Importance of Heat Pumps in different regions and markets

Rainer Jakobs, Information Centre on Heat Pumps and Refrigeration IZW e.V.
Kreuzfeldstr. 10a 64747 Breuberg, Germany

Abstract:
1920 G. Flügel probably shaped the term heat pump **first time** after 1855 Peter von Rittinger, an Austrian engineer, has designed and installed the **first known** pilot heat pump for heating only with a capacity of 14 kW, for the salt works in the village of Ebensee in Upper Austria. The starting point of our current heat pump technology was seen by Thevenot: "*It was **Switzerland**, a land poor in fossil fuel reserves but rich in hydroelectric power, which **gave the impetus to this method of heating**, from 1939, after having made some experiments around 1930*."
In 2014 Energy efficiency has again topped the EU agenda, creating both opportunities and challenges for the Heat Pumps. But also the fasted growing economies in the world, India and China, see the heat pump market as important tool in relation to its impact on power demand and green house gas emissions. On the other hand the low gas prices in the US market are strong challenges for the future Heat Pump development.
The current paper provides an overview on the importance of Heat Pumps in the different global regions and an outlook on recent developments in the different markets as domestic hot water, space heating or commercial and industrial applications.

Key Words: market challenges, market perspectives, technology challenges and opportunities, European aspects

1 INTRODUCTION

The term Heat Pump (HP) is used differently in the regions of the world based on the variety of use, climate conditions, history, developments etc. Japan used the term for the broadest application. The Japanese HP & Thermal Storage Technology Center has a interesting definition and a helpful overview figure for the application in scale and temperature (HPTCJ 2014):

In Japan, heat pumps for residential use have long been used in refrigerators and air-conditioners for cooling and heating, and are now used at almost every household in Japan. In recent years, moreover, heat pumps are incorporated in water heaters and clothes washing and drying machines, and they are rapidly coming into wide use as their performance to save energy and reduce CO_2 emissions and cost is highly evaluated.

As is the case with homes, heat pumps are also used for space cooling and heating in office buildings and shops as well as in refrigerators. Heat pumps are widely utilized for refrigerated display cases for sale of fresh food, and cooling and keeping warm of soft drinks in vending machines.

On the city level, heat pumps are utilized for "district heating and cooling¨ to supply heat to multiple buildings and structures in a collective manner. Warm heat and cold heat for district heating and cooling is also produced by "combustion-based" equipment such as oil and gas boilers, waste heat from co-generation and the like. However, heat-pump-based equipment that utilizes various types of unused heat such as heat in the air, river water and sewage boasts much higher energy efficiency and much lower environmental loads compared to "combustion-based" equipment.

In the industrial field, heat pumps are utilized in: cold storage for frozen fresh food; the method to maintain the freshness of agricultural products with cold and humid air; the method to reproduce natural environment such as temperatures and humidity and efficiently cultivate various agricultural products; and the efficient heating method to drastically reduce

boiler fuels by utilizing “vapour recompression” that compresses vapor that is usually thrown away and recycles the heat of the vapour.

The most advanced semiconductor plants have clean rooms where highly efficient HPs for business use are introduced to hold temperatures and humidity constant in all seasons around the year. Highly efficient inverter centrifugal chillers, which are capable of variable-speed operation and where the part-load operation efficiency is dramatically improved, have been recently made available on the market, and there are many high-tech companies that have enhanced the competitiveness of their products as they succeeded in significant energy conservation and CO_2 emission reductions by fully utilizing such centrifugal chiller.

Moreover, warm heat in manufacturing plants was usually supplied by the steam produced by boilers in the past. As for such application, heat pumps have also been introduced because heat pumps are more efficient to meet the demand for heat at relatively low temperatures such as in the fields of hot water supply, warming and drying.

