HEAT PUMP TECHNOLOGY FOR LARGE BUILDINGS – A POTENTIAL STILL TO BE DEVELOPED

K. Ochsner, President Ochsner Wärmepumpen Gmbh, Linz, Austria

Abstract: The traditional heat pump market in Europe has so far predominately been a market for family houses. Basically the traditional market was for newly built homes but today the retrofit market is rapidly increasing. The development of new heat pump technologies for 65˚C flow temperatures for all heat sources has been a conditional factor. In the past we do not find many applications for large capacity heat pumps (100 kW to 11 MW) in Europe. Today some few producers are developing large heat pumps commercial application, office and municipal buildings, etc., especially optimised for heating purposes. These heat pumps use specially designed compressors and refrigerant cycles in order to improve COP and provide flow temperatures up to 65˚C. These high temperatures are required for the retrofit market. The article describes the market for large heat pumps and shows how to overcome barriers to develop these potentials.

Key words: *large heat pumps*

1 INTRODUCTION

Heat pumps can dramatically contribute to reach the 2020 goal of improving energy efficiency by 20 % and at the same time to reach a 20 % renewable energy share. Heat pumps also have the ability to cut CO_2 emissions dramatically and to reduce primary energy consumption by 50 % to 80 %, compared to any fossil heating system, depending on service conditions and heat source. Therefore this technology is very important for reaching the EU energy and climate targets. While heat pumps with smaller capacities are already widely used for residential heating in some EU countries, the use in large buildings is practically zero at present. But this field shows a huge potential.

Heat pumps with larger capacities are used for heating and cooling of plants, office buildings, housing estates, administrative buildings, hotels and leisure time facilities.

Through the savings of energy and operating costs gained in the process in comparison to conventional heating and cooling systems, the utilisation is specifically cost-efficient. Machines of a certain size are also ideally suited for the utilisation of low temperature distant heating, for waste heat of any kind, process heat and geothermic energy.

Since the technology used in large heat pumps differ fundamentally from the one in smaller facilities the experiences and know-how connected to the development of conventional heat pumps cannot be transferred directly to the large capacity heat pumps.

Large heat pumps for instance are equipped with half hermetic compressors. Depending on the capacity of the facility those are mostly multicylindric piston compressors and screw compressors. Theoretically also turbo compressors can be employed. (Screw compressors and turbos do not have any bidirectional parts and therefore a quieter motion). In the case of water/water respectively brine/water heat pumps disc or pipe bundle heat exchanger are employed as vaporisers and condensers.

Figure 1: Large capacity heat pump with tube and shell heat exchanger

Large heat pumps have a potential for generation of heating and cooling that has been considered far too little. For this reason the efforts and successes of the efficiency increase of heat pumps was mainly in the application for single- and multi-familiy houses. An optimisation of large heat pumps is still outstanding and would definitely lead to an increased share of energy supply covered by this technology in trade and industry.

2 LARGE HEAT PUMPS AND SUSTAINABLE ENERGY USE

Conventional heat pumps provide useful heat mainly from natural energy sources: earth-source, ground water and air. In commerce and industry these sources can be complemented by another very important and still little utilised resource. The resource concerned is waste heat that can easily be utilised as a heat source both in commercial and industry buildings themselves as well as in other buildings. Thus large heat pumps are suitable directly in the industrial field as well as in fields that could utilise the industrial waste heat. In this way large heat pumps are suitable for office and administrative buildings, industry facilities, schools, hospitals and hotels as well as for the concentrated residential housing.

Through this broad field of application and the possibility of a variety of energy sources the large heat pump is a technically ideal solution to realise a sustainable energy use in the fields of heating and cooling supply of large buildings. Through the employment of the heat pump different sets of action can be realised which an energy industry, arranged in this way, offers.

