heat source.

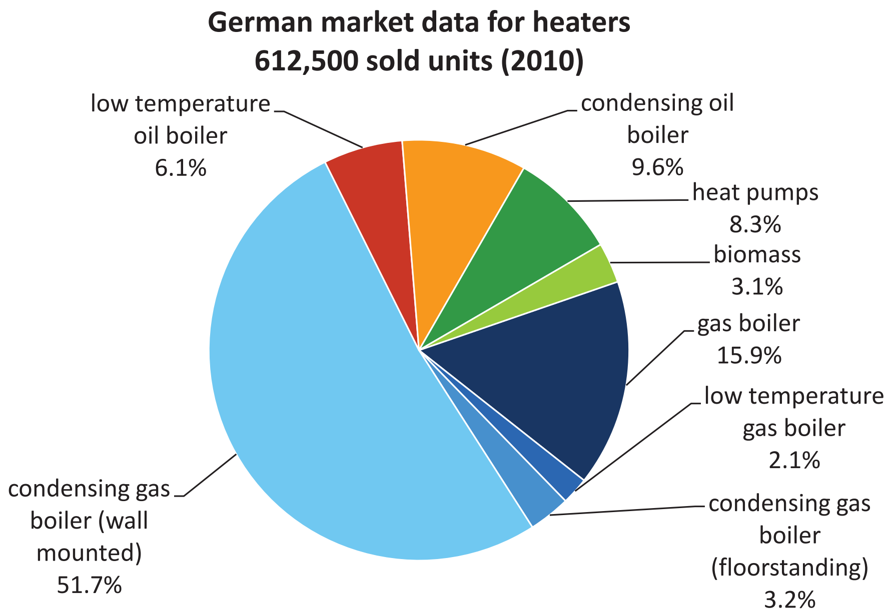


Figure 7-11: German market data for sold heater units in 2010 /BDH 2011/

Industrial heat pumps recently became available on the German market. These heat pumps not only have more power, they can also reach higher temperature levels than the models designed for the residential sector. Three different heat pump concepts using different refrigerants are available.

- Ammonia: Electrical compression heat pumps using ammonia can reach temperatures up to 90 °C.
- R245fa: Compression heat pumps using R245fa or mixtures of this refrigerant with similar properties can reach temperatures up to 100 °C.

  Current research projects aim to reach higher temperatures up to 130 °C.
- $CO_2$: CO2 heat pumps are especially efficient, if they are used to heat up water from a low to a high temperature level. They can reach temperatures up to 90 °C. Temperatures up to 130 °C could be available in the near future.

To distinguish the situation of heat pump planners and installers a survey has been conducted among 149 German companies. These companies were elected for the survey, if they mentioned industrial customers as well as heat pumps on their web sites. The survey was conducted in two steps. In the first step all of the 149 companies were called. Those who did not want to answer the questions on the telephone and those who could not be reached got an e-mail with information about the project and a link to a web based questionnaire. Out of 149 companies 25 filled out the questionnaire, which leads to a response rate of nearly 17 %. Figure 7-12 shows the response to the survey structured by telephone calls and e-mails.

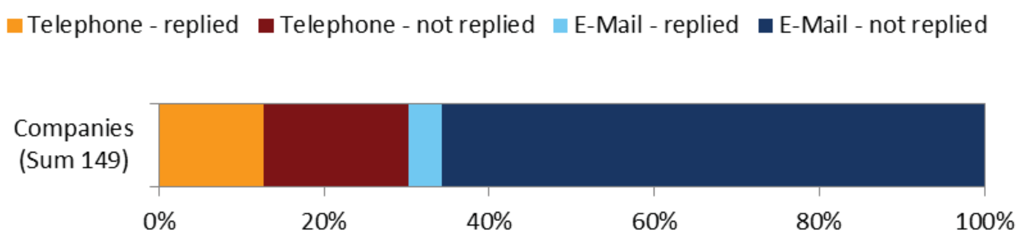


Figure 7-12: Respondents to the survey

Almost all of the respondents (96%) are experienced in planning of electrical heat pumps and 28% have experience with gas-engine heat pumps. No respondent had planned or installed a sorption heat pump.
As private households are the main application area for heat pumps most of the respondents had experience with heat pump systems for space heating (96%) and hot water production (84%). 16% had planned or installed a heat pump for process heat production. But in half of the cases the companies categorized hot water production in industrial companies as process heat.

In line with these results heat pumps are mainly applied for low temperature purposes. While 88% of the respondents had gathered experience with temperature levels of up to 55 °C, only 60 % had ever used heat pumps that could deliver up to 75°C. Only one respondent had planned ammonia heat pumps that could deliver up to 90°C.

Even though there is a large number of companies that only offer heat pump systems with small sizes of below 50 kW, 20 % of the respondents offer very large systems with more than 800 kW. Figure 7-13 shows the sizes offered by the responding companies.

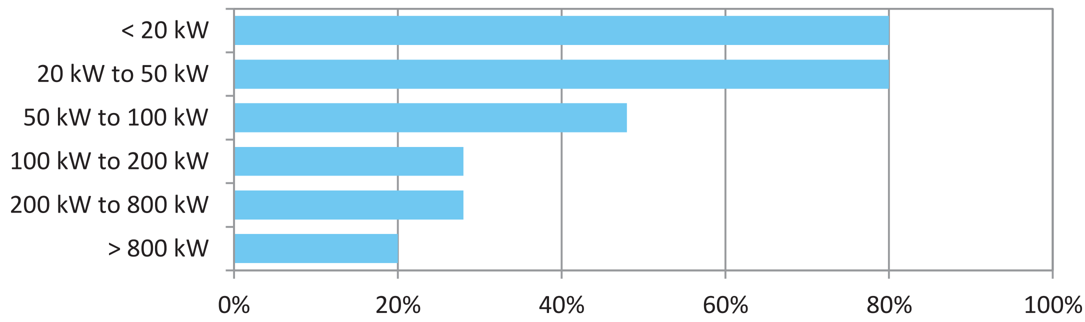


Figure 7-13: Heat pump sizes offered by the responding companies

## 7.5 Research and Literature

The oil price shock in the 1970s put energy research into political focus. The sudden rise of energy prices lead to a boom of energy related research. Energy research groups were founded and a large number of projects were started. Among other energy saving technologies the heat pump experienced a considerable increase of interest. Figure 7-14 shows the number of heat pump research projects that were funded by different German ministries. It also shows the amount of money invested into heat pump research from 1974 to 2011. Starting with a large number of projects in the 1970s the interest into heat pump technology peaked in the early 1980s. In 1981 funding of heat pump research reached an all-time high of 6.76 million €. With declining energy prices in the 1980s and 1990s heat pumps got out of focus. Since 2008 a growing number of heat pump research projects can be observed. Also the amount of money invested into heat pump research rose to 5.12 million € in 2011 and will continue to rise in 2012.

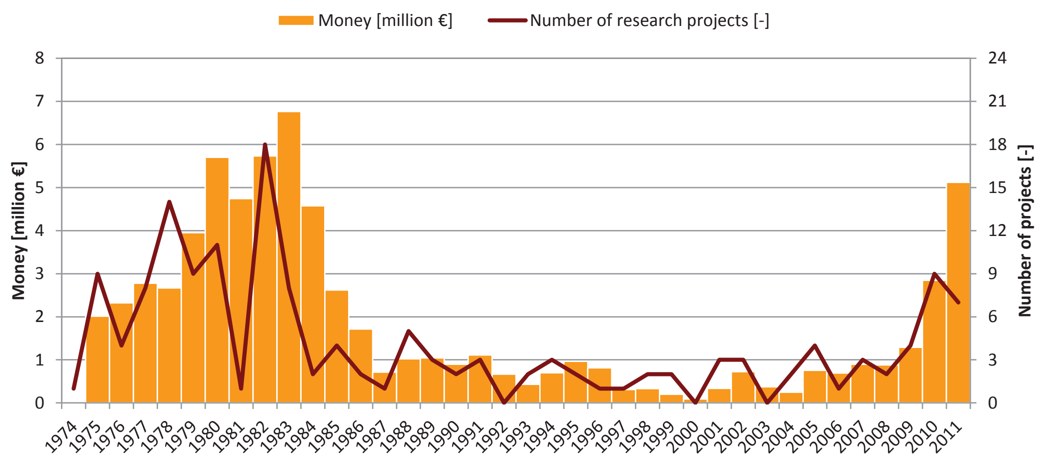


Figure 7-14: Heat pump related research projects in Germany /BMBF 2012/

To document the direct and indirect output of these research projects the amount of available literature about industrial heat pumps in German and English was analyzed. The analysis was performed by a search in the scientific search engine google scholar which can search a multitude of scientific databases. The search was performed for the terms “industrial + heat pump”, “high temperature + heat pump” and “heat pump + process heat” as well as for the German translations “Industrie + Wärmepumpe”, “Hochtemperatur + Wärmepumpe” and “Wärmepumpe + Prozesswärme”. The results of this analysis are shown in Figure 7-15 and Figure 7-16. All search terms show a rising number of publications especially since the late 1990s. In 2010 121 new publications could be found that fitted the term “Industrie Wärmepumpe”. For the English term 2350 new publications could be noted in 2010 and 2780 in 2011.

Of course the amount of available articles is overlaid with the development of the internet, but this effect should have been shrinking in the last 5 years, while a growing increase in the number of new publications can still be noted. Therefore it can be concluded that with the number of research projects also the available scientific information about heat pumps has been growing rapidly in recent years.

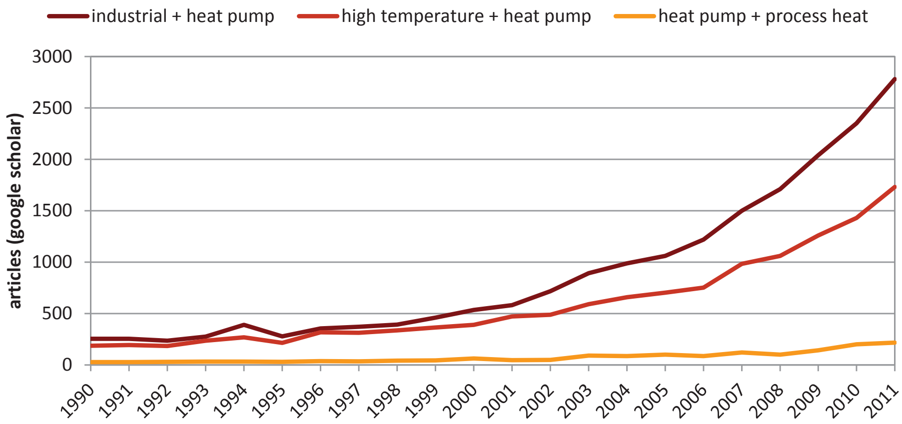


Figure 7-15: Scientific search results for industrial heat pumps (English)

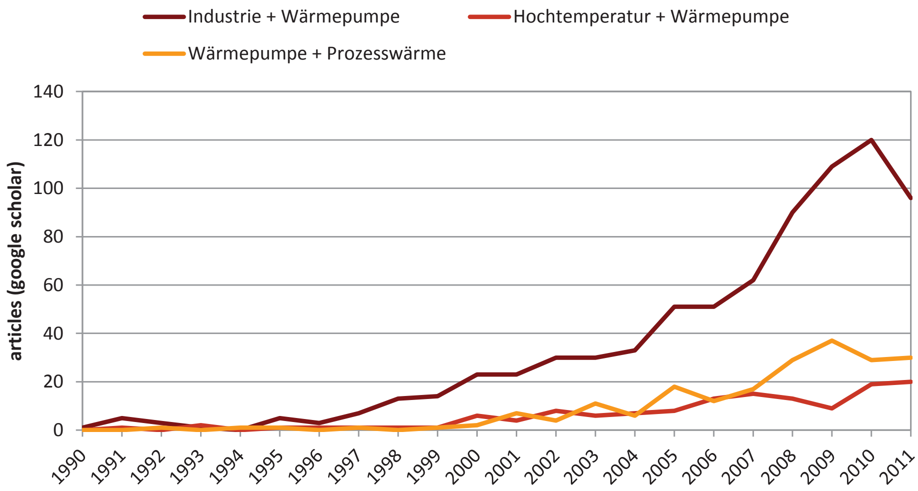


Figure 7-16: Scientific search results for industrial heat pumps (German)

## 7.6 Barriers for the application of heat pumps in the industry

Although heat pumps for the industrial use became available on the German market in recent years, just very few carried out applications can be found. To distinguish the reasons for this situation, application barriers were also a part of the survey mentioned in paragraph 7.4. Its results are in line with another survey from 2008 /Lambauer et al. 2008/. Four major barriers could be identified.

- Lack of knowledge:
  The integration of heat pumps into industrial processes requires knowledge of the capabilities of industrial heat pumps, as well as knowledge about the process itself. Only few installers have this combined knowledge, which enables them to integrate a heat pump in the most suitable way.
- Long payback periods:
  Compared to oil and gas burners, heat pumps have relatively high investment costs. At the same time companies expect very low payback periods of less than 2 or 3 years. Some companies were willing to accept payback periods up to 5 years, when it comes to investments into their energy infrastructure. To meet these expectations heat pumps need to have long running periods and good COPs to become economical feasible.
- Customer concerns:
  Installers named customer concerns as one of the most important barriers. They mostly prefer well proven gas or oil burner, as the heat production is a very sensible part of the factory infrastructure. As long as documented successful applications of industrial heat pumps are very rare, it will be difficult to persuade these customers to choose a heat pump.
- Low awareness of heat consumption in companies:
  In most companies knowledge about heating and cooling demands of their processes is quite rare. This requires expensive and time consuming measurements to find an integration opportunity for an industrial heat pump

Another reason for the poor diffusion of heat pumps into the industrial heating market can be found in the fact, that achievable temperatures were limited to 80 °C. As seen in Figure 7-10 just a little share of the industrial heat demand is needed at such low temperature levels.