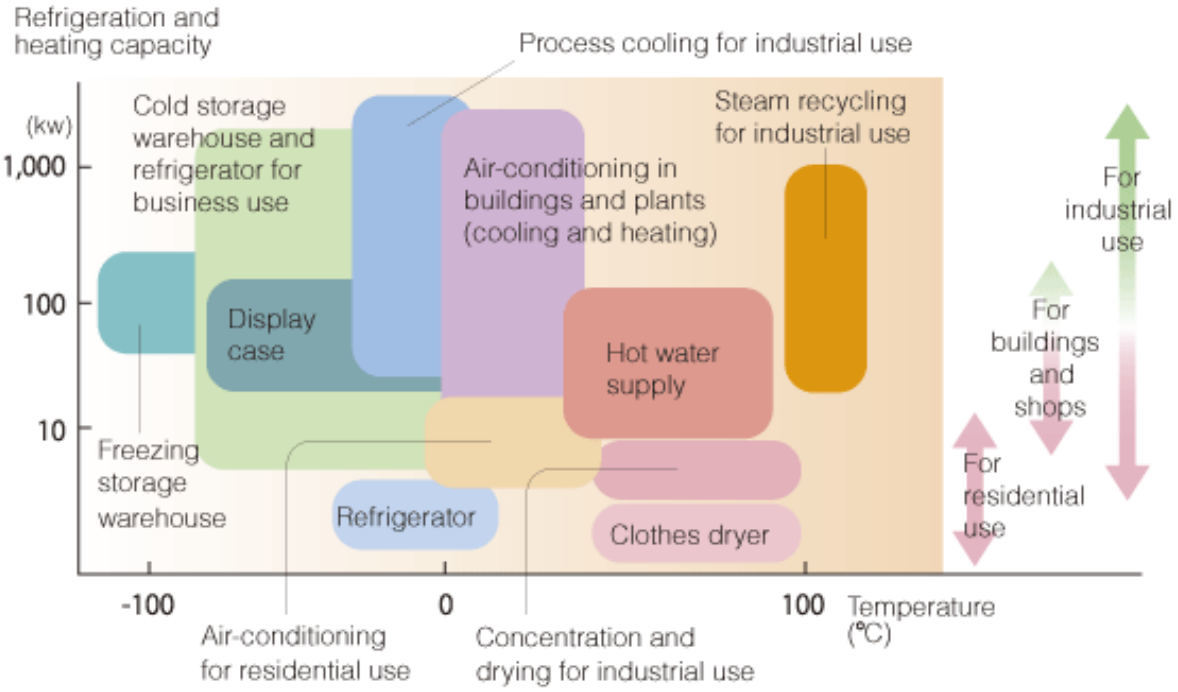


Figure 1: Various applications of heat pumps in proportion to scale and temperature

Specifically, the demand for hot water supply in production processes includes cleaning processes before car body painting (60 to 80 °C), pipe cleaning processes in food factories (80 to 90 °C), electric parts cleaning lines (40 to 50 °C), and manufacturing processes in the pharmaceutical industry (80 °C). In all of these processes, hot water is now used by exchanging heat from steam to hot water. In some cases, the amount of steam consumed accounts for only about 26.6% of the amount of fuel consumed by boilers.

The areas where air-source heat can be used by heat pumps in place of such inefficient and high-CO_2-emission pieces of equipment that burns fossil fuels include heating and hot water supply that account for most of the energy consumption in the commercial sectors, and heating and drying applications in the temperature range of lower than 100 °C in the industrial sector.

2 JAPANESE HEAT PUMP MARKET

'Eco Cute' is a name given to residential and commercial heat pump water heaters in Japan that use R-744 as refrigerant. After a strong sales peak in 2010 with 550,000 units per year the sale is at ~ 450,000 units in 2013. Eco Cute units are continuing to draw users' attention mainly for their high energy-saving performance, ability to heat water mainly by using night time electricity, which is less expensive and does not affect peak power consumption, and their ability to utilize hot water stored in the tank in the event of disrupted water supply or a disaster.

