LARGE SCALE INDUSTRIAL HEAT PUMPS - MARKET ANALYSIS, POTENTIALS, BARRIERS AND BEST-PRACTICE EXAMPLES

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Abstract: The aim of this paper is to deliver information about possible application of heat pump systems in industry based on a market analysis, an estimation of potentials, best-practice examples and a barrier analysis. The target groups are planners, consultants, energy managers and representatives from industry.
A market analysis is done to illustrate the state of the art of large scale industrial heat pumps, investment costs and operating expenses as well as to provide information about manufacturers and other information centers. For selected applications in different branches of industry best-practice examples are examined. Content of these studies are for example economic efficiency, reduction of energy use and CO_2 emissions. Furthermore a detailed barrier analysis in regard to further distribution of large scale heat pumps is carried out and possibilities to overcome these barriers are investigated and presented. The described work identifies beneficial applications for heat pumps in the industry sector and estimates the potential of heat pumps in Germany.

Key Words: ***Heat pump, Industry, process heat, waste heat, market analysis, potentials, barriers***

1 BACKGROUND AND PURPOSE OF THE PAPER

In Industry there are different possible applications for large scale heat pumps. To supply space heating/cooling and process heat there are in addition to conventional heat sources (water, ground, air) also other heat sources for example waste heat from production or cooling processes on a high temperature level available. These heat sources often can't be used directly in other processes. With the use of heat pumps this industrial waste heat can be utilized for internal production processes and space heating or it can supply external consumers, for example housing estates.
Although heat pump technology is suitable for a large number of applications in industry the potential of low cost industrial waste heat is according to the Ministry of economics of Baden-Württemberg in 2005 barely used. This fact can be referred to insufficient information of potential applicants, installers and consulting companies and in the same way these types of heat pumps require individual planning, construction and realization.
The aim of this paper is to deliver information about possible application of heat pump systems in industry based on a market analysis, an estimation of potentials, an overview on best-practice examples and a barrier analysis. The described work identifies beneficial applications for heat pumps in the industry sector and estimates the potential of heat pumps in Germany.
In order to identify beneficial applications for industrial heat pumps and to show the technical feasibility six working steps are conducted as described below.

2 STATE OF RESEARCH

So far conducted research about industrial heat pumps in Germany only refers to small and medium sized heat pumps for heating and warm water supply. Next to information brochures for potential users (see for example (LGA 2003), (LGA 2000), (Ochsner 2007), (RWE 1998), (IWP 1996)) comparisons with other heating systems are at the focal point of consideration (see for example (Leven et al. 2001), (Fischedick et al. 1997), (Hoffmann et al. 1999), (Feist, Baffia 1998)).
Furthermore there are publications about the use of medium sized heat pumps in municipal facilities (for example administrative buildings, baths), businesses (for example hotels, residential home for the elderly) and space heating of industrial production and office buildings (see (LGA 1999), (BINE 2003), (BINE 2003a)). Main used heat sources are ground, water and air. The use of waste heat as heat source as well as combination of heating and cooling processes are barely discussed (see (Wirtschaftsministerium BW 2005), (DKV 2000), (DKV 2001), (Weber 1995), (Reiner 1994), (Ziegler et al. 1994)).
According to (Wirtschaftsministerium BW 2005) and (Heidelck et al. 2000) the use of heat pumps in German industry and the tertiary sector is relatively low compared to other countries like Great Britain, USA, Spain, China, Japan, Denmark or Norway. Possible beneficial applications are:

- Heat pumps for space heating and heat recovery as part of air conditioning systems in office buildings and department stores
- Heat pumps for simultaneous heating and cooling
- Heat pumps to utilise low temperature heat for production processes
- Vapour compressors and digester house utilities for evaporation and thickening of fluids
- Combined heat, cooling and power production

Main industry branches of interest are:

- Metal processing
- Food industry
- Chemical industry
- Building material industry
- Paper, wood and textile production industry

3 MARKET ANALYSIS

A market analysis is done to illustrate the state of the art of large scale industrial heat pumps, investment costs and operating expenses as well as to provide information about manufacturers and other information centres.

