Industrial Heat Pumps, Second Phase

IEA Heat Pump Technology (HPT) Programme Annex 48

Task 1: Austrian Report

Final Report

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1 Industrial energy demand

In Austria, surveys on useful energy analyses are conducted annually since 2015 to take account of the rapid technical progress. It is provided by Statistics Austria and is based on the current final energy consumption. Useful energy analyses aim to subdivide the final energy consumption of the energy balance at sector level into so-called useful energy categories. The analysis provides thereby information on the purpose of the final energy use. (Statistics Austria, 2016)

In 2016, 35% or 386 PJ of the overall final energy consumption was spent on the production of goods and services, 35 % (395 PJ) were used for traction, and for space heating and hot water 27 % (306 PJ). Only 3 % (34 PJ) were used for lighting and IT, see Figure 1-1.

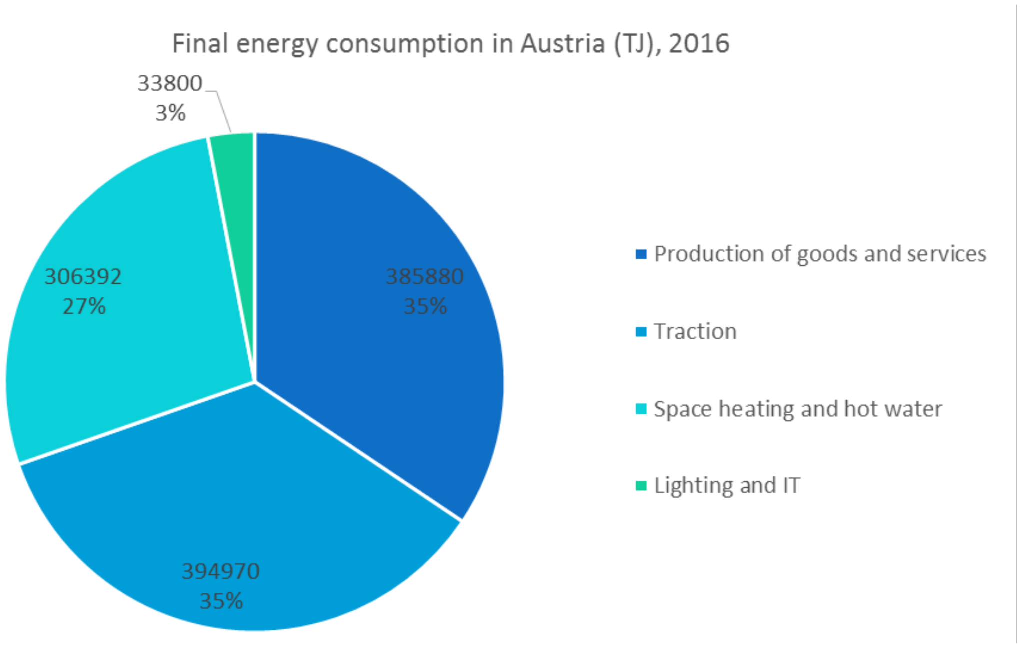

Figure 1-1: Final energy consumption in Austria according to Statistics Austria (2016)

In Figure 1-2, the useful energy analysis of the Austrian industry is summarized. The pulp and paper industry consumes the most energy, followed by the chemical and petrochemical industry, stone and earth and glass production, as well as the iron and steel production. In Figure 1-3, the fractions of six different applications are compiled. A total of 109 PJ were consumed in industrial ovens, followed by steam generation, stationary engines, space heating and air conditioning. Minor fractions are attributable to lighting, information technologies (IT) and electro-chemical applications.

According to Figure 1-4, the most important energy carrier is natural gas (113 PJ = 34%), which is used in all sectors. Biogenous residues amount for 60 PJ (= 18%) and are predominantly used in the pulp and paper industry. Electric energy is also used in all sectors, it is the main energy carrier in the chemical and petrochemical industry and in mechanical engineering.