Eco Cute products are marketed under more than 10 brand names. Manufacturers are working to develop features conducive to higher energy-saving performance and comfort. To enhance the energy-saving performance of Eco Cute, manufacturers have adopted a vacuum heat insulator in the hot water storage tank, developed a high-efficiency compressor, and improved the water-refrigerant heat exchanger performance. Also, by 'visualizing' hot water usage and electricity costs through display on the remote control, the products facilitate higher user awareness of electricity and water savings. Some models that have recently become available enable visual display on a TV screen or tablet device through home energy management systems (HEMS).

In recent years, hybrid water heaters combining an electric heat pump and gas combustion system have appeared in the market.

Commercial Air to Water (ATW) HP water heating systems are broadly classified into two types. One is the Eco Cute type using R-744, the same as residential-use models. The other is designed to use HFC refrigerant. While there are five leading commercial Eco Cute manufacturers another has also entered this segment with its commercial R-744 HP named 'Q-Ton.' The Q-Ton can operate even when the outside temperature drops to – 25 °C.

Additionally, air-source heat pumps used to supply high-temperature water e.g. 90 °C for industrial applications have also been developed (JARN 2013).

Japan has many industrial HPs in practical use. Among these are many installed cases, where the focus is on simultaneous production of heating and cooling, vapour recompression, and high temperature heat production. Especially the use is in the agricultural segment with growing sales.

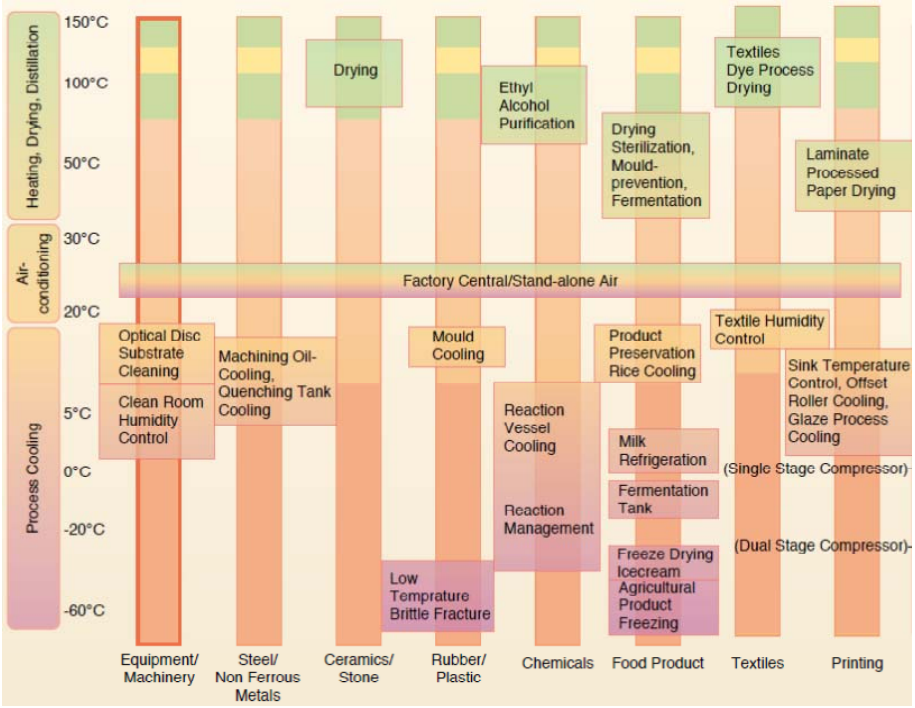


Figure 2: Industrial Heat Pump Application (Annex 35/13 2014)

3 EUROPEAN HEAT PUMP MARKET

Heat Pumps (HPs) have already successfully become the heating system of choice in some European markets, but they are still an emerging technology in other markets. In total, more than 5.4 million heat pumps have been installed in Europe since 2005-2012. Europe seems to be slowly recovering from the last years of recession.