3.1 State of the art

Only few manufactures offer large scale industrial heat pumps in their portfolio. The range of performance goes from 100 kW_{th} up to 1500 kW_{th} heating capacity (one manufacturer up to 34 MW_{th}). In regard to economical aspects the possible COP ranges from 2.4 up to 5.3 with a limit of 6 to 7 and the possible temperature level goes up to 65 °C with a maximum of around 75 °C with the current heat pump technology. This temperature level is standard with state of the art cooling liquids. In a two-stage arrangement temperatures up to 80 °C are possible. Some examples of individual planned and realised heat pumps were found that are able to provide 90 °C with a heating capacity of about 300 kW. In the range of 5 to 500 kW heating

capacity plate heat exchangers are used for liquids and in the range of 50 to 2000 kW stacking-pipe heat exchangers are preferred. For gases disk heat exchangers are used for a range of 5 to 500 kW.
Manufacturers and relevant associations do not supply useful and up-to-date information about basic condition for the use of heat pumps and figures of the number of large scale heat pumps used in German or European industry are not available. The use of sewage for heating shows growing importance for new residential areas (leading country Switzerland).
Another quite new type of heat pumps are so called “Gas-Klimageräte”. These are gas-powered air-condition systems that are able to supply cooling and heating. In operating condition “heating” these systems use the heat of outer air for the heat supply.
In regard to the feasible temperature level of heat pumps new refrigerant fluids are under development. Tests with R 227ea for example show possible temperatures of around 90 °C. The application of R 245fa should result in temperatures of more than 100 °C. So far it can not be said when these refrigerant fluids are available as state of the art on the market.

4 ANALYSIS OF POTENTIAL APPLICATIONS

To identify potential applications for heat pumps in industry and the tertiary sector it is examined how the results of international studies for example (IEA 1995) can be transferred to enterprises in Germany. Therefore the described applications are transferred to processes and the determining factors of German industry. On the other hand further potential applications are identified by evaluating industry analysis in regard to temperature level and potential heat sources. One main focus is the use of waste heat and the combination of heating and cooling processes. Herefrom outstanding relevant applications are derived and in detail analysed in the next working step.
Main possible applications for industrial heat pumps in Germany are identified by a process specific analysis of industry branches. **Table 1** shows examples of examined processes.

Table 1: Process specific examples for applications

Industry	Branch	Process	Temperature [°C]	Specific heat demand [MJ/t]
food	brewery	mash	78	61
	brewery	bottle wash-up	80	54
	brewery	barrel wash-up	80	25
pulp and paper	paper	recovered paper recycling	45	252
	paper	drying processes	100	3960-6840
	paper	finish	60	29
chemical	basic material production	chlorine production	100	270 / 1620
	plastics production	PVC production	100	18
	plastics production	polypropylene generation	50	43
building material	brick production	homogenise	80	14
wood	wood	drying	70-105	900
metal processing	automobile	washing	60	4460
	automobile	scouring	60	5 231

In regard to the possible temperature level of current heat pumps main applications are hot water supply, space heating (up to 65 °C) and low-temperature process heat.

5 BEST-PRACTICE-EXAMPLES

For selected applications in different branches of industry with special interest feasibility studies are conducted. Therefore different enterprises are contacted for which the identified application is of great benefit. Content of these studies are for example economic efficiency, reduction of energy use and CO_2 emissions. With this detailed analysis significant information about feasibility and economic efficiency of industrial heat pumps are provided. Furthermore this information is used to estimate the potentials for heat pumps in Germany. The analysis of possible applications shows that for the moment most of the current applications use waste heat as heat source and are very specific in regard to the special requirements and conditions of the analysed company. Several companies use waste heat from production processes to heat their office buildings. These applications range from around 90 kW_{th} up to around 970 kW_{th} and were installed between 1980 and 2004. One company uses groundwater for heating and cooling of two hotel-complexes with a heating capacity of around 430 kW_{th} each. One was opened in 2004 and because of very satisfying results another heat pump was installed in a new hotel building and put in operation in autumn 2007. **Figure 1** illustrates for eight different examples the possible reduction due to the use of the heat pump for the complete system in comparison to a conventional system configuration.