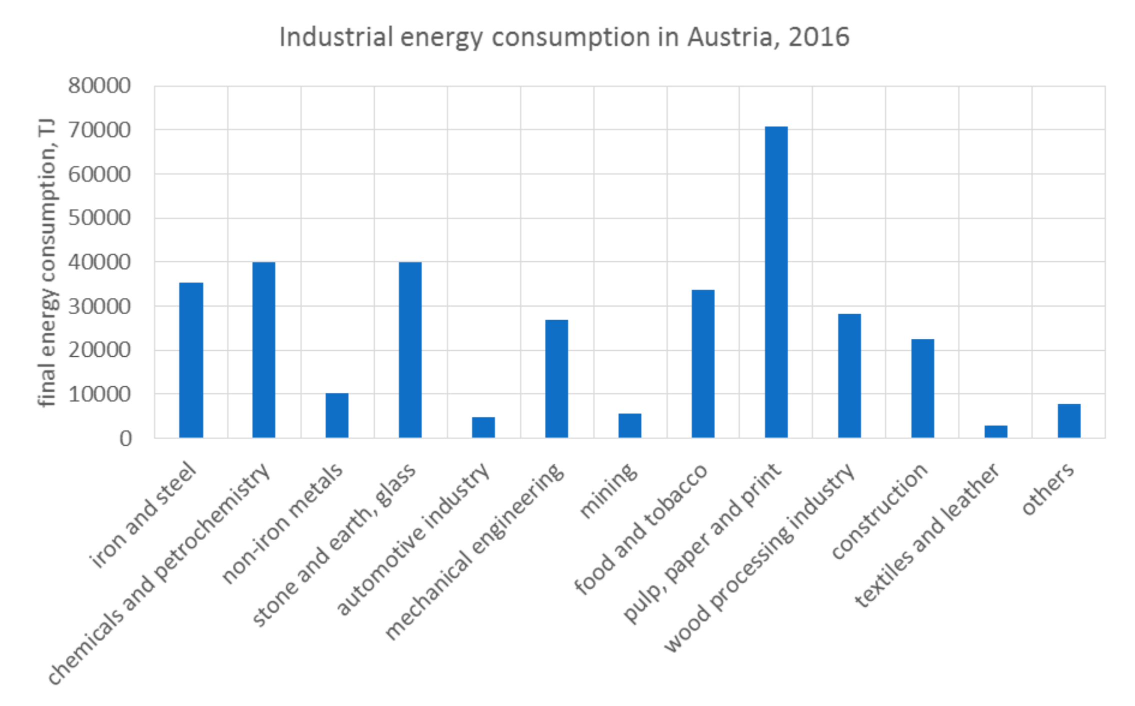

Figure 1-2: Industrial energy consumption in Austria by sector according to Statistics Austria (2016)

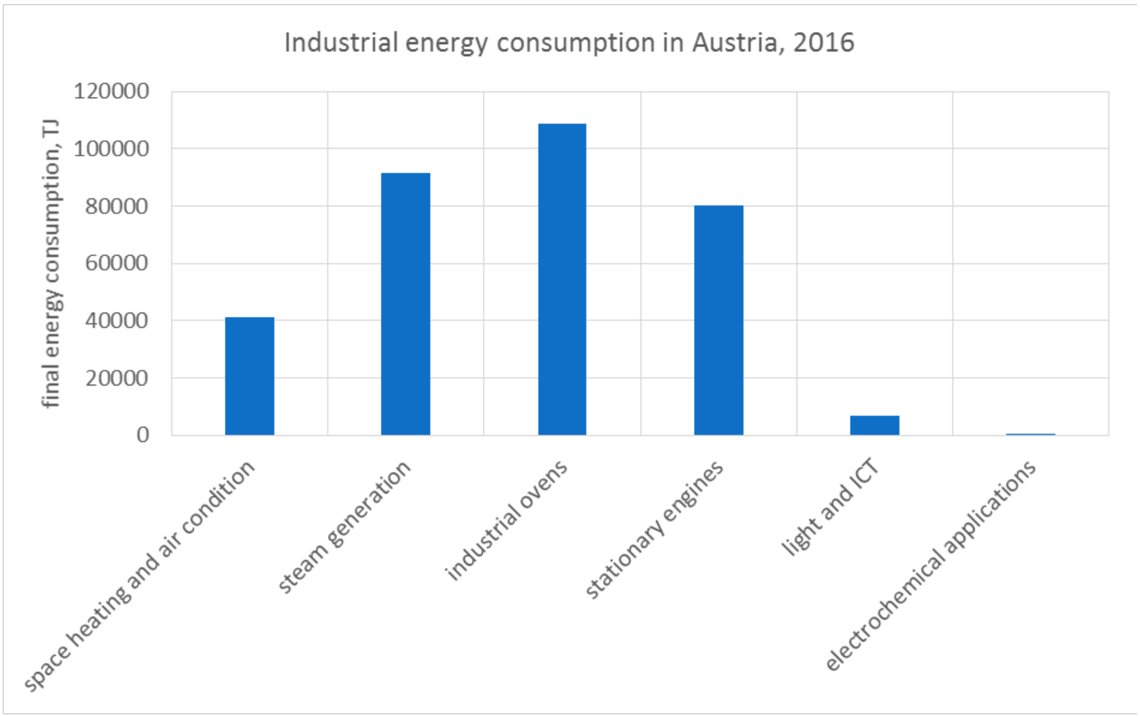

Figure 1-3: Industrial energy consumption in Austria by application according to Statistics Austria (2016)