The publication of the Ecodesign and Energy label Regulations for space heaters (HPs, gas boilers, solar thermal, etc) and water heaters are officially published on 6 September 2013. Thanks to a **single** label, consumers will be able to choose the most efficient heater for their home. This label is expected to foster the uptake of renewable heating solutions, and in particular HPs. The ongoing changes in European policies put the heat pump technology in a favorable position. The technology offers a great potential for contribution to all energy targets (triple 20) set for 2020. HPs contribute to primary energy savings, final energy savings, improving the use of renewable energy source and green house gas savings.

The challenge for the HP sector is the new F-Gas regulation which is one of the most ambitious pieces of legislation that the EU has developed in recent years. It contents an ambitious phase-down of HFCs. European industry will reduce consumption of HFCs by 37% by 2018-20 and nearly 80% by 2030.

These European targets, directives and regulations as well as innovative system demand give directions to the manufactures and their developments.

“Smart HPs” are gathering significant market interest as we move towards a low carbon future – both from existing market players and new entrants who are creating new competition. Being “smart” can enable the easier integration of HPs into the wider energy system, ultimately reducing the impact of electrification on the distribution grid, playing a role in managing supply/demand imbalances, and creating additional energy market value. But approaches to “smart HPs” are varied.

In the wake of the Fukushima accident, Germany and Switzerland have taken decisions to phase out nuclear power. In order to facilitate the phase-out, Germany has initiated a large scale energy turnaround which intensifies investments in wind power and solar photovoltaic systems. The considerable occurrences of intermittent and uncontrollable power generation in several Member States increase the need for demand side management. Smart grids and energy smartness is at the top of the agenda in most of Europe. Heat pumps are by many countries seen as a promising technology to enable meaningful load shifting. As a consequence, several heat pump manufacturers presented products with a smart grid ready logo SG-ready.

Among the many options of available heating and cooling systems, and combinations thereof, HP systems that combine both functions in one system are becoming more popular. On the other hand, Hybrid systems as a HP in direct combination with a gas condensing boiler placed in one housing opens the renovation gas-market (especially Germany and UK). The system is designed in such a way, that the unit will decide the most optimal operation mode (heat pump – combination of heat pump and boiler – boiler only) based upon economic mode (price relation between gas/electricity) or ecologic mode (primary energy factor relation between gas/electricity). With its small dimensions it fits in most cases directly at the same space as a former gas boiler.

Further trends are: HPs in combination with photovoltaic and domestic Hot Water HPs get more acceptances. NZEBs need HPs. Challenges are electricity price increase and gas price decrease.
(JARN 2013) (Nowak 2013) (Weinmann 2013)

4 RUSSIAN HEAT PUMP MARKET

Dr. Victor Shishov made a comprehensive presentation about “The status and development trends of the Russian HP market” at the European Heat Pump Summit 2013 in Nürnberg (Shishov 2013). A short summary of this research shows the great challenges of the Russian HP market:
At the present time the HP market in Russia is underdeveloped and is expecting the governmental support. In this respect the country economic development plans lend credibility to the realization of such expectations.
Realization of the governmental programs of affordable housing construction is currently under way. The scale of construction is really wide and includes all regions of the country. The programs have considerable investments available. Energy saving technologies, including HP, are applied for the new constructions. The necessary prerequisites have been created for a wide application of HP both to housing construction and the attendant infra-structure.
In Russia HP manufacturers are facing a difficult task to show that HP is the best solution in terms of energy efficiency and can serve as an optimum alternative for energy saving under Russian conditions.
Any official information about the Russian HP market is missing, because so far National HP Association has not been established, therefore all information should be taken as expert evaluation.
When HP companies studied the market for HP they revealed that potentially HP could be distributed as a favourable option through the existing dealer network selling boilers. As in Russia the demand for heat supply far exceeds the demand for air conditioning, the market potential of HP exceeds the market potential of air-conditioners many times. (The air-conditioner market is about 2-3 million pieces). The Russian HP market will be taken by those companies that understand how to build a dealer network and which will start promoting HP using the experience of other countries with a cold climate. The regions with a colder climate and longer heating season will gain the biggest savings of the annual costs of heating.
Bivalent heating systems are preferable in Russia, which are composed of two sources of heat permitting to expand the range of operating temperatures, to lower capital costs and to increase reliability. For example, HP operates until the outdoor temperature is -15…-25 °C, and if the temperature decreases further a gas boiler is switched on instead of the HP.