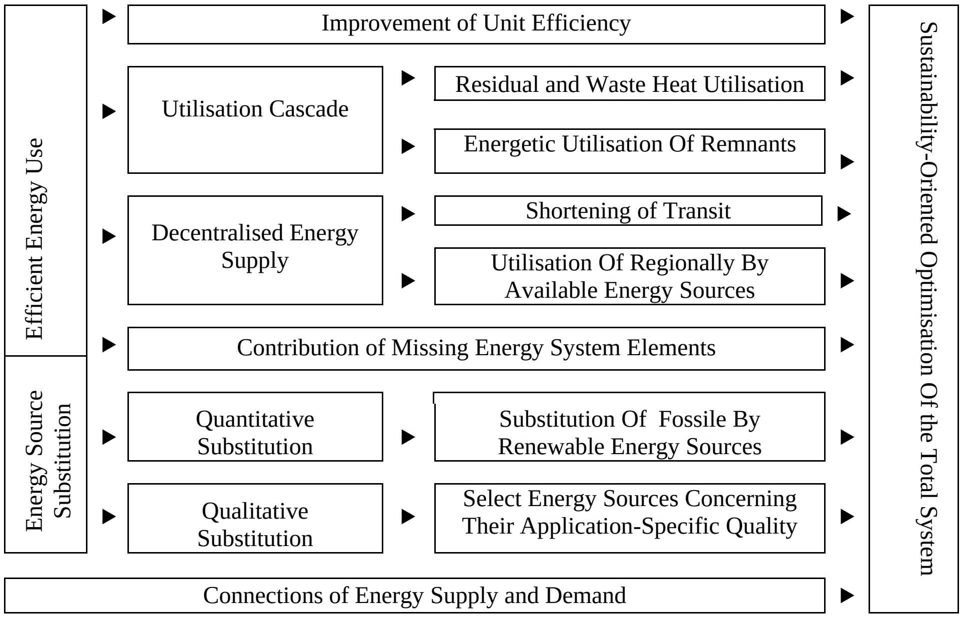

Figure 2: Procedure in improving energy efficiency and the use of sustainable energy (Malinsky 2006)

A sustainability-oriented energy industry has the target to optimise the total system with respect to economic and ecological aspects. To attain this target the strategy of an efficient energy use as well as the energy source substitution are employed.

Efficient Energy Use: A deciding factor for improvement of efficiency in energy use is not only the improvement of the facility efficiency (in these fields unemployed opportunities with regard to large heat pumps still exist and therefore the demand for research and development) but also in the realisation of the utilisation cascade. The utilisation of residual and waste heat from industrial processes mentioned above is to be seen as a starting point.

Furthermore, the utilisation of the decentralised energy supply can lead to an improvement of the efficiency in energy supply. This target corresponds to the employment of large heat pumps, thus regionally available ambient heat respectively residual/waste heat could be utilised and therefore transport of energy sources becomes dispensable.

To employ missing energy system elements in this context means that potentials not utilised will all of a sudden be able to get utilised and energy consuming business become energy suppliers because of the utilisation of waste heat through the use of large heat pumps. The newly introduced system element respectively the connection between (previously) not utilised supply potentials and demand potential is in this case the large heat pump.

Energy Source Substitution: The employment of the large heat pump further contributes to a switch in the use of energy sources and this substitution does not only occur in form of a quantitative substitution (fossil energy sources through ambient heat) but also in the form of a qualitative substitution. This means that energy sources can be employed regarding their qualities and requirements in the respective processes. While conventional energy use is characterised by the fact that the use of energy rich energy sources like crude oil and natural gas are wasted in low temperature applications, the heat pump utilises low enthalpy for the generation of space heating and thereby contributes to the energy sources being application specific and thereby efficiently employed.

3 POTENTIAL OF HEAT PUMPS IN LARGE BUILDINGS BASED ON THE EXAMPLE AUSTRIA

Considerable potential for large heat pumps is to be seen in the field of services and trade/ industry. This will subsequently be explained in more detail:

Services Industry: The share of energetic end use by public and private service organisations in Austria amounted to 11.7 % in the year 2004 and is charactarised by an annual growth of 1.6%.

The services sector consists of a variety of industries with very differing activities of economic, social as well as sovereign kind. These differences finally also have an impact on the structure of the respective energy demand.

Trade/ Industry: Besides the service area mainly the area trade/industry shows high energy consumption in the field of space heating and warm water. The energy consumption of the sector trade and industry amounts to 36.1% of the total energy end consumption and increased by 0.5% in the year 2005.