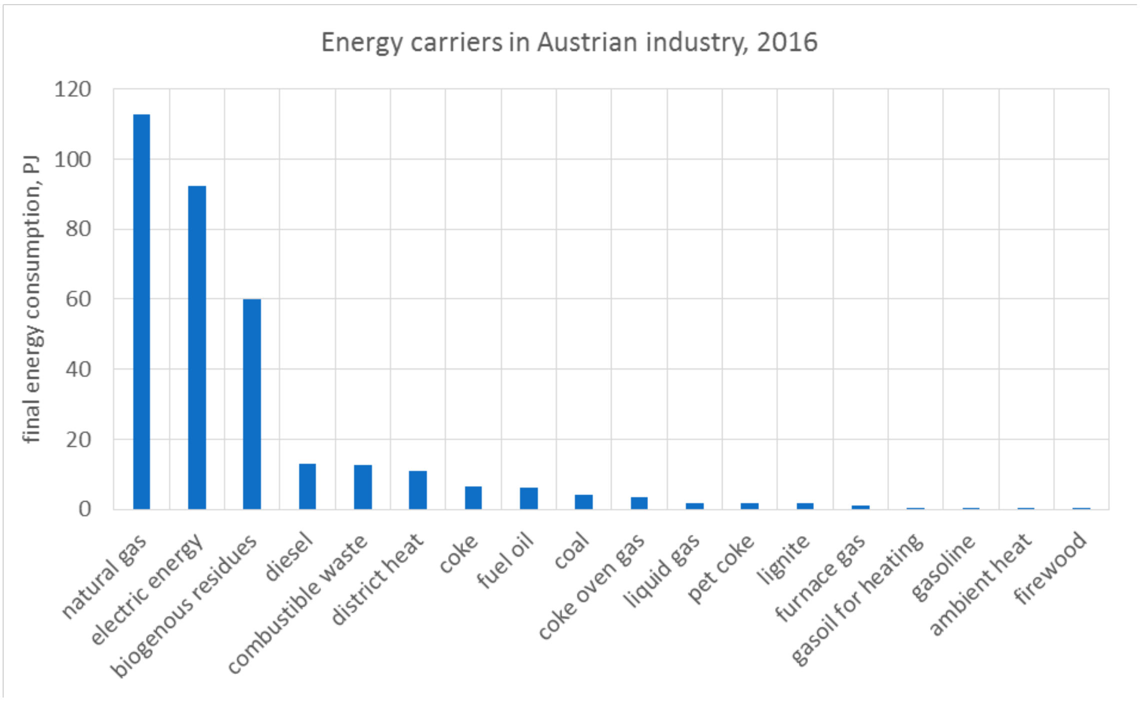

Figure 1-4: Industrial energy consumption in Austria by energy carriers according to Statistics Austria (2016)

Figure 1-5 gives an overview on the energy carriers that were used for industrial applications relevant for heat pumps, which are space heating and air conditioning, steam generation and industrial ovens. Space heating and air conditioning are typical fields of applications for heat pumps. Industrial ovens comprise all kinds of ovens ranging from low-temperature applications, such as drying to high-temperature processes, such as sintering. Steam generation also covers a broad range of temperatures. Both applications are therefore partially relevant for heat pumps.

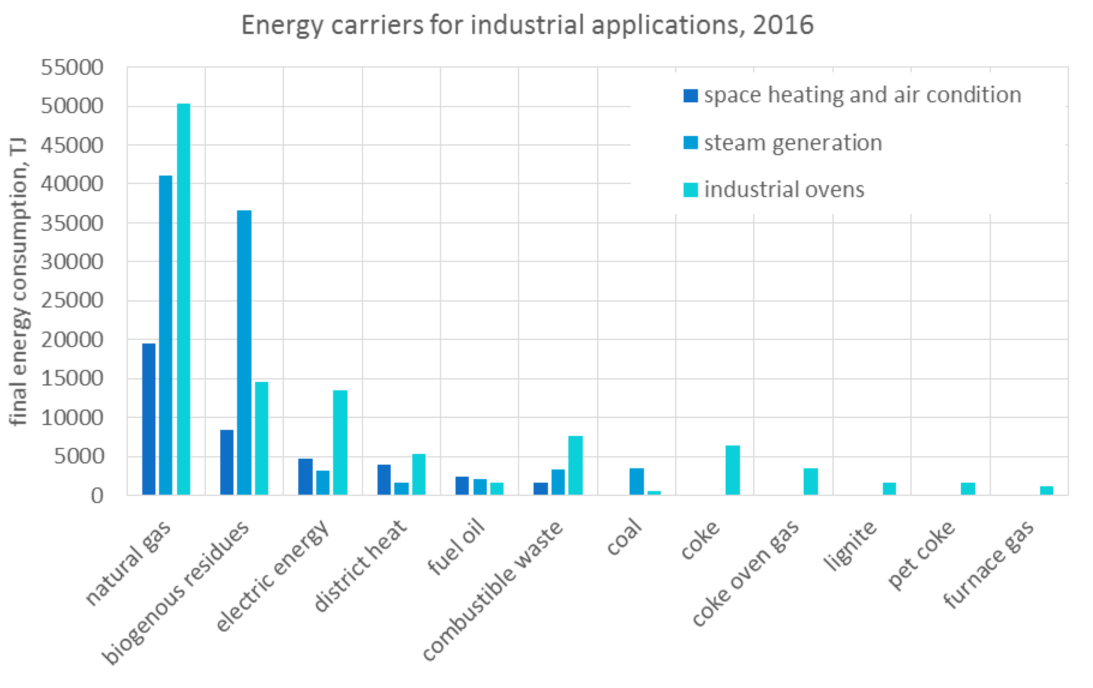

Figure 1-5: Distribution of energy carriers on industrial applications relevant for heat pumps according to Statistics Austria (2016)

2 Heat pumps in Austria

A national roadmap for heat pumps was published by Hartl et al. in June 2016, which was the result of a participatory stakeholder process. The focus of the roadmap is set on the strengths of the national heat pump sector and the users' needs.