## 7.7 Literature

**AGEB, 2011** Arbeitsgemeinschaft Energiebilanzen e.V.: Erstellung von Anwendungsbilanzen für die Jahre 2009 und 2010 für das verarbeitende Gewerbe: Projektnummer: 23/11. Berlin, 2011

**Blesl et al., 2012** Blesl, Markus; Wolf, Stefan; Lambauer, Jochen; Broydo, Michael; Fahl, Ulrich: Perspektiven von Wärmepumpen sowie der Nah- und Fernwärme zur Wärme- (und Kälte-)bereitstellung in Deutschland. Institut für Energiewirtschaft und rationelle Energieanwendung (IER). Stuttgart, 2012

**BDH, 2011** Marktentwicklung Wärmeerzeuger 2000-2011. 2011

**BMBF, 2012** Bundesministerium für Bildung und Forschung (BMBF): www.foerderkatalog.de. URL: www.foerderkatalog.de – Überprüfungsdatum: 21.09.2012

**BMWi, 2012** Bundesministerium für Wirtschaft und Technologie (BMWi): Energiedaten. URL: http://www.bmwi.de/BMWi/Redaktion/PDF/E/energiestatistiken-grafiken,property=pdf,bereich=bmwi,sprache=de,rwb=true.pdf – Überprüfungsdatum: 16.04.2012

**IfM, 2011** Institut für Mittelstandsforschung (IfM): Schlüsselzahlen des Mittelstands in Deutschland gemäß der KMU-Definition der EU-Kommission. Bonn, 2011

**Lambauer et al., 2008** Lambauer, Jochen; Fahl, Ulrich; Ohl, Michael; Blesl, Markus; Voß, Alfred: Industrielle Großwärmepumpen - Potenziale, Hemmnisse und Best-Practice Beispiele. Stuttgart, 2008

**Statistisches Bundesamt, 2012** Statistisches Bundesamt: Volkswirtschaftliche Gesamtrechnung: Inlandsproduktberechung. URL: https://www.destatis.de/DE/ZahlenFakten/GesamtwirtschaftUmwelt/VGR/Inlandsprodukt/Tabellen/Gesamtwirtschaft.html?nn=50700. – Aktualisierungsdatum: 24.05.2012

**UBA, 2012** Entwicklung der spezifischen Kohlendioxid-Emissionen des deutschen Strommix 1990-2010 und erste Schätzungen 2011. Bundesrepublik Deutschland. 2012

# 8 Japan

## 8.1 Energy use in Japan

### 8.1.1 Outline of Energy Situation in Japan

The primary energy consumption in Japan is 4.4% of world energy consumption. Energy supplied is highly dependent on fossil fuels such as oil, natural gas and coal. The share of fossil fuels is 84.0% of the total energy supply in 2009FY. Oil accounts for 45.8% of the primary energy supplied to Japan. Although this percentage has been declining from 77% in the peak year of 1973, the share is still the largest among all energy sources. About 96% of the energy resources supplied in Japan are imported from oversees.

Table 8-1: Primary energy supply by energy source (Japan 2009 FY)

| Energy source | Primary energy [PJ] | [%] |
|---|---|---|
| Oil | 9,866 | 45.8 |
| Coal | 4,452 | 20.7 |
| Natural gas | 3,778 | 17.5 |
| Nuclear | 2,465 | 11.4 |
| Hydroelectricity | 710 | 3.3 |
| Other | 280 | 1.3 |
| Total | 21,550 | 100 |

Other: Geothermal, Wind, Solar, Biomass, etc.

(Source: EDMC energy and economics statistics handbook, 2011)

The primary energy supplied is mainly used to produce oil products and electricity. Their shares of final energy consumption are 53.3 and 25.4 % in 2009 FY, respectively. Electricity is superior to an energy carrier. The electricity consumption has been increasing in use of heating as well as mechanical power, lighting, air conditioning and information & communication. The electrification rates are 19, 44 and 47% for industry, residential and commercial sectors, respectively.

Table 8-2: Final energy consumption by energy source (Japan 2009 FY)

| Energy source | Final energy[PJ] | [%] |
|---|---|---|
| Oil products | 7,355 | 53.3 |
| Natural gas and town gas | 1,351 | 9.8 |
| Coal | 591 | 4.3 |
| Coal products | 851 | 6.2 |
| Electricity | 3499 | 25.4 |
| Other | 143 | 1.0 |
| Total | 13,790 | 100 |

(Source: EDMC energy and economics statistics handbook, 2011)

Energy consumption in Japan can be divided into three sectors of industry, residential & commercial and transport sectors. The relative proportions of industry: commercial &

residential: transport are changed to 1.8:1.2:1 in 2009 FY from 4:1:1 at the time of the oil crises in 1970s.

Table 8-3 indicates final energy consumption by sector in 2009 FY. Although the energy demand of an industrial sector has been decreasing since 1980s, its demand is still dominant by 45.6 % of the total demand. The shares of commercial & residential and transportation sectors are 28.0 and 25.0 %, respectively.

Table 8-3: Final energy consumption by sector (Japan 2009 FY)

| Sector | Final energy [PJ] | [%] |
|---|---|---|
| Industry | 6,293 | 45.6 |
| Transportation | 3,451 | 25.0 |
| Residential | 2,161 | 15.7 |
| Commercial | 1,695 | 12.3 |
| Non- energy | 189 | 1.4 |
| Total | 13,790 | 100 |

(Source: EDMC energy and economics statistics handbook, 2011)

### 8.1.2 Energy use in the manufacturing industry

Manufacturing industry accounts for 94.3% of the industry sector. Energy consumption of manufacturing industry increased only slightly, despite the fact that its economic scale more than doubled after the first oil embargo in 1973. This is caused mainly by the improvement of energy efficiency and the structural change from the primary & secondary industry to the tertiary industry in the sector. Although four sectors of the manufacturing industry, namely iron/steel, chemical, ceramic/stone/clay and pulp/paper/processed paper continue to account for about 70% of the energy consumption of the manufacturing industry as a whole, their share is slightly declining due partly to energy saving in the industry.

Table 8-4: Energy use in the industry (Japan 2009FY)

| Industry | Consumption[PJ] | [%] |
|---|---|---|
| [Manufacturing] | 5,933 | 94.3 |
| Iron & steel | 1,508 | (24.0) |
| Chemical | 2,077 | (33.0) |
| Ceramic, stone & clay | 373 | (5.9) |
| Food, beverages & tobacco | 234 | (3.7) |
| pulp, paper & processed paper | 306 | (4.9) |
| Fabricated textiles | 74 | (1.2) |
| Non-ferrous metal | 131 | (2.1) |
| Metal goods & general machine | 414 | (6.6) |
| Other | 816 | (13.0) |
| [Non-manufacturing] | 360 | 5.7 |
| Total | 6,293 | 100 |

(Source: EDMC energy and economics statistics handbook, 2011)

Energy of the manufacturing industry is consumed for different types of use. Figure 8-1 indicates different types of use such as boiler, direct heating, cogeneration and others in the manufacturing industry. Direct heating is the largest amount of demand accounting for 56 % of the total demand. Including the amount of boiler use, both demands reach 90 % as a whole.

Iron & steel is a predominant sector to consume the direct heating energy, over 60% of the total direct heating demand. Chemical, petro-refinery and pulp/paper/processed paper sectors follow it.

As for fuel demand of the boiler, pulp/paper/processed paper and chemical sectors consume over 50% of the demand. Subsequently it is in order of steel product, oil/coal product and foodstuffs manufacturing industries.

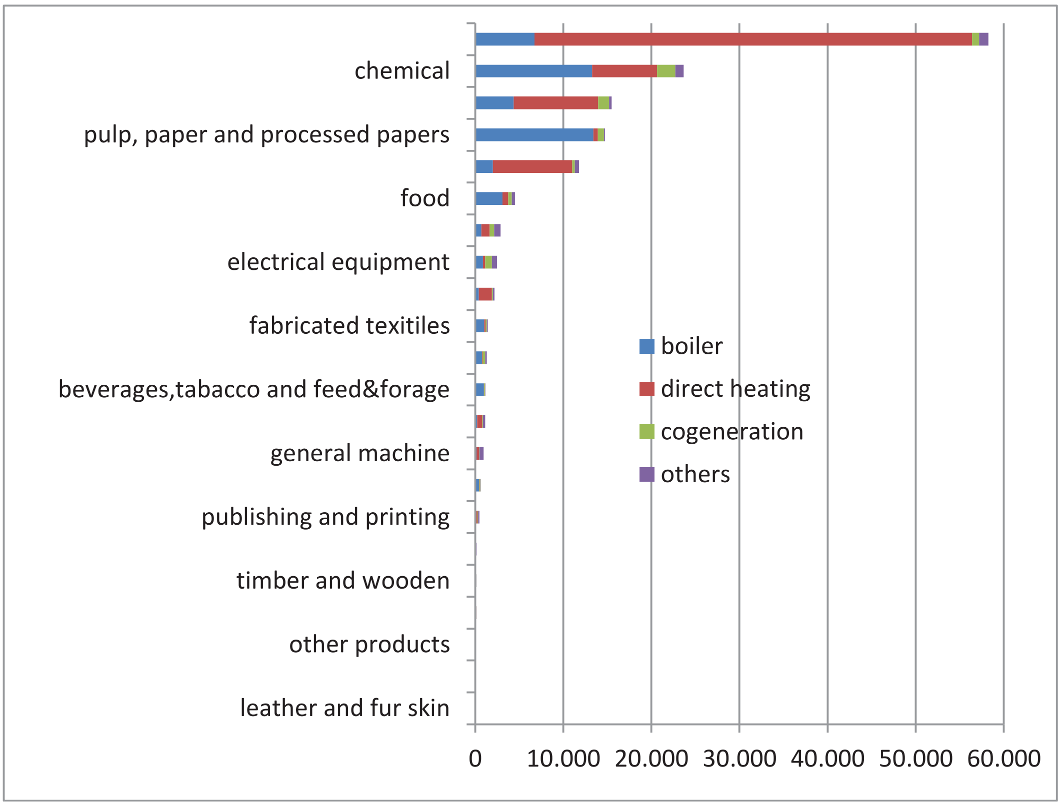


Figure 8-1: Type of energy use by sector in manufacturing industry
(million liter in oil equivalent; 2001 FY)

(Source: The structural survey of energy consumption in commerce and manufacturing, Research and Statistics Department, Ministry of Economy, Trade and Industry, 2001)

Heat produced by industrial boiler is used in various temperature ranges. Figure 8-2 shows heat demand of industrial boiler in different temperature in the manufacturing industry. Heat demands account for over 80 % in process heating over 250 °C and 17 % in the range of 150 to 200 °C, respectively. They are consumed mainly in chemical, pulp/paper/processed paper, steel and petro-refinery sectors.

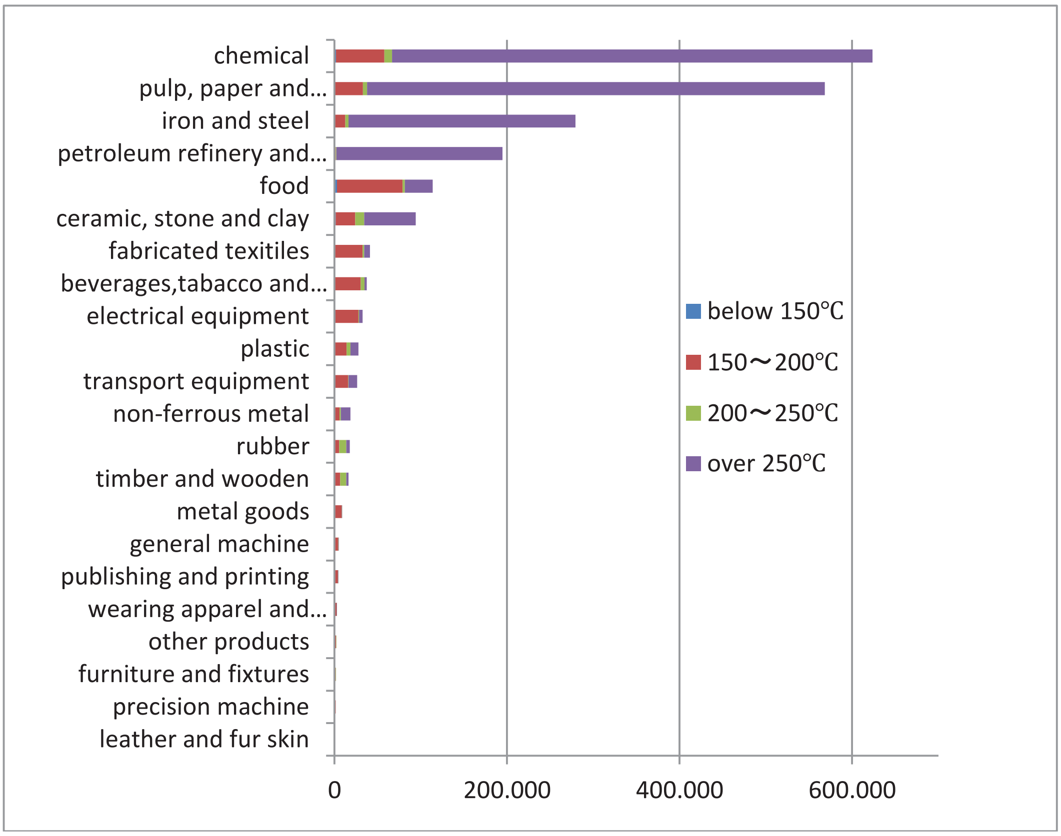


Figure 8-2: Boiler demand in different range of temperature by sector for the manufacturing industry (TJ; 2001 FY)

(Source: The structural survey of energy consumption in commerce and manufacturing, Research and Statistics Department, Ministry of Economy, Trade and Industry, 2001)

Figure 8-3 shows type of use for electricity consumption by industrial sector.