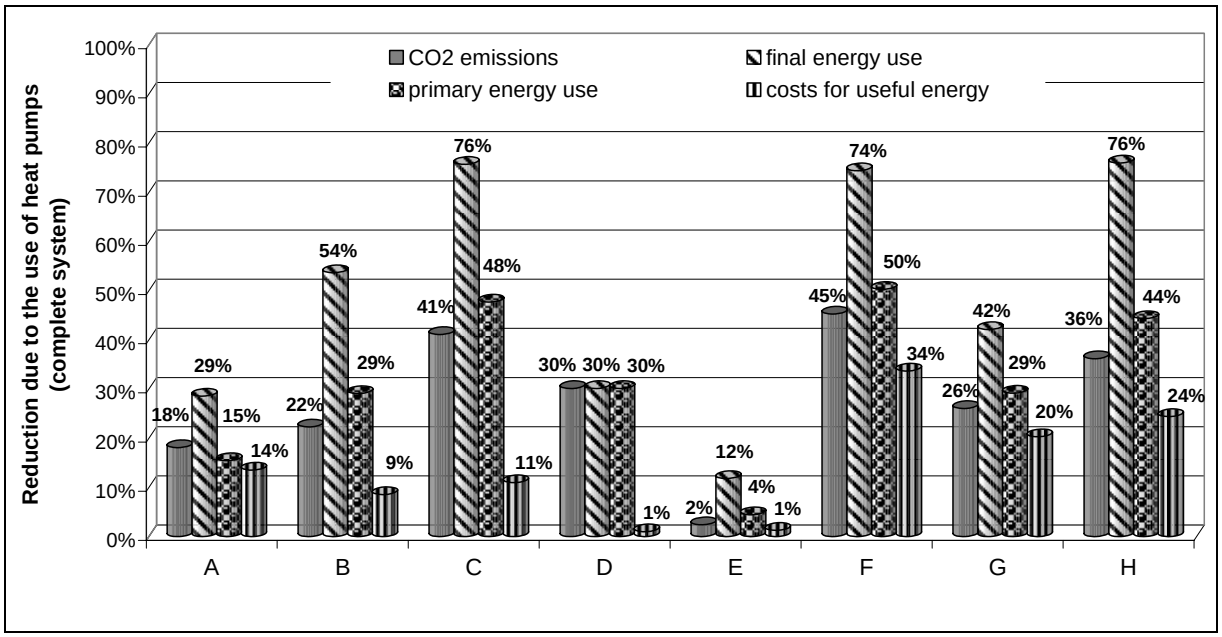


Figure 1: Possible reduction after installation of a heat pump in the complete system

Therefore the possible reduction in CO_2 emissions ranges from 2 % in case E up to 45 % in case F with an average reduction of around 28 %. The use of final energy can be reduced from around 12 % (case E) up to 76 % (case C, H) with an average reduction of almost 50 %. If you look at the primary energy use there is still an average reduction of around 31 % and it ranges from 4 % in case E up to 50 % in case F. In regard to the costs to supply one kWh of useful energy in every case the heat pump system is cheaper at current energy prices. In average the cost reduction to supply one kWh of useful energy is around 14 %. The possible cost reduction ranges from 1 % (case D, E) up to 34 % (case F). In conclusion it can be said that the amount of reduction depends on the correct integration of the heat pump in the existing system and on the heat amount supplied by the heat pump.

6 BARRIER ANALYSIS

As the use of heat pumps in German industry is rather low a detailed barrier analysis in regard to a further distribution of large scale heat pumps is carried out and possibilities to overcome these barriers are investigated and presented. To comprehend and assess the relevance of barriers empirically, the market analysis is evaluated in detail. Furthermore interviews with manufacturers and experts are conducted. Beyond that it is evaluated how energy suppliers or Contracting companies for example with financing models or expert knowledge are able to support overcoming the barriers. But the barrier analysis shows several important constraints to this development. Most mentioned barriers are:

- Cost pressure resulting from competing technologies for heat supply
- Competition with heat recovery systems
- Competing technologies for supply of other temperature levels already installed
- Process specific design essential
- Complex and cost-intensive linkage of heat pump system and existing system
- Separation of heat pump system from conventional heat supply system essential
- Risk in regard to production security (if waste heat is used as heat source)
- Requested payback period maximum 3 to 4 years
- Output temperature level of current heat pumps for many processes to low
- Lack of knowledge about possible applications and technical basic conditions for heat pumps in industry, consulting companies, utilities and planers

Next to technical barriers, mainly the insufficient high output temperature of current heat pump technology, there is a great lack of knowledge about possible applications and technical basic conditions for heat pumps in industrial processes in companies, planers and technical firms. Information brochures, corporate information platforms of manufacturers or road shows are possibilities to improve knowledge about possible applications of heat pumps in industrial processes. The cooperation of heat pump and component manufacturers to provide up to date information e. g. life cycle costs or to concentrate research and development activities could support and strengthen the standardization of components and the further development of current heat pump technology. Thereby disadvantages in regard to investment costs of heat pumps (in comparison to conventional heating system) as well as time and cost intensive design and planning processes could be reduced and minimized.