Heat pump manufacturers in Austria:

As part of the roadmap development, an anonymous, web-based survey was conducted among 34 companies in the national heat pump industry. 26 companies took part in the survey, which corresponds to a response rate of 76%. The general data of the participating companies are summarized as follows:

- 70% of the companies belong to the group of small and medium-sized enterprises.
- 62% of the companies are headquartered in Austria, 27% of those surveyed are part of an international group of companies based in Austria.
- 46% of the participants produce heat pumps in Austria; 30% have their production site abroad; the rest have outsourced their production to OEMs.
- 65% of the companies carry out research and development in Austria, 74% of those have their own R&D group or department.

Sales figures for industrial heat pumps:

The Austrian heat pump market is dominated by heating heat pumps, with the majority of systems having heating capacities of up to 20 kW. Industrial heat pumps account for a very small proportion. Since 2012, they have been assessed separately in the market statistics according to the following definition: heat pumps that are usually planned, manufactured and installed on a project-specific basis for industrial and commercial purposes. The development of the domestic market is shown in Figure 2-1.

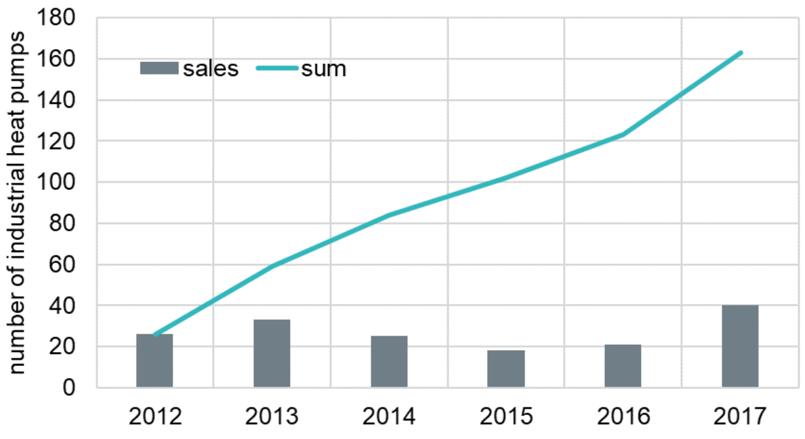

Figure 2-1: Sales figures (Biermayr et al., 2018)

Sales figures for all types of heat pumps:

Figure 2-2 illustrates the development of the Austrian heat pump market. Heat pumps for water heating and space heating are the most important products. Technology diffusion started in the 1980s, where heat pumps for water heating were predominantely installed. After a decrease, a second increase started in the year 2001 with the increase in heat pumps for space heating. An important driver for the second increase was the uptake of energy efficient buildings. Due to the low temperature in the heating system, these buildings are well suited for an energy efficient operation of heat pumps.

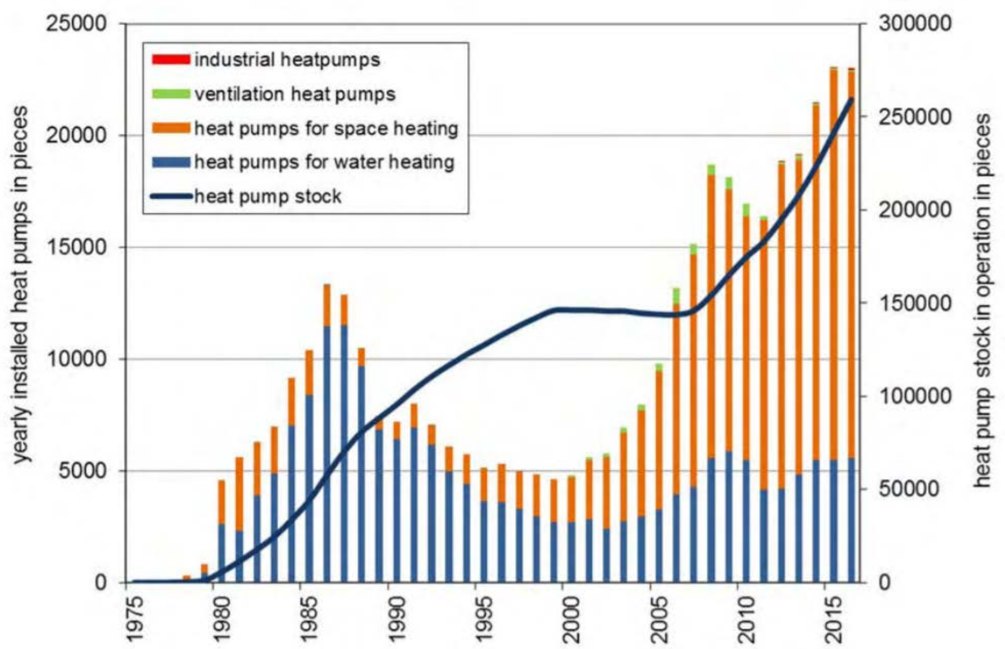

Figure 2-2: Market development of heat pumps in Austria until 2016 (Biermayr et al., 2017)