Iron & steel is a predominant sector to consume the direct heating energy, over 60% of the total direct heating demand. Chemical, petro-refinery and pulp/paper/processed paper sectors follow it.

Iron/steel, chemical, electrical equipment and pulp/paper/processed paper consume over 50% of the demand. Subsequently it is in order of steel product, oil/coal product and foodstuffs manufacturing industries.

84% of the total electricity is consumed in the power demand. Heating demand of electricity is rather small, 11% of the total electricity demand in industry. The share of electricity heating is expected to increase from the current tendency of electrification promoted by technological progress of injecting heat and industrial heat pump as well as environmental issues of preventing global warming.

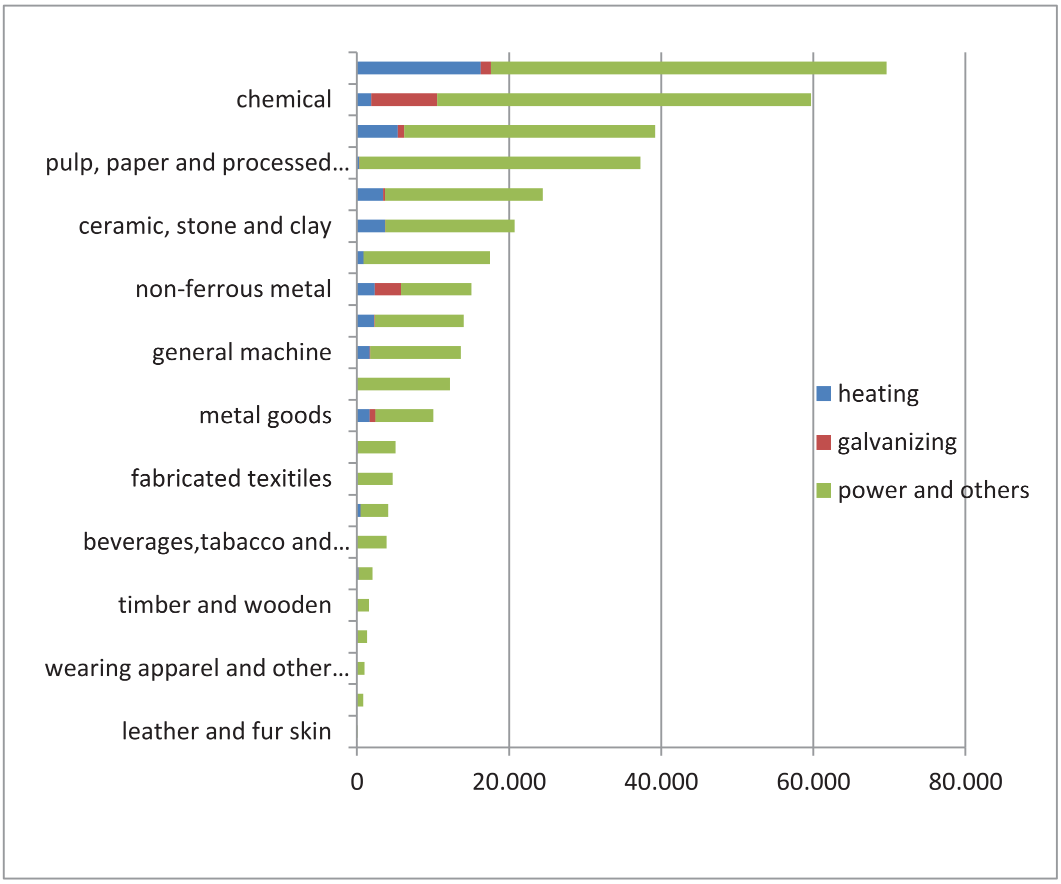


Figure 8-3: Type of electricity use by sector in the manufacturing industry (GWh; 2001 FY)

(Source: The structural survey of energy consumption in commerce and manufacturing, Research and Statistics Department, Ministry of Economy, Trade and Industry, 2001)

## 8.2 Japan Market overview

Heat pumps are adopted in greenhouse horticulture, hydroponic culture, plant factories and so on in Japanese prime industry. We can see improvements in quality of agricultural production, yield ratio and year-round cultivation thanks to the introduction of heat pumps. They are also used for drying process of agricultural, fishery and lumber products by cooling, dehumidification and heating function.

Cool and warm heat is used for aquaculture while a cooling seawater system is used for preservation of freshness and shipment of live fish in fishery sector. Refrigerating systems have been used for refrigerated warehouses located both at harvesting and consuming places for a long time.

Heat pumps are widely used from heating and cooling to washing in food processing plants. It is noteworthy that they have a heat-up and cool-down process repeatedly and this is the very process that heat pumps are able to show their strength and provide heat in the most effective way. We have been developing equipment that are able to produce water in suitable condition for food processing between 5 to 10 °C and around

90 °C at the same time. In addition, equipment with ability of producing around 100 °C water and steam are under development.

When it comes to air conditioners, especially air conditioners in factories, centrifugal type and high efficient heat pump chillers have been occupied much larger market share than conventional absorption chillers which use steam as heat sources. This is because technology innovation in recent years has made it possible to raise their COP. Improvements can be seen in humidifying of clean rooms and pure water heating in water production.

In machinery plants, some conventional steam-sourced systems are replaced by heat pump systems for heating in degreasing and chemical treatments. Heat pump systems with ability to heat cleaning solution and cutting liquid simultaneously have been put in practice.

Heat pumps have developed to comply with high temperatures of 120 °Celsius for coating and drying process. VRC is increasing at beer factories for molt boiling and alcohol distilling processes.

## 8.3 Barriers for applications

1. <u>Higher efficiency</u>
   Equipment with complying between 60 and 90 °C are thought to have the largest demand for industrial use and heat pump equipment are already in operation. However, heat pumps are less competitive in terms of an initial cost compared with boiler type systems. Therefore, we need to develop higher efficient equipment so that heat pumps can be competitive in terms of lifetime cost.

2. <u>Extending adaptability for various heat sources and demands in plant</u>
   We need to extend a temperature range of heat sources which are able to apply to daily dispatching of variable energy demand. For example, we would be able to extract refrigerated waste heat from cooling tower, high temperature heat from waste gas and heat from waste and pouring water. We need to develop an integrated technology that can extract heat from those potential heat sources by combined with heat pump systems so that we can control/adjust both the temperatures of heat source and output heat.

3. <u>Higher temperature</u>
   To meet requirements for higher temperatures over 100 °C, we hope to develop new technologies that produce super heated steam, pressurized water, hot air as well as new refrigerants with high condensing temperature, a new heat pump cycle and an oil-less compressor.

4. <u>Air source heat pumps applying to old latitudes</u>
   Although air source heat pumps are expected to be one of solutions that are available regardless of location and time, we still have room for improvements such as an application to cold latitudes and a temperature drop when defrosting.
5. <u>Competitiveness in costs</u>

High temperature heat pumps are more expensive than conventional air conditioning heat pumps. It is needed to reduce an initial cost by standardization, mass-production or use of simple components in accordance with temperature zones.

6. Variety of production menus
   Cool and warm heat are constantly required in relatively small scale of food processing plants. Heat sources should be spread out in those plants. We need to have production menus with small capacities for them. While many industrial sectors request the development of a high temperature heat pump which covers a wide range of temperature zones of large compressors and heat exchangers.

# 9 Korea

## 9.1 Energy consumption in Korea

### 9.1.1 Outline of Energy Use in Korea

The primary energy consumption of Korea is 2.3 % of world energy consumption in 2011. The total amount of the primary energy supply in Korea on 2012 is 11,669 PJ (278.7 million TOE). The total amount of energy is about 96 % of domestic energy demand is fulfilled with imported resources. Four major sources of coal, petroleum, LNG and nuclear energy occupy 96.6% of the primary energy supply in Figure 9-1.

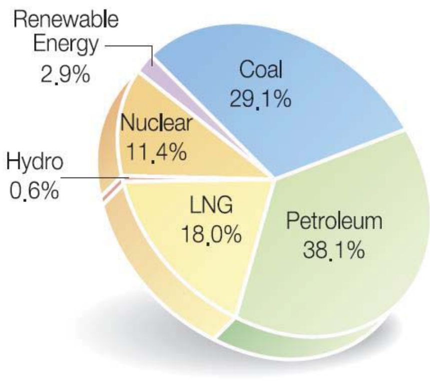


Figure 9-1: Primary energy supply by source (Korea 2012 FY)

Figure 9-2 shows the final energy consumption of Korea in 2012. Considering the fossil fuels are imported in the form of raw resources, the final energy consumption is less 25% than the primary energy, where the amount is estimated to be 8,712 PJ (208.1 million TOE). More than 60 % of coal and all the nuclear resource are converted into electric energy as a final form.

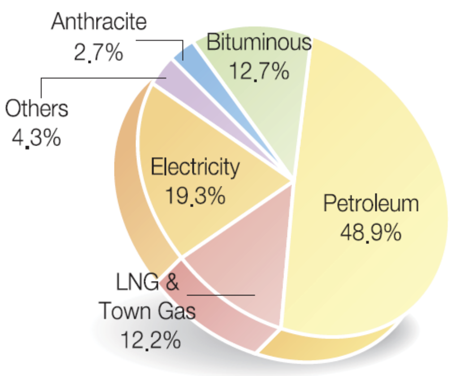


Figure 9-2: Final energy consumption (Korea 2012 FY)

Figure 9-3 shows the final energy consumption by four major sectors in Korea 2012 FY. Figure 9-4 presents annual change of energy consumption by sector. The growth of industrial sector is a major part of which portion increased from 53.7 % (1992, 2,128 PJ), 55.6 % (2002, 3,735 PJ), to 61.7 % (2012, 5,373 PJ).

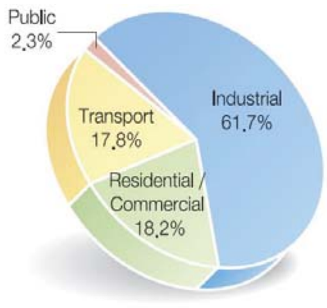


Figure 9-3: Final energy consumption by sector

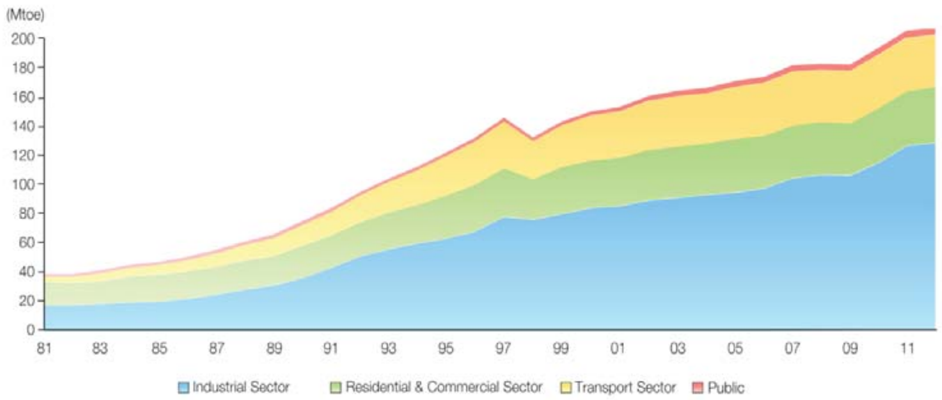


Figure 9-4: Annual history of final energy consumption by sector

(Source: 2013 Energy Info. Korea, Korea Energy Economics Institute)

Table 9-1 presents the distribution of the total energy use for the different sectors. The energy use of energy companies relates to the conversion losses that occur during for example the production of electricity from natural gas or coal. The refining sector is included in the manufacturing industry.

Table 9-1: Energy consumption by sector in 2012

| Sector | PJ |
|---|---|
| Industry | 5373 |
| Residential & Commercial | 1586 |
| Transport | 1555 |
| Public & others | 200 |
| Total | 8714 |

### 9.1.2 Energy use in the manufacturing industry

The Korean industry consists of four sectors; agricultural and fishery, mining, manufacturing, and construction. And 5,373 PJ of energy were consumed in 2012. Renewable energy of 243 PJ is included in the total industrial energy consumption, but is unclassified into subsectors. Excluding non-manufacturing sector, the amount is reduced as 87 %, 4,688 PJ. The balance of the different energy carriers in the manufacturing industry is shown in Table 9-2.

Table 9-2: Energy carriers of industrial sector in 2012

| | Coal | Oil | LNG | Electric | Total(PJ) |
|---|---|---|---|---|---|
| Manufacturing | 1,104 | 2,308 | 427 | 848 | 4,688 |
| Food. Tobacco | 1 | 7 | 29 | 35 | 73 |
| Textile & Apparel | 4 | 5 | 24 | 46 | 79 |
| Wood & Wood Prod. | 0 | 1 | 2 | 6 | 9 |
| Pulp & Publications | 0 | 4 | 18 | 36 | 58 |
| Petro. Chemical | 6 | 2,155 | 105 | 182 | 2,447 |
| Non-Metallic | 119 | 26 | 24 | 39 | 209 |
| Iron & Steel | 923 | 6 | 72 | 164 | 1,165 |
| Non-Ferrous | 0 | 2 | 10 | 0 | 13 |
| Fabricated Metal | 0 | 25 | 69 | 330 | 424 |
| Other Manufact. | 51 | 44 | 74 | 9 | 178 |
| Other Energy | 0 | 32 | 0 | 0 | 32 |
| Non-manufacturing | 199 | 193 | 0 | 49 | 243 |
| Total | 1,104 | 2,501 | 427 | 897 | 5,373 |

(Source: Yearbook of Energy Statistics (2013), Korea Energy Economics Institute)

The energy utilization by application in the manufacturing industry is shown inTable 9-3. The heat energy in the table includes both 69% of direct heating and 31% of indirect heating. Conversion loss was estimated about 514 PJ by subtracting total energy consumption out of the total energy supply.