For the different industries potential assessments for the employment of large heat pumps for the provision of space heat/air-conditioning were concluded in the study „Heat Pump Action Plan Austria (Lutz 2007). Thereby potentials, connected to the respective industry and the size of companies were compiled. The study differs between “small businesses” (1-9 employees) “middle businesses” (10-49 employees) and “large businesses” (50 employees and more). Figure 3 shows these potential estimations that were compiled in cooperation with the Federal Heat Pump Association.

Industry		**Tourism**	**Public Administration**	**Education**	**Healt**	**Credit/ Insurence**
Max. %-Potential HP Space heat	Small	50	50	50	25	25
	Middle/ Large	25	10	10	5	5
Branche		**Entrepreneurs/ Services**	**Misc. Services**	**Industry/ Trade**		
Max. %-Potential HP Space heat	Small	25	25	50		
	Middle/ Large	5	5	10		

Figure 3: Potential of heat pumps in various sectors (BWP 2007)

Based on the individual industries’ respective share of total energy consumption in the sector trade/industry the yearly growth, considering a useful energy value, for the year 2020 was predicted. The predicted useful energy demand for heating, hot water supply and cooling of the chosen industries amounts, corresponding to the chosen rate of growth, in total approx. to 26 TWh (94 PJ). Useful energy amounts to approx. 4.2 TWh (15.1 PJ) and could thereby be supplied by heat pumps.

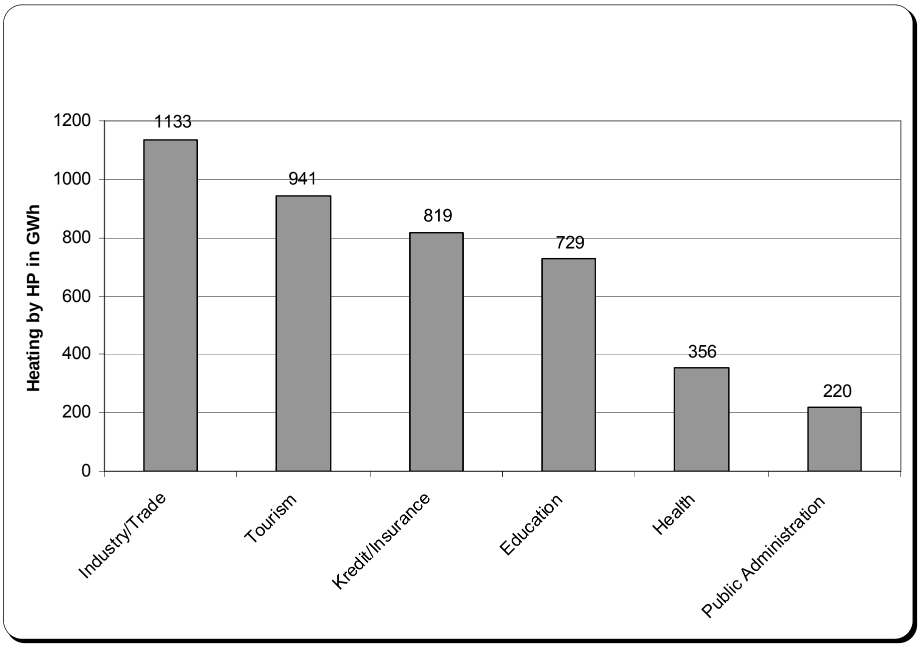

Figure 4: Potential of heat pumps In the areas services and trade/industry (BWP 2007)

Since **tourism** is an important economic factor in Austria the hotel sector is a particularly interesting sector for applying the large heat pump. 60-80 % of the hotels' total energy consumption is caused by space heating. Especially the high quality hotels mark itself through especially high energy consumption (wellness facilities, sauna, Turkish bath, swimming pools). Using large heat pumps in this field can contribute to an emission free, inexpensive form of energy supply. (A short practical example follows at the end of the article). Other field are office buildings, banks and insurance companies. Energy is used for space heating to an extent of approx. 62% in these buildings – the share for water heating amounts to 1%. Also health care and here especially the big hospitals are characterised by high energy consumption for space heating and air-conditioning. In education approx. 90 % of energy consumption is due to space heating. Here especially older buildings not structurally not oriented to low temperature heating require that large heat pumps can also generate flow temperatures of 65º C. Likewise important is the employment of (large) heat pumps in the field of public administration.