Conclusion of the roadmap for industrial heat pumps:

Despite the great technical potential, the integration of heat pumps into industrial processes is still in a very early diffusion phase, which, due to the low national sales figures, does not yet permit a serious estimation of trends. There are currently only a few national innovators and early users on the market. In contrast to heat pumps for domestic applications, which show a strong growth since the year 2000, as it was described before.

The main obstacles beside economic boundary conditions (the low gas price, expectations about amortization, etc.) to the market diffusion of industrial heat pumps concern information. The level of awareness of the technical possibilities and economically feasible application potentials among the relevant actors is low. Networking of users, system planners and producers is essential but also at a very early stage. The documentation and dissemination of a larger number of national good practice examples is considered helpful.

Framework conditions such as the increase in renewables in electricity supply and the expanded technical possibilities of heat pumps due to the availability of new refrigerants offer the national heat pump industry a wide range of innovations, patents and new markets.

This market potential was recognized by national research institutions and the public sector. The funding volume of national research and development projects focusing on the development of new concepts for industrial heat pumps increased particularly strongly in 2013 and 2014.

Research and development topics up to 2030 include in particular the implementation of sample solutions and pilot plants using heat pump technology already available on the market in selected sectors and processes, the development of improved industrial heat pumps for higher service temperatures and the development of new concepts for industrial heat pumps.

Table 2-1: Promoting and inhibiting factors for industrial heat pumps

	endogenous	exogenous
promoting	• subsidies for commercial sector • pilot and demonstration plants for innovative concepts • high efficiency of industrial processes with waste heat recovery	• currently low electricity prices • currently low rate of interests
inhibiting	• insufficient networking among manufacturers, planners and users • low level of awareness of the technical possibilities and economic feasible application potential	• cautious investment environment due to restrictive lending conditions since 2008 • continuously low oil and gas prices since 2014

3 Case Studies

In this chapter, findings on the successful process integration of industrial heat pumps are processed and documented. For this purpose, case studies are prepared on heat pumps in industrial environments. For the purposes of Annex 48, industrial heat pumps are systems which operate in the medium and large capacity range and provide heat utilisation temperatures of up to 200°C. They are used for heat recovery and for upgrading heat in industrial processes, but also for heating, cooling and air conditioning in commercial and industrial buildings.

To improve comparability, a framework was developed in the international project meetings to describe the case studies in detail. Data on installation, heat pump, costs, effect, satisfaction and experience are recorded. The framework is extensive:

Setup

- Industry, Application
- Process
- Place of installation
- Heat pump manufacturer, Contractor, Consultant, End user
- Year of commissioning

Heat pump technology

- Refrigeration circuit configuration (open or closed circuit, mechanical or thermal compression)
- Refrigerant
- Compressor type
- Heating and cooling capacity
- Heat source and heat sink (inlet and outlet temperatures)
- Evaporation and condensation temperatures
- Storage volume, if available

Effects

- Investment costs for heat pump and installation
- Annual operating hours
- Annual maintenance costs
- Annual operating costs
- Energy savings
- CO_2 emission reduction
- Energy cost savings
- Additional effects (e.g. increase in product quality)

The ten Austrian case studies of the previous project Annex 35/13 (see Zotter et al., 2013) were transferred to the framework and, if possible, new information was added. By desk research and expert discussions with manufacturers and industrial companies, a further 58 examples of industrial heat pumps were added, which are described in more detail in the following illustrations. Heat pumps which are integrated into an industrial or commercial process on the heat source and/or supply side were taken into account. Only heat pumps, that are already in operation, were considered. The examples come from various industries whose good suitability for heat pumps is already known, such as the food industry (17 examples), utility companies (11 examples) and the metalworking industry (11 examples). Figure 3-1 gives an overview of the different sectors.