Table 9-3: Energy consumption in manufacturing industry by functions in 2010

| Function | PJ | [%] |
|---|---|---|
| Heat | 1,312 | 29.1 |
| Power | 398 | 8.8 |
| Feedstock | 2,574 | 57.2 |
| Miscellaneous | 216 | 4.8 |
| Total | 4,501 | 100 |

Manufacturing industry in Korea is devided into 15 sectors. The type of energy utilization in each sector is as feedstock, by facilities, for transportation, and others. Table 9-4 is energy consumption by subsectors of manufacturing industry in 2010.

Table 9-4: Energy consumption by subsectors of manufacturing industry (Units in 100 ton in oil equivalent; 2010 FY)

| Industrial sectors | Feed-stock | Facilities | | | | Trans-port | Miscell. | Total |
|---|---|---|---|---|---|---|---|---|
| | | IDH | DH | Power | Electro-chemical | | | |
| Food products | 2 | 5,804 | 3,032 | 1,932 | 125 | 137 | 1,281 | 12,311 |
| Beverage | | 1,236 | 488 | 400 | 15 | 8.2 | 213 | 2,359 |
| Tobacco | | 169 | 26 | 69 | 2.2 | | 8.8 | 276 |
| Textile | | 2,966 | 3,624 | 2,237 | 68 | 94 | 1,024 | 10,014 |
| Wearing apparel & fur articles | | 68 | 38 | 14 | 5.1 | 18 | 108 | 251 |
| Leather, luggage & footwear | 0.4 | 100 | 57 | 49 | 6.1 | 13 | 33 | 258 |
| Wood and cork | 0.1 | 1,774 | 465 | 269 | 84 | 45 | 147 | 2,783 |
| Pulp & paper products | 2.2 | 7,400 | 7,811 | 4,394 | 67 | 59 | 1,043 | 20,776 |
| Printing and recorded media | | 32 | 213 | 91 | 1.6 | 10 | 119 | 467 |
| Coke and refined petroleum | 254,541 | 18,320 | 45,103 | 16,222 | 1.8 | 6.8 | 292 | 334,486 |
| - Coke and Briquettes | 0.6 | 2.3 | 6.8 | 12 | | 1.1 | 5.6 | 29 |
| - Refined petroleum product | 254,540 | 18,318 | 45,096 | 16,210 | 1.8 | 5.6 | 286 | 334,457 |
| Chemical products | 186,485 | 39,095 | 40,181 | 22,589 | 3,175 | 119 | 18,601 | 310,244 |
| - Basic Chemicals | 148,346 | 23,396 | 24,745 | 14,925 | 2,773 | 28 | 13,058 | 227,270 |
| - Fertilizer | 0.7 | 110 | 174 | 219 | 32 | 12 | 79 | 626 |
| - Rubber and Plastic | 38,116 | 12,796 | 12,451 | 5,210 | 133 | 21 | 4,735 | 73,461 |
| - Other chemical products | 23 | 1,089 | 1,430 | 1,126 | 53 | 23 | 583 | 4,327 |
| - Man-made fibers | | 1,704 | 1,309 | 1,109 | 186 | 35 | 146 | 4,487 |
| Medical products | | 430 | 278 | 386 | 17 | 4.2 | 144 | 1,259 |
| - Medicinal chemicals | | 56 | 78 | 57 | 6.2 | 0.7 | 19 | 216 |
| - Medicaments | | 366 | 176 | 312 | 10 | 2.4 | 114 | 981 |
| - Pharmaceutical goods | | 7.9 | 24 | 17 | 0.6 | 1.1 | 11 | 62 |
| Rubber and Plastic | 3.2 | 3,158 | 2,656 | 2,631 | 287 | 167 | 1,383 | 10,284 |
| Non-metallic products | 514 | 3,239 | 41,667 | 5,284 | 603 | 437 | 2,230 | 53,974 |
| - Glass | | 2,027 | 4,834 | 965 | 479 | 15 | 215 | 8,535 |
| - Ceramic ware | 1.3 | 124 | 2,241 | 288 | 36 | 8.1 | 137 | 2,835 |
| - Cement | 507 | 921 | 33,800 | 3,589 | 53 | 351 | 1,627 | 40,848 |
| - Other non-metallic | 5.0 | 166 | 791 | 443 | 35 | 64 | 251 | 1,755 |
| Basic metallic products | 173,192 | 4,618 | 26,493 | 15,674 | 6,000 | 106 | 11,394 | 237,476 |
| - Iron and steel | 173,079 | 1,580 | 18,822 | 13,736 | 3,581 | 62 | 10,616 | 221,477 |
| - Non-ferrous metals | 87 | 2,947 | 6,601 | 1,128 | 1,818 | 22 | 436 | 13,038 |
| - Cast | 26 | 91 | 1,070 | 810 | 601 | 22 | 343 | 2,961 |
| Fabricated metal products | 10 | 641 | 4,632 | 3,336 | 818 | 367 | 1,902 | 11,706 |
| Electronic manufracturing | 0.1 | 4,462 | 12,324 | 9,606 | 1,923 | 68 | 2,962 | 31,346 |
| Precision industry | | 14 | 216 | 277 | 17 | 26 | 240 | 790 |
| Electric equipment | | 525 | 1,367 | 733 | 320 | 99 | 581 | 3,625 |
| Other machinery and equip-ment | 6.3 | 658 | 1,886 | 1,705 | 349 | 348 | 1,062 | 6,013 |
| Motor vehicles | 31 | 2,166 | 6,217 | 4,971 | 524 | 125 | 2,735 | 16,769 |
| Other transport equipment | 0.9 | 282 | 1,620 | 1,410 | 171 | 62 | 631 | 4,176 |
| Furniture | | 24 | 226 | 285 | 13 | 24 | 149 | 721 |
| Other manufacturing | | 162 | 461 | 357 | 71 | 14 | 417 | 1,481 |
| Total | 614,786 | 97,342 | 201,078 | 94,921 | 14,665 | 2,355 | 48,696 | 1,073,843 |

(Source: Energy consumption survey 2011, Korea Energy Economics Institute)

Since heat and power is mostly supplied by facilities, energy consumption by direct heat and indirect heat and power except by electrochemical facilities is shown in Figure 9-5.

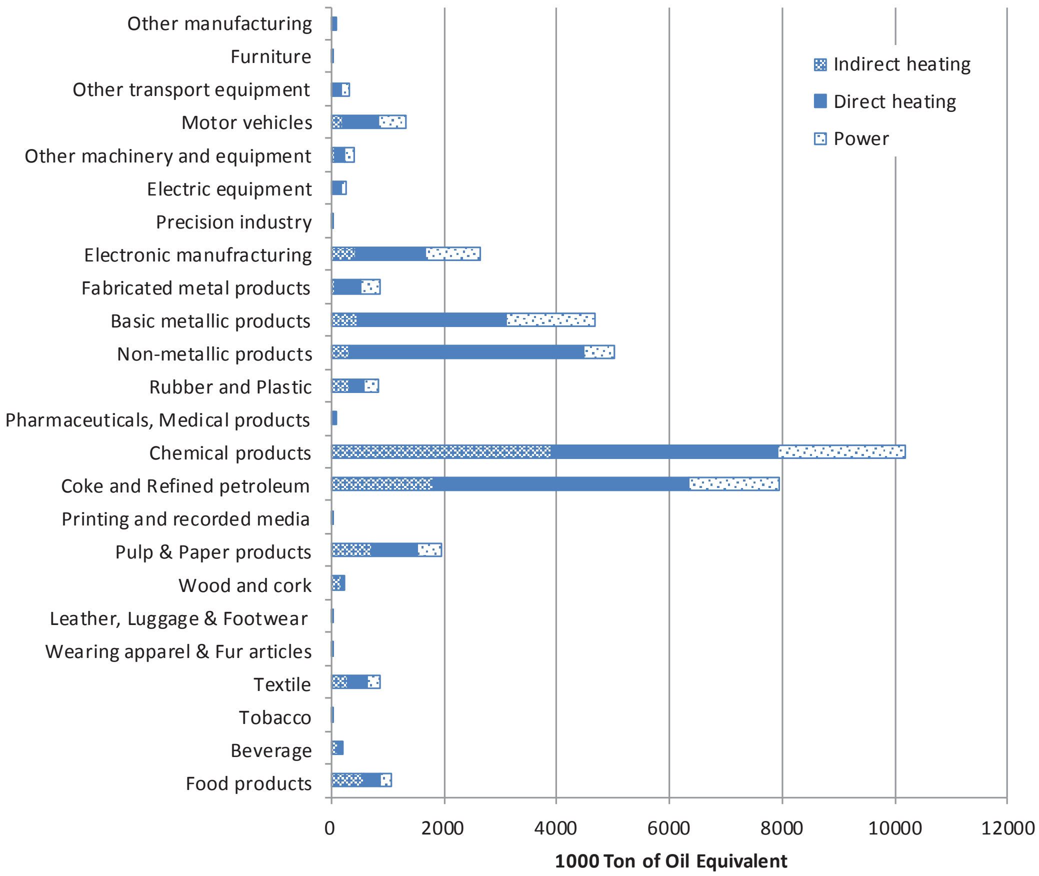


Figure 9-5: Annual history of final energy consumption by sector

## 9.2 Heat Pump Market of Korea

### 9.2.1 Market share of heat pumps

Due to its high energy-saving potential, the global heat pump market has grown rapidly in recent years. Korea strives on efforts to spread the utilization of heat pump systems, but still lags behind in market development. Table 9-5 shows the shipments of residential cooling-only air conditioners and heat pumps. As of 2010, compared to the 1.224 million cooling-only units, only 0.157 million heat pumps were sold for other applications, amounting to an 11 % market share. Various market features have contributed to the low share of heat pumps.

Table 9-5: Shipment of residential air-to-air heat pumps and cooling-only air conditioners (thousand units)

| Year | Cooling only | Heat pumps |
|---|---|---|
| 2005 | 1494 | 42 |
| 2006 | 1495 | 45 |
| 2007 | 1138 | 52 |
| 2008 | 1261 | 65 |
| 2009 | 1025 | 89 |
| 2010 | 1224 | 157 |

(Source: KEMCO 2011 Report)

### 9.2.2 Barriers for applications

From the former report on Korea market, two unique features of the Korean market are mentioned: high penetration of natural gas, and low energy prices. In 2010, the nation-wide penetration rate of natural gas in the residential sector was 72.2 %. The Seoul Special City, which is the capital and largest metropolis of Korea, had a 92.3 % penetration rate. Other major cities also have penetration rates approaching 90 %. These high numbers reflect the fact that almost every resident in the city uses natural gas, either for heating or cooling – with boilers, rather than heat pumps, taking by far the largest share.

Table 9-6 shows the retail energy prices of natural gas and electricity from IEA 2012 Key World Energy Statistics. Among the selected OECD countries, Korea has the lowest energy prices, even considering the GPD (PPP) per capita ( Table 9-6). The price of electricity for domestic consumers is, for example, only 43 % of that paid by UK domestic consumers. Low energy prices make customers more sensitive to the initial cost than to the running cost. Due to Korea's preference for floor heating, boilers are typically installed in houses for domestic hot water production. Since boilers are far cheaper than water-heating heat pumps, the payback time of a heat pump is longer than in other countries. In addition, heat pumps are usually regarded as appliances, in the same way as are air conditioners. This makes it more difficult for the concept of payback to be considered by customers.

Table 9-6: The retail prices of natural gas and electricity in OECD countries

| Retail prices ($) | Finland | Germany | Ireland | Korea | New Zealand | Poland | Spain | United Kingdom |
|---|---|---|---|---|---|---|---|---|
| Nat. gas for industry (MWh), GCV | 45.19 | 54.37 | 43.91 | 60.21 | 23.76 | 42.57 | 37.72 | 35.51 |
| Nat. gas for domestic consumers (MWh), GCV | 62.18 | 92.63 | 80.65 | 64.98 | 102.43 | 72.2 | 89.27 | 64.84 |
| Electricity for industry (MWh) | 113.64 | 157.23 | 152.39 | (61.94) | 73.72 | 121.77 | 148.77 | 127.39 |
| Electricity for domestic consumers (MWh) | 213.61 | 351.95 | 259.47 | 88.64 | 212.1 | 198.5 | 295.31 | 204.92 |

(Source: IEA 2012 Key World Energy Statistics)

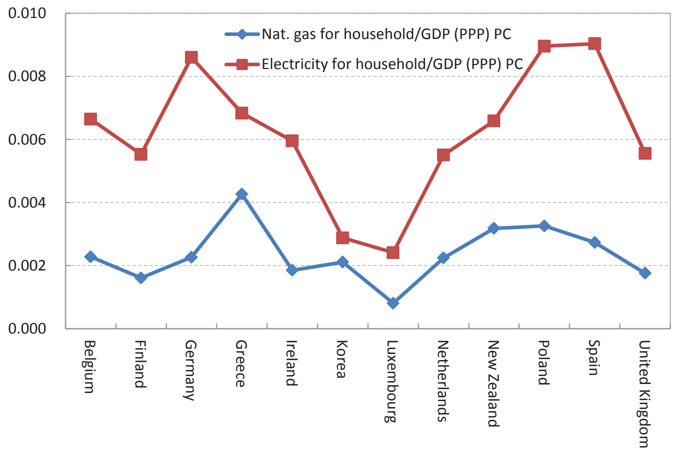


Figure 9-6: The retail prices of natural gas and electricity for domestic consumers divided by GDP (PPP) per capita

### 9.2.3 Potentials of heat pump applications

Despite the adverse market conditions for heat pumps, there is no doubt that they are energy-saving devices and one of the promising solutions for tackling energy problems. Although the situation is not favourable to heat pump market, some efforts to seek the possibilities to apply heat pumps to industrial applications relying on the low electricity price. Considering longer operating time of industrial heat pumps, the customers in industrial field find good economy of heat pump system.

