IEA Heat Pump Programme

Annex 30

Retrofit Heat Pumps for Buildings

Executive Summary

Operating Agent: Germany

iea Energy Technology Network

2010

HPP-AN30-SUM

Published by

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1. Introduction

Europe is facing unprecedented energy challenges resulting from increased import dependency, concerns over supplies of fossil fuels worldwide and a clearly discernable climate change. In spite of this, Europe continues to waste at least 20%of its energy due to inefficiency. Europe can and must lead the way in reducing energy inefficiency, using all available policy tools at all different levels of government and society. Technology is vital for reaching all the above mentioned objectives The EU is therefore piecing together a far-reaching jigsaw of policies and measures: binding targets for 2020 to reduce greenhouse gas emissions by 20%, ensuring 20% of renewable energy sources in the EU energy mix and planning to reduce EU global primary energy use by 20% by 2020.

To meet the 2020 targets, besides the energy and transport sector, energy utilisation in the built environment is one of the most important aspects that have to be addressed in the near future. Around 40% of the primary energy use within Europe is related to the building sector. At present heat use is responsible for almost 80% of the energy demand in houses and utility buildings for space heating and hot water generation, whereas the energy demand for cooling is growing, year after year. There are more than 150 millions dwellings in Europe. Around 30% are built before 1940, around 45% between 1950 and 1980 and only 25% after 1980. The high ratio of heat energy demand of the buildings, built before 1978 is demonstrated by the German situation in Figure 1

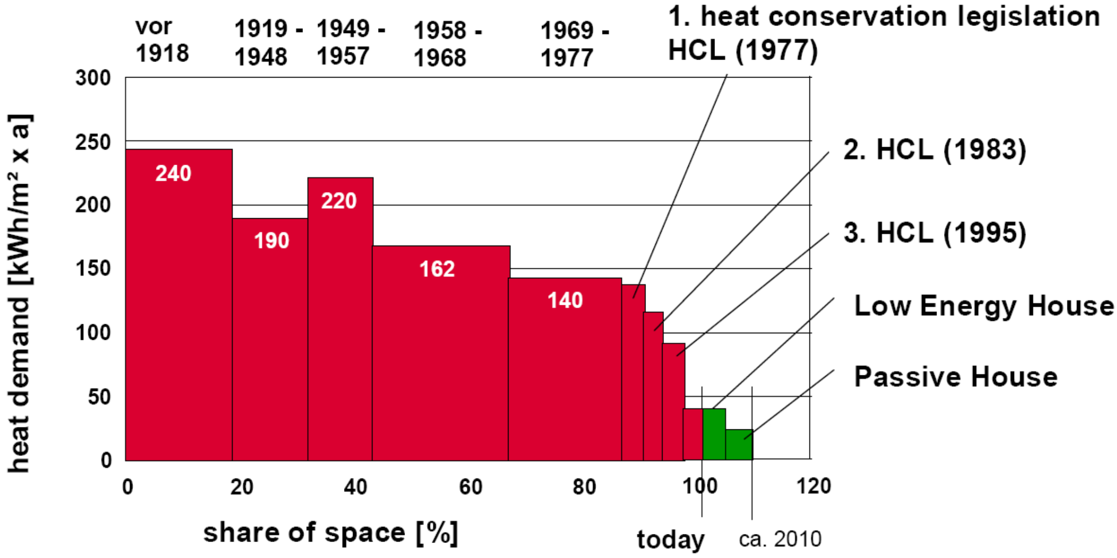


Figure 1. Heat demand of the building stock in Germany [1]

Retrofitting is a means of rectifying existing building deficiencies by improving the standard and the thermal insulation of buildings and/or the replacement of old space conditioning systems by energy efficient and environmentally sound heating and cooling systems.

In order to realise the ambitious goals for the reduction of fossil primary energy consumption and the related CO_2-emissions to reach the targets of the Kyoto protocol besides improved energy efficiency the use of renewable energy in the existing building stock have to be addressed in the near future. This is possible and realistic with the existing technology and knowledge.