Is the area trade/industry analysed concerning potential within the industry, the dependence of the respective process a different potential in demand regarding space heat and cooling demand can be determined. Likewise a different amount of low temperature waste heat that can be utilised with heat pumps. Following are some examples:

Sugar Refinery: Energy consuming steps of production in the sugar industry are in particular the cleaning of sugar beet and the following process steps of extraction and juice cleaning. In these processes a low temperature heat between 60º C and 80º C is needed.

Dairy Processing: This industry excels in a considerable demand for low temperature heat that is mainly employed in the sterilisation of milk as well as in the thickening of milk in sour milk products. Moreover, the energy is on the one hand used for heating of the storage during the ripening process on the other hand it is consumed for the use of cooling machines.

Butcheries and slaughter houses: Energy is mainly used to drive machines and tools but also for cooling, space heating and steam generation.

Breweries: Large shares of the energy consumption are due to beer production and the provision with low temperature heat.

Next to the energy demand of these industries supply potentials exist that could be utilised through the heat pump. Figure 5 shows demand and supply of the area trade/industry.

Industry	Branch	Demand		Supply Temp.
		Non Electrical Heat	Cooling Demand	Low Temperature Heat Demand
Food Industry	Dairy Factory	High	High	Low
	Sugar Production	High		Low
	Cooling House		High	Low
Beverage Industry	Brewery	High	High	Low
Textile Industry	Spinning Mill	High		
	Textile Print Shop	High		
	Rope Manufacturer	High		
Leather Processing	Shoe Production	RH/ Ventilation		
Wood Industry	Saw Mill	None		None
	Joinery	None		None
Paper and Pulp	Paper Mill	High		Very High
Print Shop	Print Shop	High		
Plastics Production	Plastic Production		Low	
Chemical Industry	Fertiliser	Low		Very High
	Technical Gases	Low	Very High	Very High
Bricks and Cement	Bricks Production	High		Very High
	Cement Production	High		Very High
Glassworks	Glass Production	High		Very High
	Glass Processing	High	Middle	High
Iron and Ore	Steelworks	High	High	Very High
	Hot/ Cold Rolling Mill		High	Very High
	Foundry	High		

Figure 5: Heat demand and supply temperature (heating - cooling) in various industries (Lutz 2006)

4 POTENTIAL FOR HEAT PUMPS IN LARGE BUILDINGS IN THE EU

In Austria the potential for large heat pumps in the field of large buildings and commercial use is estimated to be 15 PJ, while the total energy demand for heating and cooling in these areas amounts 94 PJ. The potential for large heat pumps is therefore about 15 %. As the share of energy demand of Austria in the former EU-25 amounts to 2.24 % the energy demand of heating and cooling in the described areas would be about 4,200 PJ (2.24 % = 94 PJ). The potential of large heat pumps can then roughly be estimated as 630 PJ (15 % out of 4,200 PJ).

Large heat pumps could provide an amount of **630 PJ useful energy** in the field of large buildings and commercial use throughout the EU (based on Energy demand of EU-25). Conventional heating systems have average efficiency factors of η=92%[1]

With an average efficiency factor of 92 % the energy consumption using conventional heating systems (oil, gas, electro heating) would be 684 PJ final energy. The amount of energy savings through large heat pumps achieving a SPF of 4[2] therefore would be 527 PJ.

The above data based on Austrian potentials are to be seen as a rough estimate as no data about the EU-market penetration of large heat pumps and their potentials are existing yet. Heat pumps are already widely used for residential heating (small sizes) in some EU countries; however, the use in large buildings today is practically zero.

5 BARRIERS TO THE INTENSIFIED EMPLOYMENT OF LARGE CAPACITY HEAT PUMPS

Why have large heat pumps not yet been established on the market? There are enough advantages. Alone the reduction of CO_2 emissions, the reduction in consumption of primary energy resources, but also the benefit that residue energy could be utilised, that heat pumps on site produce no emissions (tourism!) would be an important argument in favour of this technology.