Aside to these efforts, the Korean government supports measures to improve energy efficiency and the use of new renewable energy sources because it considers them as key players to achieve its goal of Green Growth with Low $CO_2$. On the government's road map to Green Energy, heat pumps were selected as one of the 15 green energy sectors to increase energy efficiency. KETEP (Korea Institute Energy Technology Evaluation and Planning) selected four heat pump systems in its Green Energy Strategy Road Map 2011, and has supported their technical development, which it hopes will create a new heat pump market in Korea.

## 9.3 Literature

[1] Korea Energy Economics Institute, "Energy Info. Korea", December 2013.

[2] Korea Energy Economics Institute, "Yearbook of Energy Statistics", Vol. 32, December 2013.

[3] Ministry of Knowledge Economy, "Energy Consumption Survey" – 11th Edition, 2011.

[4] M. Kim, G. Lee, B.-J. Shin, 2013, The heat pump market and its potential in Korea, IEA Heat Pump Centre Newsletter, Vol. 31, No. 4, pp. 10-12.

[5] Korea Energy Management Corporation, Annual Report 2011

[6] IEA, 2012 Key World Energy Statistics.

# 10 The Netherlands

Industrial processes in general need higher temperature levels. Recent developments of heat pumps focus on higher delivery temperatures of heat and a high temperature lift (difference between low (source) and high (delivery) temperature). Another trend is that industrial production processes require lower temperatures for heating. Application of heat pumps may therefore grow in the near future and contribute to further $CO_2$ emission reduction.

Bottle necks for this growth form the unfamiliarity with heat pumps of engineers and process designers, the complex level of integration of the installation in existing plants, the high investment costs, some experiences with unreliability in old projects, lack of references and lack of knowledge of the new higher temperature options. For successful introduction of high temperature heat pumps in industry bundling and distribution of knowledge is of importance. Process designers, engineers, consultants, contractors and end users need to be familiar with the heat pump technology, the possibilities, the advantages, good references and being aware of the do's and don'ts.

In a study by KWA commissioned by AgNL [Pennartz, 2011] the following subjects are described:

- an overview of the heat pumps options in various industrial sectors and energy consumption
- recent technological developments around industrial heat pumps after 2000
- a number of cases studies of industrial heat pumps after 2000.

## 10.1 Energy use in manufacturing industry

The energy balance of the Netherlands is shown in the Table 10-1 (left). The table depicts the net balance per energy carriers. Table 10-1 (right) presents the distribution of the energy use in the different sectors. The energy use of energy companies relates to the conversion losses that occur during, for example, the production of electricity from natural gas or coal. The refining sector is included in the manufacturing industry.

Table 10-1: Energy balance in the Netherlands (left)
distribution of energy use (right)

| **Energy Carrier** | **PJ** |
|---|---|
| Oil | 1221 |
| Natural Gas | 1435 |
| Coal | 328 |
| Electricity | 88 |
| Misc | 163 |
| **Total** | **3235** |

| **Sector** | **PJ** |
|---|---|
| Energy Companies | 431 |
| Industry | 1344 |
| Transport | 500 |
| Residential Buildings | 412 |
| Commercial Buildings | 546 |
| **Total** | **3233** |

The main industrial sector in the Netherlands is the chemical industry located in some concentrated areas around the Rotterdam harbor. The other main industrial sectors are food industry and the greenhouse sector. Manufacturing industry used 1344 PJ in 2006.

The energy carriers that are used by industry serve different functions (heat, power, feedstock). Table 10-2 presents the energy use by these functions for the different industrial sectors. Power relates to the energy use for driving machines or lighting. Feedstock is the so-called non-energetic energy use, where the energy carrier is used to make a product, like plastics and petrol. The conversion loss refers to the losses that occur in decentralized electricity production by industry (combined heat and power).

Table 10-2: Primary Energy use in Dutch industrial sectors

| | Heat (PJ) | Power (PJ) | Feedstock (PJ) | Conversion loss (PJ) | Total (PJ) |
|---|---|---|---|---|---|
| Food & drug industry | 62.8 | 24.8 | 0.2 | 3.7 | 91.5 |
| Textile industry | 3.3 | 1.4 | 0 | 0 | 4.7 |
| Paper & board industry | 24.7 | 13.3 | 0 | 3.7 | 41.7 |
| Chemical industry | 261 | 36 | 455 | 21 | 773 |
| Refining | 116 | 9.6 | 0 | 62.1 | 188 |
| Building materials | 26.8 | 5.2 | 0.1 | 0.1 | 32.2 |
| Basic metal industry | 38 | 12.6 | 73.3 | 13.6 | 138 |
| Metal products | 19.0 | 15.9 | 15.5 | 0 | 50.4 |
| Rubber & plastic products | 7.7 | 9.4 | 0 | 0 | 17.3 |
| Other | 0 | 0 | 7.6 | 0 | 7.6 |
| Total | 559 | 128 | 552 | 105 | 1344 |

Table 10-3: Temperature levels of heat demand

| Interval | Chemical + Refining (%) | Basic metal + metal products (%) | Other (%) |
|---|---|---|---|
| < 100°C | 5 | 15 | 29 |
| 100-250°C | 11 | 0 | 38 |
| 250-500°C | 27 | 5 | 13 |
| 500-750°C | 21 | 0 | 0 |
| 750-1000°C | 26 | 10 | 0 |
| > 1000°C | 10 | 70 | 20 |

## 10.2 Market overview

Potentially large energy savings are possible through the application of heat pumps in the industry. Developing and dissemination of knowledge is important for successful growth of the application of heat pumps. To stimulate the application of heat pumps it is useful to analyze heat pumps which have been placed in the past and analyze how they operate in practice. Over the past 20 years there were several feasibility studies and heat pump projects supported by the TIEB and SPIRIT programs of Novem (the predecessor of RVO) which were reported upon.

Table 10-4: Overview of older heat pump projects

| Factsheet | Company old/new name | location | process | Condition |
|---|---|---|---|---|
| | Oriental Foods | Landgraaf | Drying of Tahoe | Company closed |
| | Plukon | Asten Ommel | Slaughterhouse | Feasibility only |
| | Solphay/Dishman | Veenendaal | MDR on Aceton | End of production |
| | Purac Biochem | Gorinchem | MDR on lactose | End of production in NL |
| | Hartman/Jardin | Enschede | Garden furniture | Feasibility only |
| | ITB | | Plastics | Feasibility only |
| | Quality Pack | Kampen | Crate washing | Company closed |
| | Beukema/Eska Graphic Board | Hoogezand | Paper drying | Feasibility only |
| | Huwa Bricks factory | Spijk | Brick drying | Feasibility only |
| | Frico | Sint Nicolaasga | Cheese evaporative drying | Company closed |
| | Hoogovens/Tata steel | IJmuiden | Heat Transformer | Corrosion problems |
| | ARCO/Lyondell | Botlek | MDR on Distillation | no data available |
| NL-01 | Shell | Pernis | MDR on Distillation | running |
| NL-02 | Unichema/Croda | Gouda | MDR on Distillation | running |
| NL-03 | Hoechst | Vlissingen | MDR on Distillation | End of production in NL |
| NL-04 | Campina | Veghel | MDR on evaporation | running |
| NL-05 | De Graafstroom | Bleskensgraaf | MDR on evaporation | running |
| NL-11 | Dommelsch Brewery | Dommelen | MDR on wort | running |
| NL-13 | GPS | Nunspeet | Heating from condensor | running |
| NL-15 | AVEBE | Ter Apelkanaal | MVR on patatoe starch | running |
| NL-16 | Cerestar/Cargill | Sas van Gent | MVR on | replaced by new MVR |
| NL-17 | Fapona/Berendsen | Apeldoorn | Laundry drying | running |

A study has been undertaken to look into the operation of these "older" projects looking into the experiences of the companies, if there have been any changes of the design over time, whether operating & maintenance of the installation is difficult (high level of knowledge, complexity, etc.), if promised energy savings are achieved and whether there are remarks which can be defined as lessons learned.

All companies described participated in this evaluation study. Striking is that those projects described as case and feasibility studies supported by governmental subsidies (TIEB) were never realized, despite the fact that acceptable payback periods and significant energy savings were calculated in these studies. For the other projects much has changed in the past twenty years like plant closures, moving production, no demand for the product, changes in operations, etc. As a result six of the analyzed heat pumps have been removed nothing to do with any possible malfunction of the heat pumps.

Of the eleven remaining heat pumps, ten are still in use. These are eight Mechanical Vapour Recompressors (MVR), one Thermal Vapour Recompressor (TVR) and one heat pump, which uses the heat from the condenser of the refrigeration installation for process heat. Most of these are now described in new factsheets in Task 4. Only one company was not participating with new data.

Companies with a running heat pump have generally no idea why a heat pump was chosen, given the long period since the investment decision. Most of the heat pumps still run according to their original design having relatively high operating hours (5,000-8,000 hours/year) and mostly in full load. In several cases the maintenance is outsourced for reasons of complexity, high operating hours and capacity problems in the technical department. Operating the installation is generally regarded as a relatively simple. The installations have few problems and/or malfunctions. Companies have no insight on whether the system achieves its efficiency, or whether the intended energy savings have been obtained. They have no reference, given the initial situation.

- When a steam-powered evaporation process is switched to an MVR, which is electrically powered, it must be taken into account that the ratio between heat and electricity demand shifts towards electricity. This is unfavorable for the use of gas turbines, when a company has these in use.
- A point of interest for heat pump installations which processes polluted water is that the heat exchangers require relatively high-maintenance when they have to process large quantities of polluted water.
- An additional advantage of a TVR, or a MVR is that these systems reduce the emission of odors, since all vapors are condensed.

The heat pumps generally run satisfactorily, this study provides no indications to suggest that there are major risks associated with the use of heat pumps in industrial environments.

After a long period of 'silence' there seems to be renewed interest in the market since 2010, resulting in a fast increasing number of applications. A number of new Industrial Heat Pumps have been installed resulting in a long list of projects. These projects are described in fact sheets under Task 4.

## 10.3 Barriers and trends

Knowledge of heat pumping technologies is an important building stone in further increasing the heat efficiency of industrial processes. But knowledge is not the final piece but it's only the beginning of a whole transition process. Companies have a lot of options for energy conservation and generation and decision space, which can lead to taking no explicit decision. The challenge is to organize competition among technology solutions that leads to more explicit decision making. Decisions on applications of heat pumps are made in competition with investments on other technologies or in other parts of the industrial process.

Until recently heat in many industrial sectors has been by-product of electricity from cogeneration and therewith heat had a low economic value. Cogeneration has been a very 'hot' technological solution in the past decades for quick gains in energy conservation. Due to the strong competition from cogeneration in industry as a heat source only a few heat pumps were installed in the past 15 years, except for vapour recompression in distillation columns. In addition compression heat pumps were not suitable for temperature levels higher than 80 °C. Nowadays there a number of developments which widens the opportunities for industrial heat pumps:

- Due to the decline of the so-called spark spread, the difference in operating costs between CHP and heat pumps are considerably narrowed. It is to be expected that a lot of CHP-installations after depreciation will not be replaced. Paper and Pulp industry being an example. In those cases, there is more attention to the internal use of process heat and thus for heat pumps.
- By using other than the traditional working fluids for refrigeration and new technologies heat pumps can lift to reach 120 °C;

- Through the use of so-called "temperature glides" the heat / electricity ratio (COP) is significantly improved.
- The introduction of chillers with an additional compression step, which are perfect for the heating of hot water or cleaning process.
- The early development of acoustic and thermochemical heat pumps and heat transformers the path towards even higher temperature ranges up to 250 °C.

These technological developments do not or barely reach industry. In addition, heat pump suppliers generally have a backlog by the negative experiences in the commercial and domestic building sector.

An important aspect also is that heat pump suppliers, knowing the possibilities of alternatives, are in most cases the last link in the supply chain, where consultants and installers often lack the knowledge in finding good economic solutions. An important issue therefore is how technology suppliers, technical personnel and management, that takes the investment decision, communicate with each other. It is the experience that management is less interested in the technical side and much more in solutions for the company. Newly developed heat pump technology has been analysed in four major business cases in chemical industry. The experience gained here leads to the conclusion that more is needed than knowledge on technology only. A 'technology marketing' process is needed to be able to discuss on the same level as industrial management decision making. Knowledge, skills and competence have to be developed in that process. The approach is further discussed in Task 5.

## 10.4 Heat pump potential

In the Netherlands heat pumps of different types can be applied in all levels of industry ranging from bulk distillation in chemical industry to the level of milk processing at the farm or growing tomatoes in greenhouses and steam production in paper and pulp. In every application, even for domestic buildings, the approach will have to be based upon the Trias Energetica in industry a systematic approach in improving the energy efficiency of industrial processes is the onion-model developed in industrial heat technology.

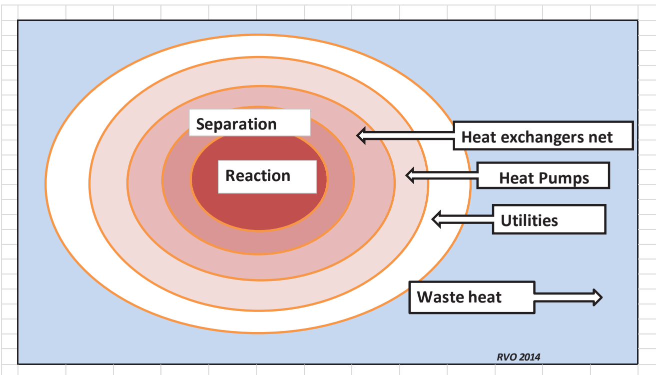


Figure 10-1: Onion model for energy efficiency improvement [Reissner, 2013]

This model will be discussed further in Task 2.