Four levels of renovation can be distinguished:

- Demolition and rebuilding
- Envelope and outer wall renovation up-keeping the main skeleton and complete retrofit of the interior
- Large scale replacement and renovation of the energy system with small renovation on the envelope, other then double glazing and crack-filling
- Replacement of the existing heating boiler at the end of its life time

Large scale renovation, as in the German example, occurs mainly on collective owned buildings. In privately owned buildings the main renovation is in measures which do not go further then the last two levels, being the replacement of existing heating boilers or hot water tanks and, if well planned, of the existing heating system towards floor and convector heating offering lower heat distribution temperature as well as better comfort. Also modern triple glazing is favoured in these situations.

The challenge for retrofit with renewable energies systems lie in this area. Besides solar thermal units and the use of biomass, environmental heat with heat pumps is of specific interest. Heat pumps are among the most environmentally friendly and efficient heating technologies available by using geothermal, aerothermal and hydrothermal renewable energy.

It is well known that the heat pump is a thermodynamic cycle that transports heat from a low to a high temperature level, which in accordance with the second law of thermodynamic is not possible without additional energy input driving the process. This driving energy input is much smaller than the heat energy delivered at the higher temperature level. This is the fundamental difference compared with a conventional combustion device which always has a heat output lower than energy supplied by the fuel.

There are mainly two types of heat pumps being used today, the vapour compression heat pump with a mechanical compressor requiring mechanical drive energy and the absorption heat pump using instead of a mechanical compressor a thermodynamic cycle requiring thermal drive energy.

Heat pumps for heating and cooling can be divided into three main categories:

- Heating-only heat pumps, providing space heating with or without water heating
- Heating and cooling heat pumps, providing both space heating and cooling
- Heat pump water heater only

Heating only heat pumps with water distribution systems (hydronic systems) are predominantly used in Central and Northern Europe. Electric driven vapour compression systems are dominating the market and ambient air, soil and groundwater are the mainly used heat sources to deliver aerothermal, geothermal and hydrothermal renewable energy.

Heating only heat pumps are classified by their method of operation:

Monovalent heat pumps are heating systems which meets the annual heating demand alone. Ground-coupled or ground-water heat pump systems are due to the constant temperature of the heat sources during the heating season operated in the monovalent mode.

Bivalent heat pumps are systems in which the heat pump is supplemented by an auxiliary heating system in order to assist the plant on unusually cold days or when the heat pump is out of operation. Bivalent heat pumps are sized for 20-60% of the maximum heat load only, but normally meet around 50-95% of the annual heating demand, e.g. in a European residence. The term “bivalent” is employed for an auxiliary heating system based on a different supply of energy, used to operate the heat pump, e.g. oil, gas or coal boiler.
In a monoenergetic system the auxiliary heating is based on the same supply of energy used for the heat pump, e.g. an electric resistance heater for low outdoor temperatures.

Today’s modern low temperature systems, e.g. floor or wall heating are designed for 35/28 °C supply/return temperatures, whereas conventional radiator systems, still dominated in the existing building stock, require high distribution temperatures, typically 60-90 °C for the supply. The directive for Energy performance for the building stock is therefore an additional driver for heat pumps, which, with the exception of Sweden, are still concentrated to new one- and two-family houses.

The present market is dominated by heat pumps with low temperature distribution systems, whereas economic competitive and energy-efficient heat pumps for the retrofit of high temperature heating systems in existing buildings are still in the development stage. The aim is mainly directed to economic ground-coupled and air-to-water systems with around 60 °C heating temperature and high COP. Possible solutions are CO_2 as working fluid, multi-cycle systems or speed regulated compressors.

Heating and cooling air-to-air heat pumps, the most common types in residential applications in the mature heat pump markets of Japan and the USA, are of increasing interest for the retrofit market in Europe, especially in the southern parts of the region. The air is either passed directly into a room by the space-conditioning unit or distributed through a forced-air ducted system. The output temperature of an air distribution system is usually in the range of 30-50 °C.