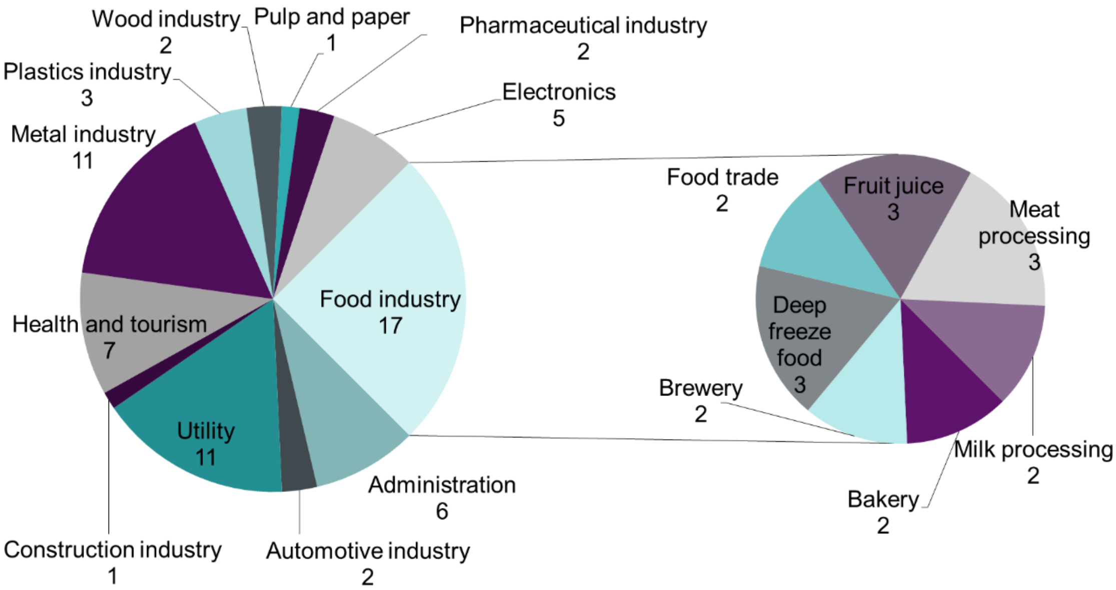

Figure 3-1: Breakdown of Austrian case studies for industrial heat pumps by sector

Different heat sources are used. The most common heat sources are processes that require cooling and waste heat flows from which heat can still be extracted. In addition, the waste heat from refrigeration machines and compressed air systems as well as flue gas condensation is used (Figure 3-2 left). Industrial heat pumps are most commonly used for heating buildings (33 examples) or for providing district heating (19 examples). Process heat supply occurs in 13 examples (Figure 3-2 right).

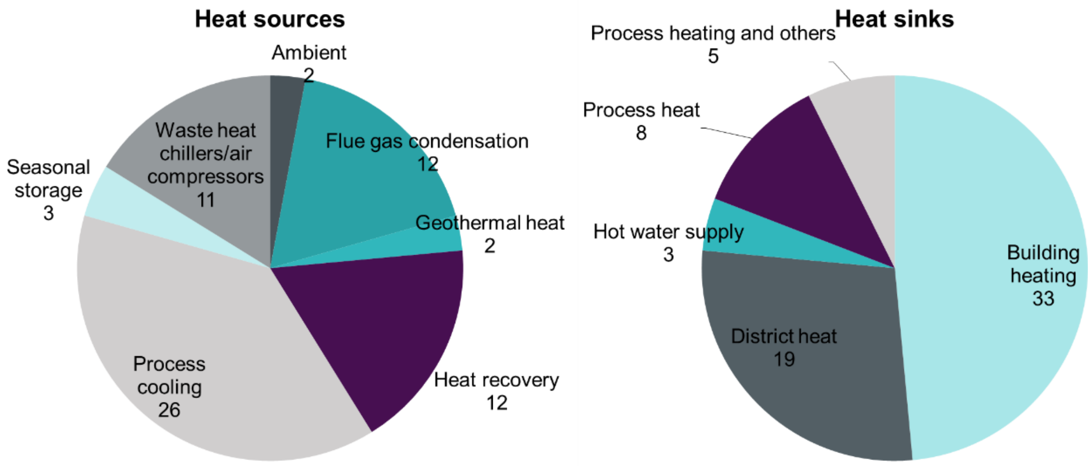

Figure 3-2: Heat source and sink for industrial heat pumps (Austrian case studies)

Among the examples there are 88% of compression heat pumps and 9% of absorption heat pumps, in 3% of the cases both absorption and compression heat pumps are used. Figure 3-3 gives an overview of the coefficient of performance (COP) reported for compression heat pumps.

For the comparison, the COP for heating applications is used, it is defined as the ratio of supplied heat to electrical energy consumed. There are 27 data points available, resulting from different sources and methodologies including performance data from the manufacturers' data sheets, information from the operators on the design of the heat pump and monitoring results. The different colors represent different source outlet temperatures. The lines serve as orientation and show the COP as a function of the heat supply temperature (sink outlet temperature) for different source outlet temperatures (10, 20, 30, 40 and 50°C). This is a fictitious heat pump with a constant Carnot efficiency of 0.5 with a pinch of 2 K in the evaporator and condenser (see below). The majority of the COPs collected are in the range of 3.5-5.5 (approx. 70%), the minimum is 3.3 and the maximum 6.5.