### 10.4.1 Chemical industry – distillation

(by D. Bruinsma and S. Spoelstra)[Bruinsma, 2011]

Distillation is the main separation technology in refineries and the chemical process industry, because of the attractive purification characteristics, the high production capacity and turndown ratio, and the straightforward design procedures. More sophisticated techniques have become state of the art to handle streams with less favorable thermodynamic properties, in particular small relative volatilities and azeotropic mixtures. The high energy demand in bulk distillation columns (1-100 MW) and the low thermodynamic efficiency (5-10%) remain the major drawbacks. A number of improvements have been developed over the years directed at reducing both operating and capital cost.

In extractive distillation (ED) a solvent or separating agent is added in order to increase the relative volatility of the components to be separated. In azeotropic extractive distillation the separating agent is used to break the azeotrope. As a consequence the reflux ratio, column diameter and reboiler duty can be reduced and/or the column height can be lower. Commercial low volatility solvents include sulfolane, triethylene glycol (TEG), NMP and NFM. The recovery cost of the solvent is an integral part of the economy of extractive distillation processes. ED is particularly effective for relative volatilities below 1.2. Industrial examples of ED processes are purification of aromatics in petro chemistry, butadiene recovery in naphtha cracking and separation of cycloparaffins from naphtha.

Instead of affecting the thermodynamics of the system also selection of the column internals is a way to increase distillation efficiency. Random and structured packings with specific surface areas from 250 up to 900 $m^2/m^3$ are continuously being improved with the objective to optimize stage height, pressure drop, liquid load, and turn down ratio. The main recent advancements in tray columns focus on high-capacity trays with centrifugal devices or structured packing demisters although at the cost of an increased pressure drop.

Since the 1980's dividing wall columns (DWC's) have been introduced which allow the separation of three component feeds in a single column leading to interesting reductions in both energy consumption and investment cost. Recently even more complex DWC's have been constructed to separate four component mixtures in pure products.

In contrast to improvements of the VLE or the column internals, both inside the column, a number of energy reducing measures can be considered outside the column by addressing the reboiler and condenser. These include side reboilers, dephlegmators and heat pumps. Side reboilers use waste heat at a lower temperature than the bottom reboiler and thus increase the exergetic efficiency. Dephlegmators or reflux condensers are compact heat exchangers, such as PFHE's, used to reduce energy consumption in low temperature gas separations. Heat pumps lift the temperature level of the top vapor in order to use this as the heat source for the reboiler.

Heat pumps for distillation purposes can be divided in three types: mechanically driven, heat driven and heat transformers. Mechanically driven heat pumps can be found, among others, in the following types:

- Vapor recompression heat pump (VC)

- Mechanical vapor compression heat pump - Subcritical and Trans critical (MVR)
- Thermal Vapor Recompression HP (TVR):
- Compression-resorption heat pump (CRHP)
- Absorption heat pump (AbHP) and Adsorption heat pump (AdHP)
- Thermo acoustic heat pump - linear motor driven (THP)
- Heat Integrated Distillation Column (HIDiC).

An analysis was made of distillation heat pump potential in the Netherlands, leaving out columns that do not cross the pinch and oil refinery columns. The data show that the total heat pump potential is in the order of 2.4 GW and that the average temperature lift over the column is 59 °C. These data are given in Table 10-5 (J. Cot and O.S.L. Bruinsma, Market survey, Heat pumps in bulk separation processes (2010), ECN report 7.6548.2010.0xx).

Table 10-5: Distillation in the Netherlands

Across the pinch distillation in the Netherlands

| Distillation in NL | |
|---|---|
| Total $Q_{reboiler}$ (GW) | 2.36 |
| Total $Q_{condenser}$ (GW) | 2.39 |
| Average $T_{reboiler}$ ($^0$C) | 128 |
| Average $T_{condenser}$ ($^0$C) | 69 |
| Average $\Delta T_{column}$ ($^0$C) | 59 |

Figure 10-2 represents the distribution of the reboiler duties in the Netherlands for columns with increasing temperature lift; only those columns that cross the pinch have been included.

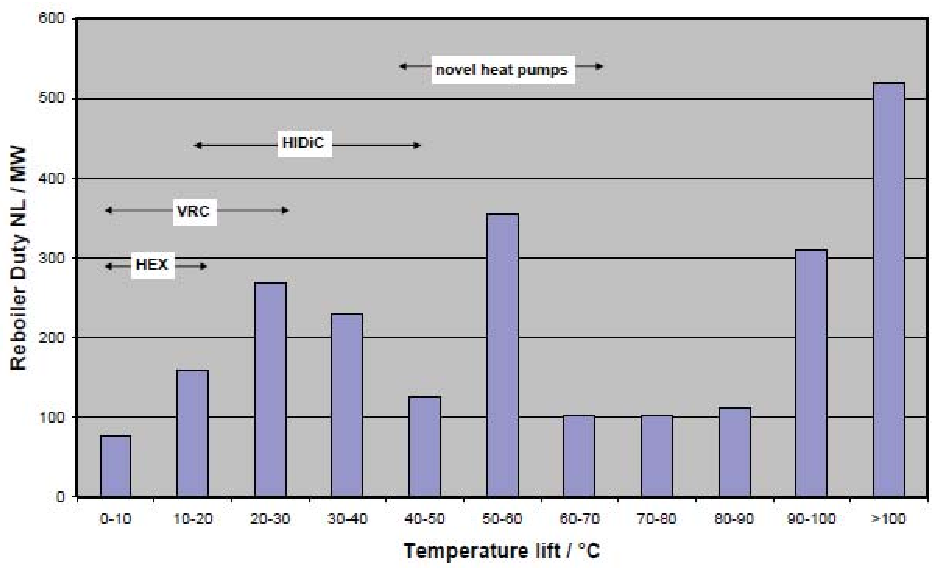


Figure 10-2: Reboiler duties for across the pinch columns in the Netherlands (2006)

In the graph four recommendation regions are identified:

- Temperature lifts below 20 °C compact heat exchangers with small ΔTHEX are crucial for the performance of the heat pump system,
- VRC's should be applied below 30 °C, which covers about 23 % of the across the pinch columns
- HIDiC's are probably interesting for temperatures in the range 15-45 °C, about 29 % of the across the pinch columns, partly overlapping with VRC but with a higher savings efficiency
- Novel heat pumps for temperature lifts of 45-70 °C, would contribute an additional 21 %.

Based on this analysis the combination of VRC, HIDiC and novel heat pumps would lead to an estimated 820 MW savings, which is almost 35 % of the reboiler duties of all across the pinch columns in the Netherlands.

### 10.4.2 Food industry

With an energy use of more than 62PJ in heat food industry is a large sector in Netherlands with main sub sectors: Dairy (18.0), Potatoes processing (8.7), Margarine (7.6) and Bakeries (4.8). Cooled Warehouses are a specific but important sector. Within these sectors processes like drying and cooling are the main process operations with a lot similarities in process.

*Evaporators in dairy industry*

The GEA handbook on Milk Powder Technology [Westergaard] states that the transforming of a liquid product into a dry powder requires means the removal of practically all water, the amount of which often exceeds the weight of the final product. During the water removal the processed product is undergoing deep changes of physical structure and appearance, starting with thin water like liquid and terminating with dry powder at the end of the process. Therefore, one single method of water removal cannot be optimal throughout the whole process, as also the product composition is different from one food product to another. In the food and dairy industry the following dehydration methods have been adopted:

- Evaporation
- Spray Drying
- Vibrating Fluid Bed Drying
- Integrated Fluid Bed Drying
- Integrated Belt Drying.

Each method should be adjusted to the properties of the processed material at each processing step. The more difficult the product, the more complex the plant.

As the development went on, the concentration was carried out in forced recirculation evaporators. In this evaporator the milk streams upwards through a number of tubes or plates. On the outside the heating medium, usually steam, is applied. The heating surface is thus increased in this system, but the evaporation surface is still limited, as the tubes and plates remain filled with product, which therefore becomes superheated in relation to the existing boiling temperature. Not until the product leaves the top of the tubes, are the vapors released and the product temperature decreases. For the separation of liquid and vapors, centrifugal separators were preferred. In order to obtain the desired degree of evaporation the product was recycled in the system. The concentration was thus controlled by the amount of concentrate discharged from the plant.

*Refrigeration*

An in depth study [Pennartz, 2011] has been done into the potential for heat pumps in the industrial sectors that use considerable amounts of refrigeration. Residual or waste heat available in the food sector is shown in table 1 for temperature and PJ primary energy per year. The various heat sources of the waste heat are listed in the table. Most of the waste heat is available from the condensing heat of refrigeration plants. The temperature level is between 30 °C and 40 °C. This energy source amounts to 28 PJ a year. Similarly the heat consumers have been investigated showing that 14 PJ is consumed by various processes at temperature levels between 60 °C to 110 °C. There is more residual heat available than required.

In this view, the heat demand of the food sector of 69 PJ in total can be reduced by 14 PJ by the use of high temperature add-on heat pump on refrigeration plants.

Table 10-6: Overview of available condenser heat in Dutch industry

**Heat Pumps applications and potential**

| Sector | Total primary energy consumption (2008) | Total electrical energy consumption (2008) | Total heat (2008) | T residual heat available | Residual heat available | Delivered by: | T heat consumers | Reuse heat consumption | Consumed by: | Electricity consumption by refrigeration | Available condensing heat (T=35°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | PJ | PJ | PJ | °C | PJ | | °C | PJ | | PJprim/j | PJth/j |
| | | | | | | | | | | | |
| **Sectors industry** | | | | | | | | | | | |
| Cooled warehouses | 2,4 | 2,2 | 0,2 | 35 | 2,8 | condensers refrigeration | 80/ 60 | 0,1 | building, water | 2,0 | 2,8 |
| Rubber and plastic | 9,6 | 7,4 | 2,2 | 35 | 1,8 | cooling tower, condenser refr | 80 | 0,1 | building, rubber | 0,9 | 1,8 |
| Potatoes processing | 8,7 | 2,0 | 6,7 | 30-120 | 4,0 | eg. steam pealing, condensers refr. | 70-110 | 1,2 | pasteurizer, dryer, blancheur | 1,1 | 1,5 |
| Cacoa | 2,3 | 1,1 | 1,2 | 60- 70 | 0,15 | cocoa milling | 120 | 0,25 | preheating air for drying | 0,1 | 0,2 |
| Fruit and vegetables | 2,9 | 1,4 | 1,5 | 70-120 | 0,8 | condenser, blancheur, sterilizer | 70-90 | 0,5 | blancheur, building | 0,4 | 0,6 |
| Coffee production | 0,9 | 0,5 | 0,4 | 30,0 | 0,1 | condensers refrigeration | 70 | 0,1 | building | 0,1 | 0,1 |
| Margarine, Fats and Oils | 7,6 | 0,8 | 6,8 | 35 | 0,3 | condensers refrigeration | 80 | 1,0 | tank storage, pipe tracing | 0,2 | 0,3 |
| Meat procesing | 4,3 | 2,8 | 1,5 | 30 | 1,8 | condensers refrigeration | 70 | 0,25 | hot water cleaning | 1,3 | 1,8 |
| Dairy | 18,0 | 5,0 | 13,0 | 40-60 | 2,5 | bruden condensate from evaporators | 90 | 1,8 | spray dryer | 1,8 | 3,2 |
| Soft drinks | 1,0 | 0,5 | 0,5 | 30 | 0,1 | cooling section pasteurizers | 80 | 0,1 | pasteurizers | 0,0 | 0,0 |
| Beer industry | 3,9 | 2,0 | 1,9 | 35, 100 | 1,2 | condenser, wort boiling | 70-110 | 0,6 | pasteurizers, wort boiling, building | 0,5 | 0,8 |
| Bakeries | 4,8 | 1,8 | 3,0 | 30, 200 | 0,3 | condensers, flue gas oven, boilers | 30-70 | 1,0 | air preheating, builing, water, dough rising | 0,9 | 1,4 |
| Fish processing | 0,8 | 0,6 | 0,2 | 30,0 | 0,5 | condensers refrigeration | 80 | 0,1 | building, hot water | 0,3 | 0,5 |
| Biscuits, confectionary, chocolate, icecream | 2,0 | 0,8 | 1,2 | 30, 200 | 0,6 | condensers refr., ovens | 60-100 | 0,5 | pasteurizers, water, cookers, storage raw materials | 0,4 | 0,6 |
| Other food | 69 | 40 | 29,0 | 30-70 | 9,0 | various | 70-90 | 6,0 | various | 8,0 | 12,8 |
| **Total Food** | **138** | **69** | **69** | | **26** | | | **14** | | **18** | **28** |
| | | | | | | | | | | | |
| Chemical industry spcialized products | 10,2 | 4,0 | 6,2 | various | | | various | | | 0,8 | 1,6 |
| Oil and gas production | 40,8 | 10,8 | 30,0 | 90 | | compression gas | 80 | | building | 1,9 | 3,9 |
| Chemical industry bulk | 300 | 75 | 225,0 | various | | | various | | | 3,0 | 5,4 |
| Refining | 140 | 24 | 116,0 | various | | | various | | | 3,6 | 6,5 |
| Other industry | 104 | 16 | 88,0 | various | | | various | | | 1,3 | 2,6 |
| **Total Other** | **595** | **130** | **465** | | | | | | | **11** | **20** |

The feasibility of high temperature add-on heat pumps depends on an analysis of:

- Residual heat, heat demand and electricity demand
- Energy monitoring of maximum and minimum capacities, average values, operating hours.
- Apply an integral approach, evaluate the competing technologies such as high efficient hot water boilers, combined heat and power (CHP) plants. A heat pump is more flexible than a CHP, since they are available in small sizes and can operate efficiently in part load.
- Investments, replacement of heating equipment.

From a sustainable point of view: refrigeration installations should not be installed, without the use of condensing heat (such as desuperheater heat, condensing heat at 30 °C, add on with high temperature heat pump >80 °C).