In the scope of a research project (IER Stuttgart/Company Ochsner heat pumps) the barriers for the broad application of large heat pumps was investigated. The analysis shows that especially the following points are barriers to the propagation of this technology:

- Competition from conventional heat recovery
- Cost pressure of competing technologies
- Competing technologies for covering higher temperature ranges are already installed
- Process specific facilities necessary
- Integration into existing systems necessary
- Integration into existing systems is time-consuming and expensive
- Separation of heat pump circulation from conventional energy supply necessary
- Required payback time ≤ 3 to 4 years
- Risks concerning production guarantee
- Attainable temperature level so far too low for many applications
- Missing knowledge concerning process technologies and the heat pump technology in industry, consulting, utility companies etc.

The mentioned barriers are principally reducible to technical – economic reasons as well as lacking information.

5.1 Technical Requirements

At present heat pumps for family house applications are being optimized also for higher supply temperatures. Only very few manufacturers of large heat pumps have done so for larger capacities. The increase in efficiency of large heat pumps both in heating and in

---

1 Oil boilers η= 90 %, gas-boiler η= 85 %, condensing gas boiler η= 95 %, electro heating η= 100 %
2 SPF of 4 means: 3 parts geothermal (ambient) heat from 4 parts total energy output

cooling applications is one of the steps to encounter the cost pressure of competing technologies. In order to optimize heat pumps for high flow temperatures the following points are important:

1. Improvement of the refrigerant cycle technology (compressor, condenser, expansion valve, evaporator) to increase COP value. Improvement of compressor technology for providing highest screw compressor efficiencies.
2. Heat Exchanger
With water/water respectively brine/water heat pumps tube and shell heat exchangers offer highest performance.
3. Design system for outlet temperature of 65°C
Regarding the supply temperature in the heating mode, the traditional supply temperature to the heating system of maximum 50°C is not sufficient for retrofit and is not in accordance with hygienic regulations for domestic hot water in many European countries. The goal is to enable an outlet temperature of 65°C in order to make the range suitable for the renovation market.
4. Using improved compressor technology
Compressor technology is the key component of a heat pump. The aim has to be to search for the most advanced compressor technology available on the market.

5.2 Barriers due to Information Deficits

A second kind of barrier generally exists because the fact that heat pumps can also be employed in industrial fields is not yet widely known, even if the heat pump technology itself certainly is. This information deficit must be addressed as successfully as once the deficit for heat pumps for small power ranges. Heat pumps are a technology which strongly needs to be explained to people. Since the market for large heat pumps is still very new perception and know-how deficits concerning the possible applications still exist. For this reason it is necessary both to inform and teach the end-consumer, the planner and the installer. An enforced linking between heat pump producers, components producers and research facilities could promote a standardised series construction with an optimisation geared toward the whole concept. This would be important since many producers of large heat pumps currently plan individually and produce individual pieces (and hence expensive).

6 BEST PRACTICE

HOTEL IN AUSTRIA

As mentioned above the high energy costs are presently a very big problem for many hotels. According to data of the OEHV (Austrian Hotel Association), energy costs amount to six percent of the yearly net turnover from tourism enterprises. The energy costs in the last three years rose by 25 percent, whereby the constant rising costs of fossil resources are mainly responsible for this progression. Today the increasing costs for space heating and water heating can hardly be taken into account in the calculation of the room prices and for this reason reduces the profit per guest.

In addition, also the dependency on fossil resources means a risk for tourism companies: particularly in their vacation tourists will not show understanding if, due to political disputes or scarcity of raw materials, hotel rooms, showers and swimming pools remain cold. Security of energy supply is thus a central requirement for satisfying guests; a requirement that in future will hardly be fulfilled with fossil energies. A large heat pump is therefore an ideal heating system, which can solve all these problems and fulfil the requirements of the guests.