Currently, HPs with fixed frequency are used in most cases; however the percentage of inverter models will grow steadily on the market.

The experience of HPs application in various climatic conditions of Russia has been gained and as a result it enables the opportunity of more precise, economically sound application of such technical equipment in this country. Geographical preferences concerning the use of new equipment have been highlighted in Russia, thus the regions in the south and the east.

The promising HP sales areas in Russia can be divided into four zones:

- Areas with insufficient gas supply (Murmansk, Arkhangelsk Oblast, etc.);
- Areas with problematic power supply of large industrial facilities (Khabarovsk Krai, etc.);
- Areas in which the application of ASHPs (Air Source HPs) has been established (low-rise construction, cottages, and offices);
- Social facilities and related infrastructure (schools in rural areas, holiday homes, etc.)

5 INDIAN HP MARKET

Pradeep Kumar and Tarun Garg made a presentation about “Energy Efficiency in Building Sector in India through Heat Pump Technology” at the European Heat Pump Summmit 2013 in Nürnberg (Kumar 2013). A short summary of this research shows the great challenges of the Indian HP market:

India, the whole world knows is one the fastest growing economies in the world along with China. India has also witnessed a tremendous growth in infrastructure sector particularly in building construction. A number of residential and commercials projects have been completed and many are in pipeline. Economic development also reflected in change of life style and there has been a tremendous demand for better comfort and that has led to more and more use of air conditioners both in residential and commercial buildings.

The growing demand on air-conditioning has opened a floodgate for many companies to invest and launch their products in India. Almost every month a new product or a company is introduced in air-conditioning market. No doubt with is growing demand for air conditioning India and Indian consumers need efficient and affordable products but with so many options available and no support to identify the best product they are in a bit of confused state. India has its own policy to deal with climate change or drive energy efficiency program but these programs are not technology driven.

Therefore there is an urgent need not only to introduce a technology but also test its performance in Indian conditions and make it affordable. Probably then only a market niche for a product or technology can be created.

Some of the important factors are the challenges in buildings:

1. Reduction of the annual energy consumption from 200 to < 90 kWh/m² a by increasing room conditions from 24 to 26-28 °C and direct use of e.g. photovoltaic electricity production, at least for half of the electricity demand of the building.
2. Residential and commercial electricity consumption is ~34 % of the total.
   At a conservative 9 % growth rate electricity consumption of building sector by 2020 will be more than 2 times the present consumption.
3. Between 2001 and 2011 the housing stock in Urban India grew by 50% i.e. 26 million. By 2030 India will need up to 10 million new housing units per year- rapid population growth, rising incomes, decreasing household sizes and present housing shortage.
4. Numbers of air-conditioning grew from 2006: 2 millions to 2011: 4.7 millions and is expected in 2016:10.2 millions and 2021: 20 millions.
5. Numbers of electrical geysers (for domestic hot water grew from 2006: 27 millions to 2011: 38.9 millions and is expected in 2016: 55.7 millions and 2021: 78.1 millions.

Case Study for a single residential flat:
One flat for 5 persons;
40 litre hot water per person/ day;
electricity consumption: 9 kWh/day for heating

Energy saving due to HP is around 2021 kWh/a, which is around 16.6 % of the total energy consumption of a residential flat. HP has a potential of saving around 16.6 % in cooling mode and around 31 % in heating mode.