### 10.4.3 Paper and pulp

by [De Vries, 2012]
The pulp and paper sector is with 26 PJ a significant energy user in Netherlands and currently ranks fourth in the industrial sector for its energy use. This 26 PJ is primarily used as gas to power cogeneration systems conversing this into 17 PJ’s of heat. This heat is then after being used as process heat dumped into the environment as heat from drying (11 PJ), losses from conversion (4 PJ and into the waste water (2 PJ). Energy costs in paper and pulp in the Netherlands are 15 - 35% of the variable costs of production.

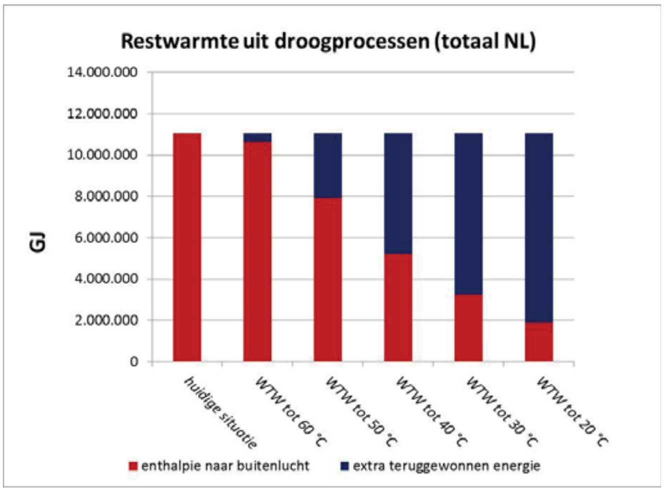


Figure 10-3: Waste heat and temperature levels in Paper and Pulp

Manufacturers have under the Multi Year Energy Agreement with the ministry of Economic Affairs constantly been working on energy efficiency for the production processes, which lead from 1990 onwards to the wide spread application of cogeneration. Several studies have been executed in the nineties of last century to find the right solution for the application of heat pumps, but due to the low costs of process heat an economical investment was not feasible. Due to the decline of the so-called spark spread, the difference in operating costs between CHP and heat pumps are considerably narrowed. It is to be expected that a lot of CHP-installations after depreciation will not be replaced. In those cases, there is more attention to the internal use of process heat and thus for heat pumps. A first R&D project has in 2013 lead to a 250kW’s pilot project with a high temperature heat pump producing steam at 120 °C re-using the waste heat from the drying section. This option at this moment seems only viable for larger paper & pulp industries. According to the CEPI statistics (2012) there are in Europe some 350 paper industries of the size.

There are various possibilities to recover thermal energy from steam and waste heat in the paper drying process. These include:

- Mechanical vapor recompression and reuse of the superheated steam in the drying process;

- Use of heat pumps to recover waste heat;
- Recovering heat from the ventilation air of the drying section and using this heat for the heating of the facilities when needed.

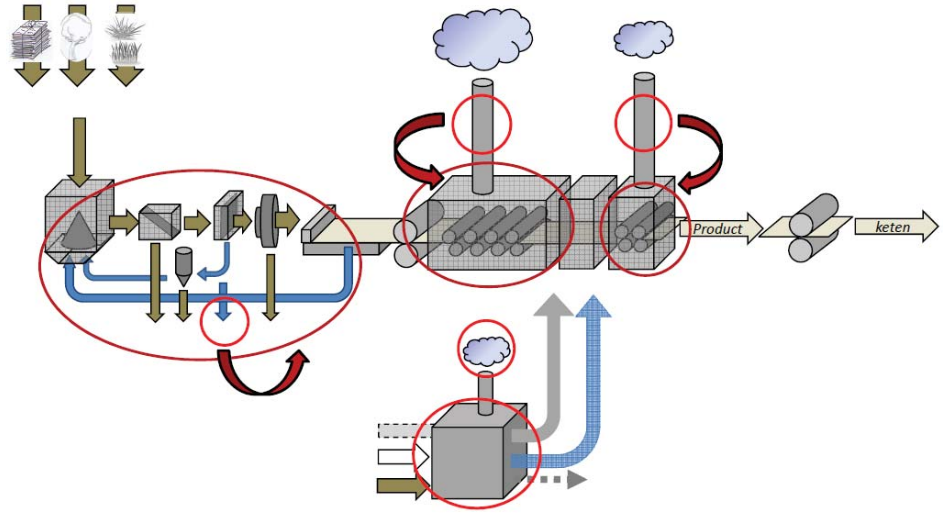


Figure 10-4: Waste heat streams that can be used (source KCPK [de Vries, 2012])

The challenge is to find the right solutions to re-use the in the process. As paper and pulp processes are rather big the best option is to re-use the heat close to where the waste heat appears.

### *10.4.4* Miscellaneous industrial areas

***(see www.energiezuinigebedrijventerreinen.nl***) [Energie]

There is small success with energy conservation and the application of renewable energy at industrial areas for mixed/miscellaneous use. This is remarkable as there are many economical options for renewables and conservation. Where heat pumps in Netherlands are state of the art in commercial buildings this is not yet the case at these mixed industrial areas.

The overall energy use on existing areas with a size of 10 - 50 ha is 170 PJ which is 6% of the overall Dutch energy use. With a conservative estimate that there is potential for energy conservation of 30 – 40% this sums up to 60 PJ [6]. On the positive side is that there are good examples with new developments where renewable energy and energy conservation are basic boundary conditions to fulfill when a company considers to settle in that area. These boundary conditions are set by local governments. Of these area three examples are:

- 15 ha Kolksluis near Zijpe where heat pumps combined with a collective ATES are the main technologies
- Ecofactorij near Apeldoorn which is discussed in a factsheet under Task4
- Trompet near Heemskerk.

In the development of a new area it is of importance to develop the planning process at a very early stage and to attract companies by giving bonuses and over a long period never to depart from the goals of the planning for the area.

For existing industrial areas it is part of the renovation process which is challenging and with some small successes. Examples are given in some factsheets under Task 4.

### 10.4.5 Agriculture

Agriculture in Netherlands covers a large area from mushroom growth, 'bollenteelt', pig and chicken farms, dairy farming, cheese making and greenhouses. The major energy user in this segment are the greenhouses. Even for low energy growths heat pumps can give primary energy savings up to 35% [Ruiter, 2011]. In the period 2003-2013 approximately 40 growers of various crops have implemented heat pumps in their greenhouses. They comprise the following crops:

- Roses (2x)
- Tomatoes (3x);
- Orchids (Phalaenopsis) (8x);
- Freesia (2x);
- Anthurium (2x).

Recently the experience have been analyzed [Geelen, 2013] showing considerable difference with the well-established market of commercial buildings. The already installed heat pumps are 'traditional' applications. As in Paper & Pulp industry the greenhouse sector has in the past decades massively invested in cogeneration which now gets into economic problems due to negative spark spread.

By combining electric drive heat pumps with cogeneration more heat is generated and less electricity is produced for the power grid. This increases the flexibility in operational management of the energy system[26]. Heat storage as well co-producing for neighboring greenhouses and prediction of weather can lead to efficiency in management. A system is described in a factsheet.

***Dairy Farmers***

As an average Dairy Farms use 5,000 $m^3$ gas and 35,000 kWh of electricity. If all 17,500 Dairy Farms in Netherlands would adopt the ECO 200 system with heat pumps using the heat extracted from the milk storage it would give a saving up to 2PJ's. Campina Melkunie the large Dairy industry focuses strongly on these possibilities in order to get the complete chain from cow to end user of milk and cheese at a level of energy neutral. In all individual chains heat pumps are a key technology.

[26] a solution which is not possible with Paper & Pulp as these cogen systems in this sector normally are built with over capacity of heat

## 10.5 Manufacturers and suppliers in Netherlands

The market for industrial heat pumps is for an important part derived and developed from the market of industrial cooling and refrigeration. These manufacturers and suppliers are gradually 'discovering' the market of heating in industrial processes, but also in other markets. With their profound knowledge of thermodynamics they are developing and applying new innovative products in a fast growing market.

Compressor technology being the core of the technology with one main well established manufacturer Grasso from Den Bosch, part of GEA. The other manufacturers and suppliers in Netherlands use components from Grasso and other suppliers to create and build innovative and outstanding products. Some of the products are standardized and some of the suppliers make tailor made solutions. Many of these have applications in all different sectors ranging from industry to greenhouses, skating rings and commercial office buildings.

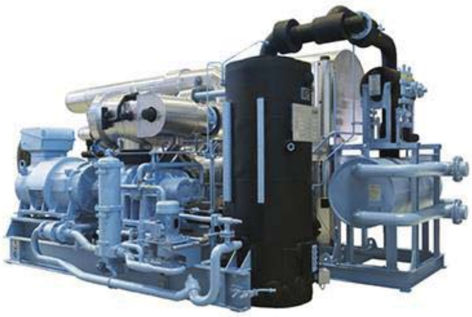

Figure 10-5: Grasso FX P heat pump

- **Grasso. Grenco** (www.grasso.nl), old established company and manufacturer of screw and piston compressors of different sizes. Factories in Den Bosch (NL) and Berlin (D). Under the GEA group also active in several industrial sectors with MVR compressors. The Dutch division is typically a department derived from refrigeration having developed the add-on heat pump for which they got the NVKL-Award in 2012, with an example project at Wiseman Dairies in UK.

- **IBK-Refrigeration** (www.ibkgroep.nl) from Houten, as the name suggests are specialists in refrigeration but at the same time supplying innovative heat pump concepts. IBK Refrigeration is part of the IBK-group. The first add-on heat pump was built at Unilever in Rotterdam (factsheet NL 08). Another interesting application is in ice skating rinks (factsheet NL 29). In a further development IBK is now involved in a pilot of e high temperature heat pump in paper and pulp industry, for which they got the NVKL-Award 2014.


Figure 10-6: NVKL-Trofee 2014

- **Energie Totaal Projecten** (ETP – www.etp.tv) from Dordrecht is a company delivering overall projects from engineering, design, financing, servicing and maintenance including performance guarantees for all sectors with larger systems. Their main markets are in commercial buildings and greenhouses. Based upon a chiller from international high standard they have developed a standardized high performance compact heat pump which is skid built. Heat pumps are standardized in sizes from 85kW to 3.8MW's. Several patents are pending on new breakthrough technologies. Example projects are under Greenhouses (NL-27).


Figure 10-7: ETP HWD-3800 skid

- **KODI** (www.kodi.nl) from Heerhugowaard started just like ETP as a consultancy and installer in commercial buildings and agriculture. Not happy with the products on the market KODI developed with a subsidy from Novem a high performance heat pump concept for greenhouses (see factsheet NL 27d). Standardized compression heat pumps based upon Grasso technology is now installed in several smaller industrial areas. KODI is also involved in projects like Kolksluis industrial area. On their site they give a long list of reference projects.

Figure 10-8: Typical KODI heat pump in Greenhouse

- **Reduses** (www.reduses.nl) from Nijkerk is part of a group of companies delivering all services from consultancy to installing, maintenance and monitoring. Installect,

GeoComfort and Instead are the partners where Installect is responsible for installation and design, GeoComfort for the ground source (innovative concept of mono-source) and Instead for the monitoring and maintenance (innovative concept where monitoring is used as benchmarking between companies and as tool for maintenance). Reduses is manufacturer of gas engine driven heat pumps up to 250 kW's. The gas engine is from Volkswagen. Reduses have their own certified lab to do performance tests.

Figure 10-9: Reduses gas engine heat pump

- **De Kleijn Energy Consultants & Engineers** (www.industrialheatpumps.nl) is a consulting company in Druten with a focus on industrial projects and tailor made innovative solutions (factsheet NL 11). Their focus on industrial heat pumps is clear with their website and the recent visit by NEDO in 2014. For RVO Kleijn is executing a communication strategy on heat pumping technologies.

- NRG-TEQ (www.nrgteq.nl) from Rosmalen is a manufacturer of heat pumps in the range from 4 – 400 kW's. Until recently NRG-TEQ was only active in domestic and commercial buildings.

It is of importance to notice that next to these Dutch companies other large companies are active in this market where the local office often developers innovative applications with components from their 'mother'. Carrier from Hazerswoude, together with French office, is such an example. Their heat pumps are rather popular in greenhouses and commercial buildings.

## 10.6 Literature

| | |
|---|---|
| Bruinsma, 2011 | Heat pumps in distillation; O.S.L. Bruinsma; S. Spoelstra, ECN report - ECN-M--10-090 – November 2011 |
| De Vries, 2012 | Ervaringen met warmtepomptechnologie in de papier en karton industrie, Laurens de Vries, (KCPK), presentation of a meeting of DT-IHP, June 2012 |
| Energie | www.energiezuinigebedrijventerreinen.nl |
| Geelen, 2013 | Monitoring van (energetische) prestaties en knelpuntenanalyse WKO-systemen in de glastuinbouw, ir. C.P.J.M. Geelen en ir. K.J. Braber; Arnhem, December 2013 |
| Pennartz, 2011 | The state of the art of industrial heat pumps in the Netherlands, A.M.G. Pennartz M.Sc., August 2011, KWA – Amersfoort, Report number 3005660CR03 |
| Reissner, 2013 | Reissner, F., Gromoll, B., Schäfer, J., Danov, V., Karl, J., 2013a. Experimental performance evaluation of new safe and environmentally friendly working fluids for high temperature heat pumps, European Heat Pump Summit, Nürnberg, Germany |
| Ruiter, 2011 | Quickscan toepassing van warmtepompen voor energiebesparing bij teelten met een laag energiegebruik, J.A.F. de Ruiter (KEMA), KEMA report June 2011 |
| Westergaard | Milk Powder Technology, Evaporation and Spray Drying, ed. Vagn Westergaard, 5th Edition, GEA Process Engineering |

# 11 Sweden

## 11.1 Energy use in Sweden in 2011

The overall final energy use in Sweden redistributed by energy carrier is shown in Table 11-1:

Table 11-1: Final energy use by energy carrier in Sweden in 2011 [1]

| Energy carrier | PJ | TWh |
|---|---|---|
| Oil | 386 | 107 |
| Natural gas | 24 | 6.7 |
| Coal | 55 | 15 |
| Biomass | 275 | 76 |
| Electricity | 454 | 126 |
| District heating | 170 | 47 |
| **Total** | **1364** | **379** |

The overall final energy use in Sweden is dominated by electricity and fossil fuels standing for a share of about one third each. Biomass has an outstanding share of 20 % and district heating stands for the remaining 12 %.