The Austrian four-star - superior hotel "First Almwellness Hotel Tuffbad" in the village of Lorenzen in Carinthia decided to substitute the old oil heating system by a large heat pump as heating system. In spring 2003 the hotel opened its gates. The four-star hotel connects wellness, health resort and the strength of the elements with a genuine nature. An ecological heating also fits in with the philosophy of the house.

Figure 6: First Almwellness Hotel Tuffbad in the village of Lorenzen in Carinthia

The municipality had already installed a heat pump to use the 12°C ground water for the heating of the municipality bath. The hotel operator decided to use ground water as well for the heating of the hotel and to replace the existing oil heating by a heat pump system. Two water/water heat pumps with a capacity of 54.4 kW each, supply at present approx. 1.500 m² under-floor heating inclusive swimming pool, wellness and restaurant. The heat pumps also replace the oil heating for hot water supply.

INDUSTRIAL BUILDINGS IN AUSTRIA

Figure 7: Organic farm Achleitner - company headquarters In Upper Austria

The organic farm Achleitner, a vegetables wholesale business, is one of the largest passive houses in Austria. The challenge to technical planning was the diversity of requirements for space heating and air conditioning. In this building cooling houses, loading zones, offices, an organic fresh market and a restaurant are integrated. Heating and cooling are considered one entity in the building. 12 kilometres of pipes in the floor bear the base load. A ventilation system turns itself on and off when required. When needed heating or cooling is taken from storage. Centrepiece of the energy generation are two heat pumps that are used for heating as well as cooling. The two heat pumps have respectively 54.4 kW heat output and 44.5 kW refrigerating capacity. The heat pumps dispose of a scroll compressor, premium steel plate heat exchangers and have a coefficient of performance of 5.5.

TOP CURRENT REFERENCES

Citygroup Datacenter Frankfurt

The data center was built by the so called Gold-standards of LEED (Leadership in Energy and Environmental Design). LEED is the benchmark for sustainable building in the United States. The building is equipped with 2 large heat pumps with a capacity of 175 kW each.

Commissioning	2008-03-10
Heat source	chilled water
Heat pump type	2 x IWWS169ER2
Compressor type	1 x Screw
Installation data	heat source: 15/10
Supply temperature	50/40 °C
Capacity	2x175 kW

Museum Center Hagen

Two brine-water heat pumps provide geothermal power to the modernised Karl Ernst Osthaus museum and the new build Emil Schumacher museum in Hagen.

Commissioning	2008
Heat source	brine-80 geothermal probes
Heat pump type	2 x ISWS204ER2
Compressor type	1 x Screw
Installation data	heat source: 5/1
Supply temperature	40/35°C
Capacity	2x235,9 kW

7 CONCLUSION

The main application for large heat pumps are currently in the field of space heating/hot water preparation and air-conditioning – also in commercial application, the building sector and industrial low temperature processes. Huge potential has been identified in these mentioned sectors. Potentials which have to be developed in detail. As we are talking of new applications there is still a lot of work to be done. To increase the awareness of the potential and demonstrate proper application of large capacity heat pumps a special seminar will be organised on June 3rd, 2008 by Ochsner and IER Institute of the University of Stuttgart.

8 REFERENCES

Heidelck R., Kruse H., Laue H.-J. 2000. *Wärmepumpen in Gewerbe und Industrie – ein Überblick,* Hannover

Malinsky A.H, Lutz G. 2006. *Regionales Systemmanagement – eine Methode zur nachhaltigkeitsorientierten Optimierung von Energiesystemen*, Marburg

Lutz G. 2006. *Überbetriebliche Energienetzwerke im Rahmen einer nachhaltigen Energienutzung*, Linz

Ochsner K. 2007. *Wärmepumpen in der Heizungstechnik – Praxishandbuch für Installateure und Planer, Heidelberg*

Lambauer J., Fahl U., et al. 2008. *Noch unveröffentlichte Studie: Großwärmepumpen – Potenziale, Hemmnisse und Best-Practice Beispiele,* Stuttgart

Lutz G. 2007. *Österreichischer Wärmepumpenaktionsplan* (Study commissioned by BWP/LGWA), Linz

Ochsner K. 2007. *Geothermal Heat Pumps A guide for Planning & Installing*