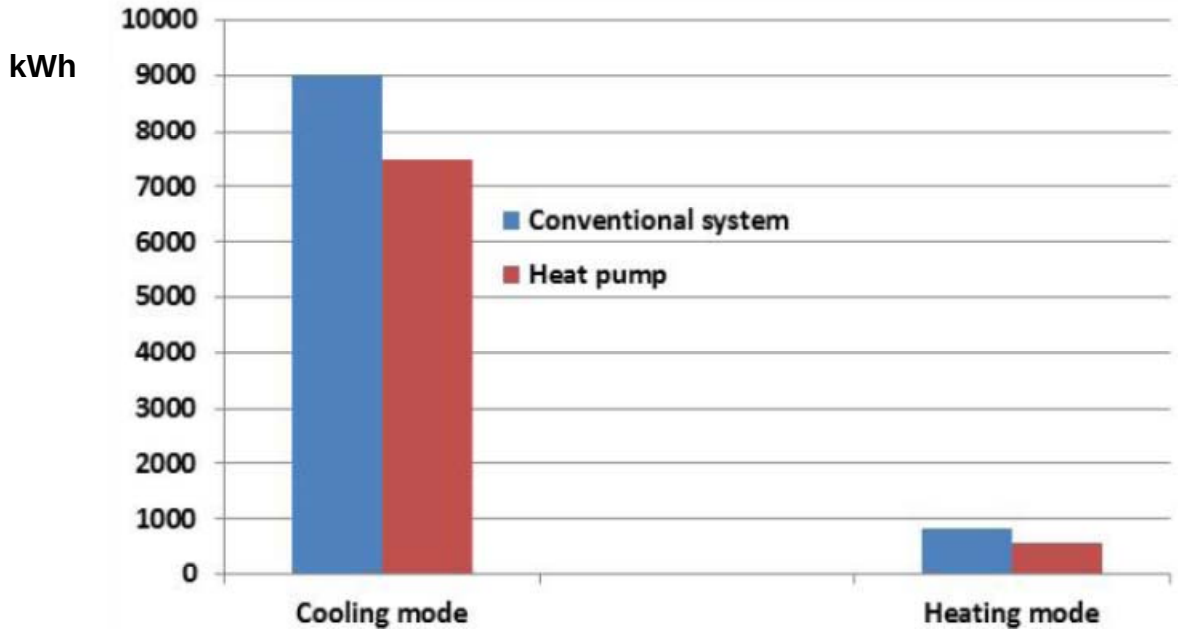


Figure 3: The heat pump potential for a single residential flat in kWh/a

For the question “Why heat pump is not popular?” Kumar and Garg conclude:

1. There is no research and development program within the country.
2. Unawareness among various stakeholders exist about the benefits of heat pumps.
3. Initial high cost and no government incentives.
4. India is heavily dependent on other countries for any development in Heat Pumps.
5. No certification program.

Further observations:

1. India represents huge potential for the consumer durable industry as the penetration level of many appliances is very low
2. Growth in AC sales will be faster than car sales, in the next decade
3. In spite of the erratic power supply in all Indian towns, more and more households are installing a RAC, and many have moved up to at least two
4. Many new apartments boast of pre-fitted RAC in every room
5. Energy demand for RAC will go up
6. Government policies & standards encourage energy efficient design or retrofit of buildings
7. Government policies & standards help achieve efficient use of energy and its conservation in the buildings or building complexes
8. No program supports exclusive use of air source heat pumps in India
9. Significant impact of ASHP on energy demand & consumption

6 CONCLUSION

Heat Pumps have already successfully become the heating system of choice in some markets, but they are still an emerging technology in other markets.
Heat pump application starts with domestic hot water HPs, HP tumble driers, and space heating in residential and commercial buildings and extends to commercial and industrial HPs for production processes with large capacities and high temperatures.

In Europe the HPs contributed to the “triple 20” European energy targets and will be an important player to reach these targets. The challenge is the new F-gas regulation.

Japanese Heat Pump market is the most developed market. Efficiency and broadest application from residential up to industrial usage is the forerunner for other markets.

The Russian Market is still today an underdeveloped market, but with great potential. The colder climate is the challenge.

The Indian market with one of the fastest growing economy is a showpiece demanding for the usage of HPs due the need to reduce the energy demand per single residential flat. Without HPs India will not match their rapid population growth.

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