Heat pump water heater often use air from the immediate surroundings as heat source, e.g. in the storeroom in the basement, but can also be exhaust-air heat pumps, or desuperheaters on air-to-air and water-to air heat pumps. The nominal capacity of water heaters is between 0.4 and 1.4 kW.

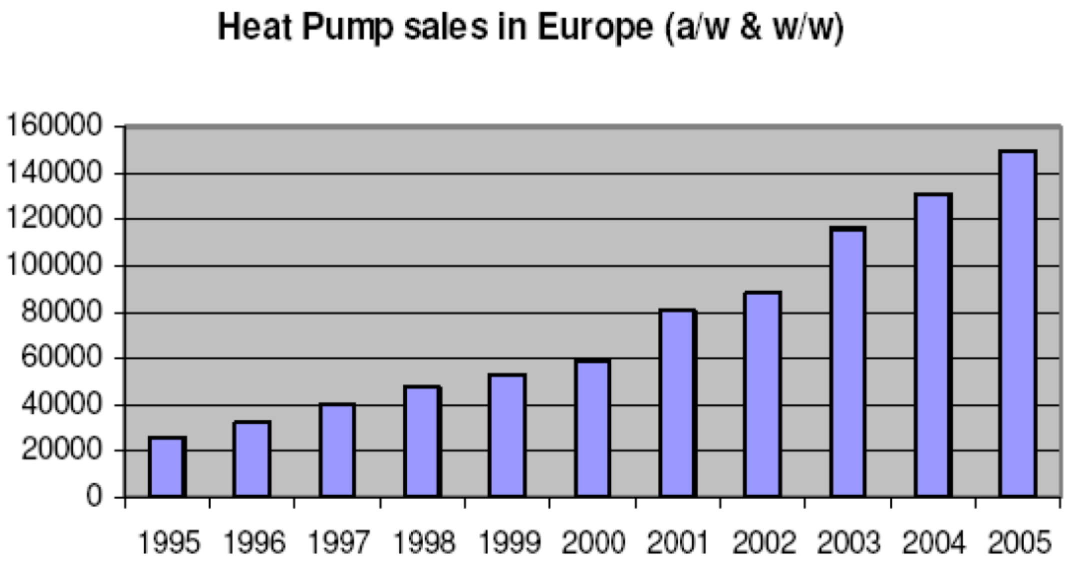


Figure 2. Heat pumps sales in Europe between 1995 and 2005

Figure 2 shows the small but steadily increasing heat pump sales in Europe between 1995 and 2005 mainly for new buildings, in particular one- and two-family houses. There is, however, as already indicated, a much larger potential for replacement with heat pumps and other competing technologies in the housing stock as well as individual domestic dwellings. If this is feasible depends on the existing building and heating systems and the cost of necessary adaptations.

Figure 3 shows the changes in heat pump sales in 8 selected European countries. While markets in Germany, Austria and Switzerland still see large sales of ground source heat pumps, those in Norway and Finland are dominated by air-air heat pumps. This is due to a high percentage of houses equipped with direct resistance heating. Air-air heat pumps are marketed as heating devices with additional comfort cooling functionality in all Scandinavian countries. Heat pumps using ambient air as heat source have shown the strongest growth in recent years. When considering total sales figures, air source heat pumps are dominating the European heat pump markets in 2007.

The total market size for the 8 countries surveyed here has reached 392 756 units in 2007, a 6% increase over last years 370 447 units. The outlook for 2008 is very positive with an expected two digit growth for all countries with the exception of Sweden, the only European countries where the heat pump market is dominated by the retrofit of the existing building stock.