7 POTENTIAL ANALYSIS FOR LARGE SCALE HEAT PUMPS IN GERMANY

To estimate the technical potential that can be made available by the use of heat pump technology in the German industry sector, calculations in regard to the usable temperature level and the identified applications based on the energy consumption of different branches of industry are conducted. The possible reductions in primary energy consumption as well as CO_2 emissions are calculated. This analysis is done for different sizes of enterprises within the same branch of industry to consider for example differences in energy costs and production structure.
The conducted analysis shows for Germany that for hot water supply in industry around 14.56 PJ per year could be provided by heat pumps. For low temperature process heat and for heating three different steps are calculated in regard to the possible output temperature of heat pumps (70°C, 80 °C and 100 °C). At current technological level (70 °C) heat pumps could supply around 161.37 PJ for heating and 55.13 PJ process heat per year. Altogether heat pumps witch current technology have the potential to supply 231.06 PJ per year. By raising the temperature to 80 °C this number increases of about 10.56 PJ per year supplied by heat pumps. To raise the possible temperature level up to 100 °C would result in an increase of possible heat supply of additional 147.91 PJ per year.

Figure 2 illustrates the potential of heat supply for heat pumps for selected industry branches. This graph shows the importance of raising the possible output temperature of industrial heat pumps from currently around 70 °C up to 100 °C.

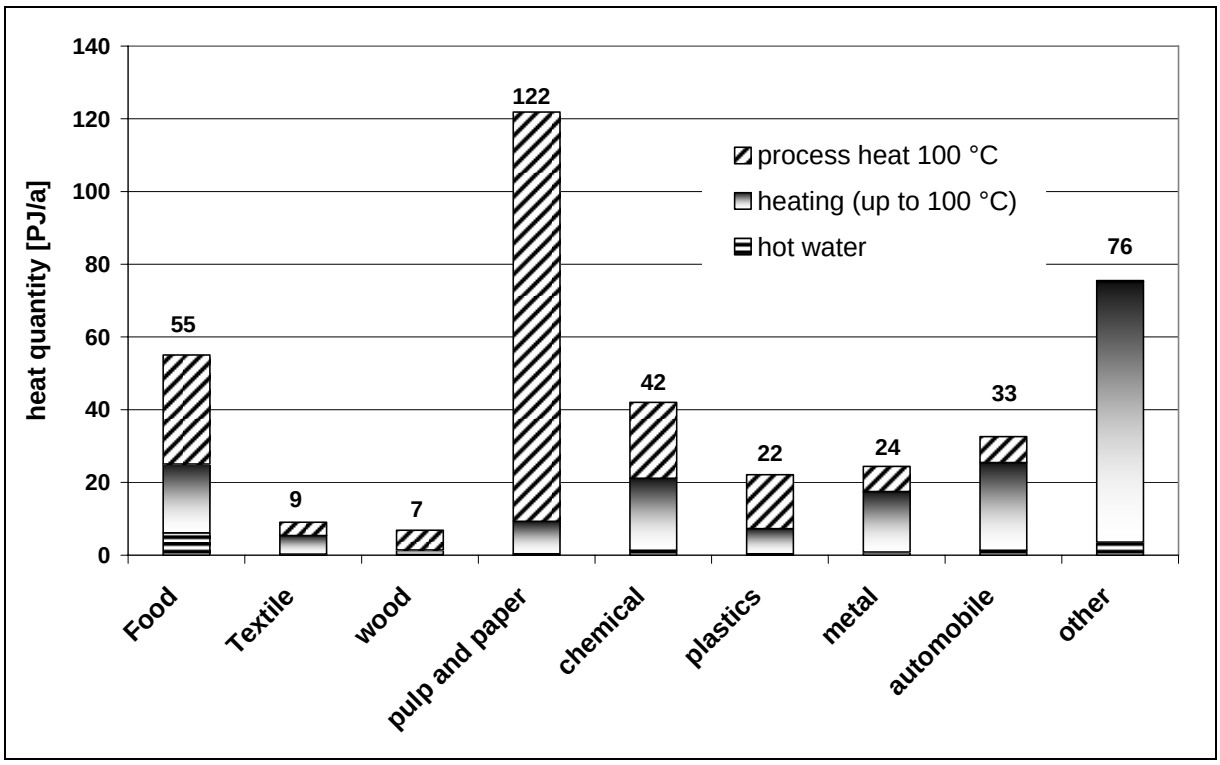


Figure 2: Possible heat supply with heat pumps for selected industry branches

Altogether it can be said that heat pumps (output temperature 100 °C) have the possibility to provide around 389.53 PJ per year what is equal to around 16 % of the total energy consumption of German industry in 2005. But up to now just a very small number of this potential is used.

8 CONCLUSION

According to the current analysis of potential applications and the best-practice examples it can be concluded that the main applications are hot water supply and space heating. For most industrial processes the possible temperature level of current heat pumps is not sufficient. But the use of waste heat offers in addition to the result of the potential analysis another huge potential for heat pumps in industry. Furthermore the contact with manufacturers, potential users, planers, associations and information centres shows that the knowledge about large scale heat pumps is rather low. For the application of heat pumps specific conditions must be adhered in order to get satisfying results.

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