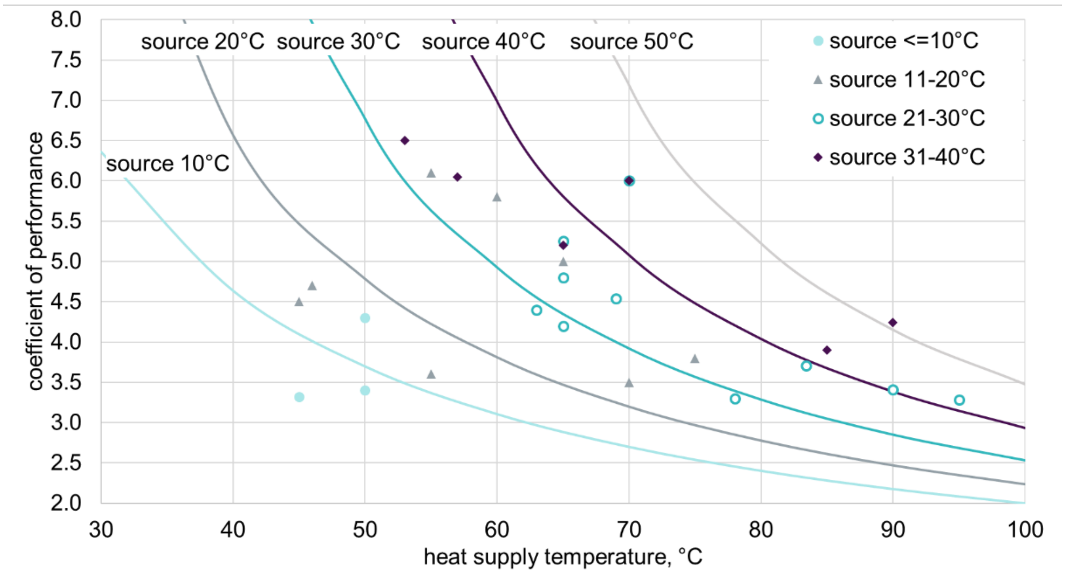

Figure 3-3: COP for compression heat pumps (27 data points)

Based on the COP, possible CO_2 and cost savings can be calculated compared to heat generation with a natural gas boiler. Heat pumps with a COP of 3.5-5.5 save 70-81% of CO_2 emissions. 33-58% of current energy costs can be saved if electricity prices for non-household customers who purchase 20-70 GWh/a are assumed. If more than 150 GWh/a are consumed, the savings can be in the range of 59-74%.[1]

The Carnot efficiency of a heat pump describes how close the COP of the real cycle comes to the maximum possible COP of the ideal Carnot cycle. It is the ratio of the real COP to the ideal COP. The COP of the ideal Carnot process depends only on the evaporation and condensation temperature. To estimate the evaporation and condensation temperatures for the examples, it is assumed that the evaporation temperature is 2 K lower than the source outlet temperature and the condensation temperature is 2 K higher than the sink outlet temperature. Figure 3-4 shows the Carnot efficiency as a function of the temperature lift (sink outlet temperature - source outlet temperature). Most data are available for heat pumps with R134a (11 data points) and ammonia heat pumps (NH_3 = R717, 6 data points). The Carnot efficiencies are predominantly between 0.4 and 0.7. Higher values between 0.7 and 0.8 were calculated for the ammonia plants. Wolf et al. (2014) give typical Carnot efficiency for water/water heat pumps of 0.45-0.5. The remarkably high Carnot efficiencies of the ammonia plants can be explained on the one hand by the fact that ammonia is a refrigerant with good thermodynamic properties, whose cycle comes closer to the thermodynamic optimum than other refrigerants. On the other hand, the estimation of the condensation temperature does not consider the desuperheating of the refrigerant in the condenser. As a result, the actual condensation temperature is lower than assumed. This increases the coefficient of performance of the ideal cycle and the Carnot efficiency is lower than the estimated value.

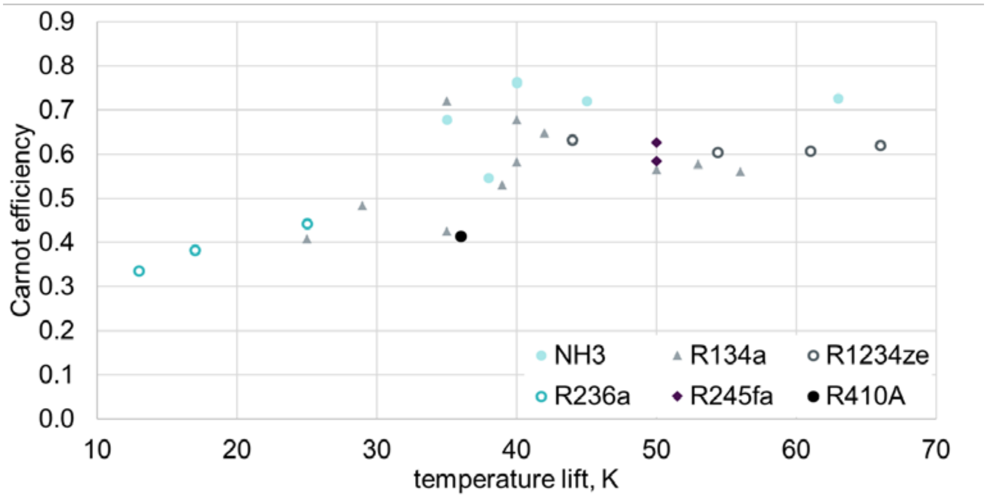

Figure 3-4: Carnot efficiency for compression heat pumps (27 data points)