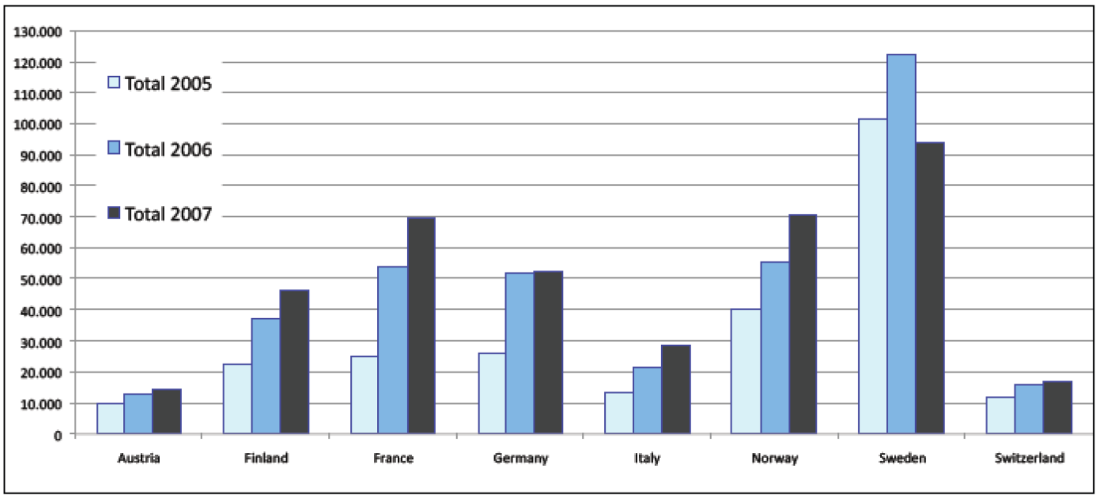


Figure 3: Heat pump statistic in selected European countries [2]

Figure 4 shows the estimated long-term market growth of heat pumps in Europe with an estimated growth rate of 10% per annum up to 2015, which, however, based on a much larger retrofit market shares compared to the present situation.

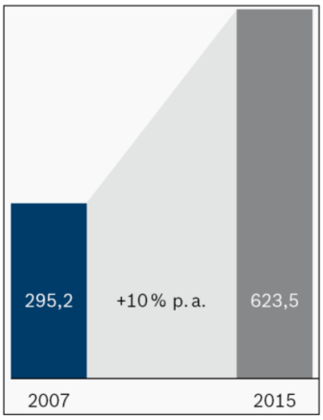


Figure 4 Long term market growth of heat pumps in Europe (sales units x 1.000)

2. IEA Heat Pump Programme Annex

From the beginning of the International Energy Agency's (IEA) Heat Pump Programme (HPP), as most national programmes too, in the various IEA-countries the markets have been mainly concerned with the development and application of heat pumps for new buildings. Recognising the potential of the retrofit market, the IEA-HPP initiated Annex 30 an international collaboration on "Retrofit Heat Pumps for Buildings".

The primary focus in this annex is on domestic buildings. In order to reach the goals of the annex solutions should be found and experience must be gained on:

- The application of available heat pumps in standard buildings that have been improved, resulting in a reduced heat demand.
- The development and market introduction of new high temperature heat pumps that use a compact source for application in existing buildings
- The use of reversible (heating-cooling) heat pumps (air-to-air), in buildings without centralized heat distribution systems, to achieve easy use of aerothermal renewable energy

The annex started in spring 2005 and has been finished end of 2008.Active participants are Germany with the operating agent IZW e.V. and six companies, France and the Netherlands. Sweden is represented by a Swedish-German Company.

The programme has been subdivided into four tasks:

Task 1: Overview Europe, State of the art – market analysis
Task 2: Matrix of Heat Pumps (Case studies, R&D projects)
Task 3: Overcoming economic, environmental and legal barriers
Task 4: Successful factors for the marketing of retrofit heat pumps

The results of the tasks have been discussed at three open workshops [3, 4, 5] and eight closed expert meetings.