### 11.1.1 Energy use in the manufacturing industry

Figure 11-1 presents the distribution of the total energy use across the different sectors in Sweden including the redistribution on energy carriers for the industry sector.

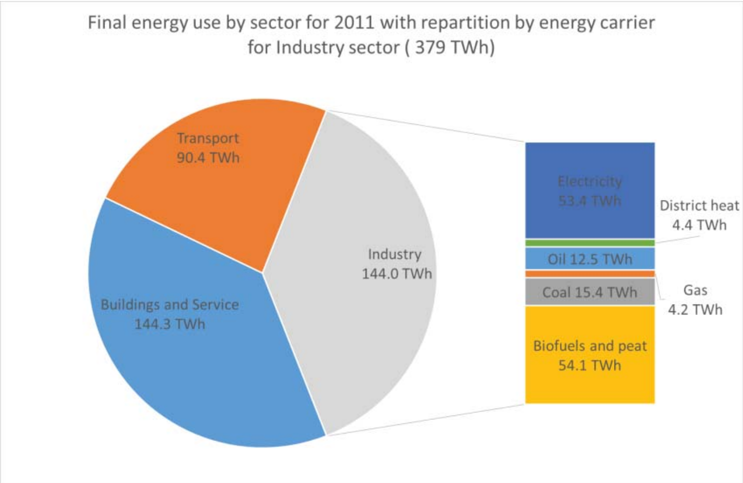


Figure 11-1: Final energy use 2011 by sector with repartition on energy carriers for the Industry sector [1].

Electricity and biofuels are the major energy carriers used in the Swedish manufacturing industry. The pulp and paper industry being one of the largest energy users mainly consumes biofuels (spent liquors to a large extent) whereas the iron and steel sector largely depend on electricity and coal (for coking processes).

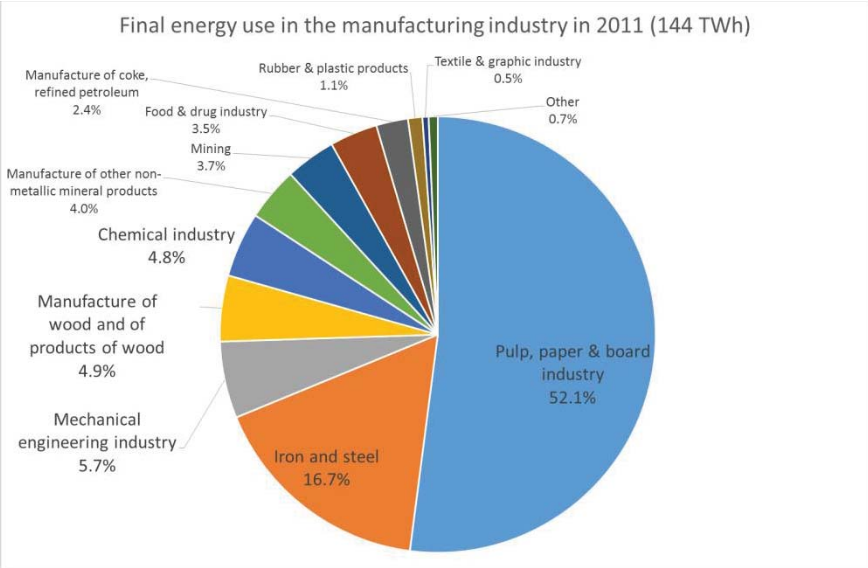


Figure 11-2: Final energy use in the different industrial sectors in 2011 (144 TWh in total) [2,3].

In Sweden the energy use in the manufacturing industry is dominated by a relative small number of sectors. The major energy user is the pulp- and paper industry standing for more than half of the total industrial energy use. The iron and steel industry is the second largest user, while the chemical, mechanical and wood manufacturing sectors are using similar amounts of energy, together standing for about 16 %. The remaining 16 % is used by the non-metallic mineral sector, food and drug sector, refinery sector and other smaller industrial sectors [1].

In Table 11-2 the energy use in the manufacturing industry is presented with fuel and electricity consumption details. Industries having a high percentage of electricity in the energy supply are less suitable for heat pump applications as there are less excess heat streams to be expected, with e.g. waste heat from electric motors being difficult to recover.

Table 11-2: Industry sector fuel and electricity use in 2011 [2,3].

| Industry sector | Fuel [TWh] | Electricity [TWh] | Total [TWh] |
|---|---|---|---|
| Pulp, paper & board industry | 2.1 | 3.3 | 5.4 |
| Iron and steel | 2.6 | 2.5 | 5.1 |
| Mechanical engineering industry | 0.2 | 0.4 | 0.7 |
| Manufacture of wood and of products of wood | 5.0 | 2.0 | 7.1 |
| Chemical industry | 52.5 | 22.6 | 75.1 |
| Manufacture of other non-metallic mineral products | 2.4 | 1.0 | 3.4 |
| Mining | 2.4 | 4.6 | 7.0 |
| Food & drug industry | 0.4 | 1.2 | 1.5 |
| Manufacture of coke, refined petroleum | 4.7 | 1.0 | 5.7 |
| Rubber & plastic products | 16.2 | 8.0 | 24.2 |
| Textile & graphic industry | 2.5 | 5.8 | 8.2 |
| Other | 0.4 | 0.6 | 1.0 |
| ***Total*** | ***91*** | ***53*** | ***144*** |

### 11.1.2 Market overview

A report on industrial excess heat in Sweden from 2009 presents the status of available excess heat in the different industrial sectors and the changes in excess heat delivery from 1999 to 2007. It also estimates the theoretical potentials for the different sectors. In Figure 11-3 the excess heat delivery (standard and upgraded by heat pumping) from the different industrial sectors. Due to a change in the coding system the sectors are grouped somewhat different compared to the previously presented data[27].

The amount of delivered excess heat increased by 0.8 TWh from 1999 to 2007 reaching 4.1 TWh/year. The largest supplier of excess heat is the pulp and paper sector that also increased its excess heat supply (without heat pumping) by 60 % from 1999 to 2007. Together the energy-intensive industry sectors (pulp and paper, iron and steel, petroleum refining, and chemical industry) stand for more than 90 % of all excess heat supply. Other industry sectors supply about 8% of excess heat but represent about 40% of the total number of companies supplying heat. The largest increase in heat supply of about 60% from 1999 to 2007 is seen for the wood manufacturing industry, but even the food sector increased its supply considerably (about 44%). Upgraded excess heat from low temperature heat sources by heat pumping represented about 630 GWh in 1999 but the amount delivered dropped to 265 GWh in 2007 [4].

[27] The report cited [4] uses the SNI 2002 codes while more recent data is using SNI 2007 codes.

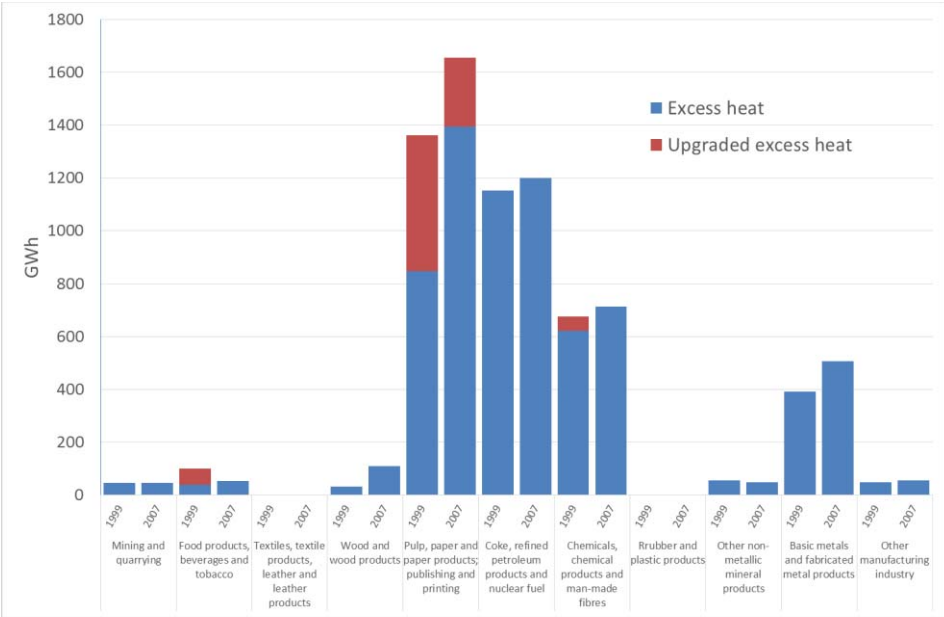


Figure 11-3. Delivered excess heat from industrial sectors in 1999 and 2007 [4].

An estimation of the potential for excess heat deliveries from the manufacturing industry sectors is presented in Table 11-3. The potential delivery estimate ranges from 6.2 to 7.9 TWh/year and is an estimated based on statistical data for the actual heat delivery as well as the industry sectors' fuel use. The calculated potential is up to 1.9 times larger than the delivered today.

The report cited here [4] discusses both the potential as well as barriers for excess heat delivery for each sector. According to the authors, a general discussion for the whole manufacturing industry sector is not possible due to varying prerequisites for the different sectors depending on their structure, location and surrounding infrastructure. A number of aspects mentioned that are relevant for industrial heat pump applications are stated in the following.

Increasing energy prices force industry to focus on energy efficiency measures and improve the profitability of heat recovery projects in general. Heat recovery from flue gases has become much more common, with biomass being used as fuel favoring the heat recovery potential due to a higher moisture content in the flue gases. The temperature level for flue gas heat recovery is rather high but even heat pump application in the lower temperature range might be considered.

Table 11-3: Excess heat delivery in 2007 and theoretical potential for manufacturing industry sectors in Sweden [4].

| Industry sector | Delivered excess heat 2007 (GWh/Year) | Calculated theoretical potential of excess heat (GWh/Year) |
|---|---|---|
| Mining | 50 | 250 – 300 |
| Manufacture of food products: beverages and tobacco | 61 | 80 – 120 |
| Manufacture of textiles and textile products | 0 | 0 |
| Manufacture of wood and of products of wood | 110 | 250 – 300 |
| Manufacture of pulp, paper and paper products | 1392 | 2000 – 2500 |
| Manufacture of coke, refined petroleum products, chemicals and chemical products | 1908 | 2500 – 3000 |
| Manufacture of rubber and plastic products | 3 | 10 – 20 |
| Manufacture of other non-metallic mineral products | 48 | 150 – 250 |
| Manufacture of basic metals | 502 | 900 – 1300 |
| Other | 58 | 100 – 140 |
| **Total** | **~ 4100** | **~ 6200 - 7900** |

For small scale enterprises the amount of excess heat often is rather small and heat recovery measures have not been considered yet. For district heat an increasing number of small suppliers however have a beneficial effect on the stability/reliability of the system. Considering heat pump applications, increased awareness for heat recovery have the potential to reduce the company's vulnerability with respect to changing energy prices.

### 11.1.3 Barriers for application

A number of barriers hindering increase excess heat delivery from the manufacturing industry are given in the cited report [4] with the ones relevant for heat pump applications are indicated here.

In particular for the small to medium size enterprises, the amount of excess heat often is considered too small or companies are not aware enough of the potential for excess heat recovery. Increasing energy prices might change this in the future.

In e.g. the wood manufacturing sector the fact that the drying equipment – representing an interesting source of heat recovery – is not running continuously is a major barrier for application. Similar problems exist in the pharmaceutical industry that is often operating batch processes with limited heat recovery potential.

The energy-intensive industry-sectors in Sweden are exposed to international competition leading to a strong strive for energy efficiency increase. Increased use of low temperature heat sources internally decreases the potential for district heat delivery but might open up for increase heat pump use. For example within the pulp and paper industry low temperature black liquor evaporation and pulp drying are applications that strive at using heat sources at lower temperature level.

### 11.1.4 References:

[1] Swedish Energy Agency (2013) *Eneriglöget 2013*, ET 2013:22, Eskilstuna, Sweden.

[2] Swedish Energy Agency (2012) *Annual Energy Balance Sheets 2010 – 2011*, EN 20 SM 1206, ISSN 1654-3688, Eskilstuna, Sweden.

[3] Swedish Energy Agency (2013) *Energy use in manufacturing industry, 2011 Final data*, EN 23 SM 1301, ISSN 1654-367X, Eskilstuna, Sweden.

[4] Cederholm, L-Å, Grönkvist, S, Saxe, M (2009) *Spillvärme från industrier och värmeåtervinning från lokaler* (Waste heat from industry and heat recovery in buildings, in Swedish), Report 2009:12, Svensk Fjärrvärme, Stockholm, Sweden.

# 12 Literature survey

## 12.1 Review of all countries

In [1] a total of 11 countries, namely France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, the UK, the USA, and China, were surveyed to estimate $CO_2$ reduction potential by introducing current-technology heat pumps into the food and beverage fields. On the assumption that an electric drive compressor heat pump is used, applications at a boiler energy use end temperature of below 100 are selected as a heat pump applicable range.

As a result of this estimation, it has been concluded that the emission of 40 million tons of $CO_2$ per year can be reduced in all 11 countries by replacing applications at an end use temperature below 100 boiler energy in the food and beverage fields with heat pumps (with MVR in the beer brewing industry included). A total $CO_2$ reduction effect of 25 million t $CO_2$/year in the 10 countries other than China can be expected.

[ 1] Heat Pump & Thermal Storage Technology Center of Japan: Survey of Availability of Heat Pumps in the Food and Beverage Fields, March 2010