[1] Gas boiler efficiency 90%, CO_2 emissions from electricity generation 276 g/kWh (OIB, 2015), CO_2 emissions from natural gas 236 g/kWh (OIB, 2015), energy prices for the first half of 2017: electricity price for non-household customers with 20-70 GWh/a 8.8 ct/kWh (EControl, 2017a), electricity price for non-household customers >150GWh/a 5.4 ct/kWh (EControl, 2017a), gas price for industrial customers 3.4 ct/kWh (EControl, 2017b)

Figure 3-5 shows the examples sorted by the time of commissioning (65 examples). A distinction is made between the sectors, where heat pumps are frequently applied - food industry, utilities, metal processing. It can be seen that numerous plants went into operation after 2012. This shows that the spread of industrial heat pumps is increasing in Austria and that more information on the systems is being published - either by manufacturers in the form of references, operators who present their systems at conferences or platforms such as "klimaaktiv" (see klimaaktiv, 2018), where energy efficiency projects are presented and awarded with prizes.

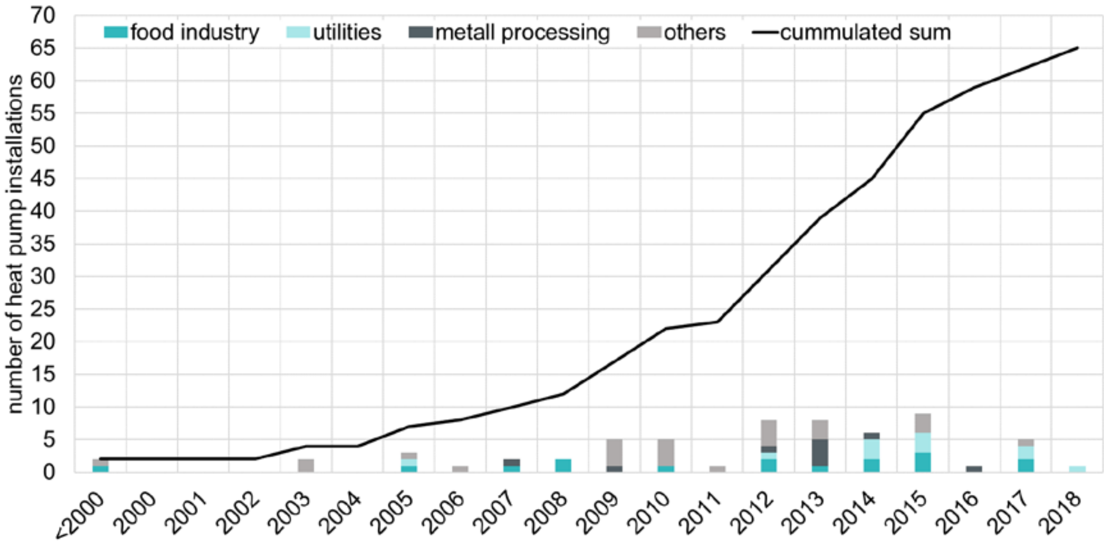

Figure 3-5: Commissioning of heat pumps examples in the period 2000-2018

4 Summary

In Austria, industrial heat pumps still in an early diffusion phase with a few national innovators and early users on the market. Sales figures are available since 2012. By 2017, about 160 industrial heat pumps have been sold in Austria.

Within the framework of Annex 48 and the previous Annex 35, examples of industrial heat pumps in Austria are collected by desk research and expert discussions with manufacturers and industrial companies. A total of 68 examples is available so far. The examples come from a variety of industries whose suitability for heat pumps is already well known, such as the food industry, utility companies and metal processing.

Heat pumps are currently most frequently used in the food industry. These heat pumps are usually used for simultaneous heating and cooling, such as refrigeration machines with waste heat recovery. The heating capacities of the examples are in the range of some 10-100 kW, the heat is mostly used in the company itself (building and production hall heating, as well as process heat). Heat pumps that supply heat around 80°C, which is required for these applications have been available on the market for many years. The second large group of applications are power plants providing district heating. Heat pumps are mainly used for flue gas condensation to further increase fuel efficiency. Both compression and absorption heat pumps are used for this purpose. Heat pumps that use industrial waste heat and supply heat in the MW range generally feed into district heating networks. The number of heat pumps in district heating networks is increasing as a result of the further development of heat pumps to higher heat supply temperatures using new refrigerants. In the examples, the flow temperature of the district heating systems is between 60 and 95°C.

The published COPs of the compression heat pumps are in the range of 3.5-5.5. An estimate of the possible CO_2 and cost savings compared to heat supply with a gas boiler shows that these heat pumps can reduce CO_2 emissions by 70-81% and energy costs by 33-74%. Increasing the efficiency of processes and avoiding CO_2 emissions are important drivers for the further diffusion of heat pumps in industry.

5 Literature

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