3. Overview of results

A main challenge for Annex 30 is the limited availability of heat pump technology fit for retrofitting the different situations in existing buildings. Existing buildings are normally laid out for high temperature hydronic heating systems or decentralized room heating and have limited access to a sustainable heat source needed by the heat pump system. Older buildings frequently are not isolated up to the present standards and require either large capacity, quick acting heating equipment or a major insulation upgrade that may not be feasible within the market conditions or even technically impossible.

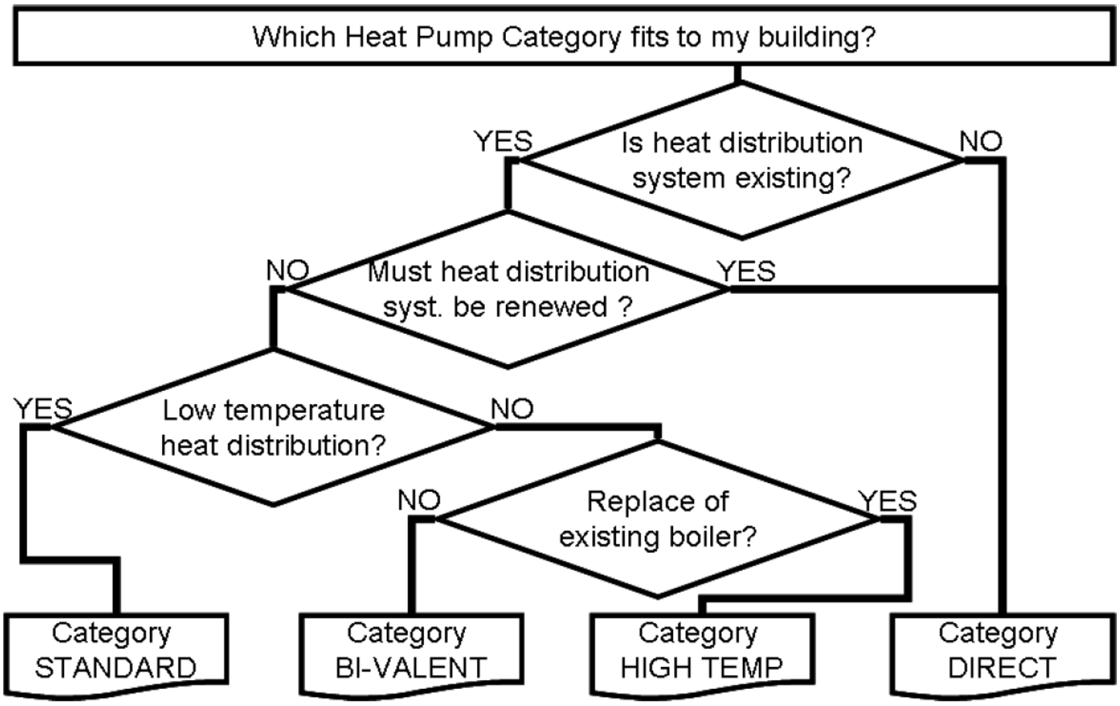
The main technological barriers for retrofitting with heat pumps are therefore:

- Finding solutions for coping with the high design temperature of conventional heating systems in existing residential buildings with distribution temperatures up to 70 °C-90 °C
- Creating heat sources at acceptable costs, preferably ground coupled and capable of seasonal storage

These heat pump solutions for renovation are not yet readily available or so expensive that these are only applied in a niche top segment of the market.

To achieve as quickly as possible more of this promising potential, barriers need to be removed or overcome. E.g. it is difficult to distinguish between different types, in which case a type of heat pump can be used and which assumptions a building should fulfil. Therefore a selection chart, which only distinguishes four categories (Standard, Bi-Valent, High Temp, Direct; cf. Task 2), was created to simplify selection of heat pumps (Chart 1). One of the four possible solutions of Chart 1 is still technically challenging for industry but also high temperature heat pumps are about to be introduced to the markets.

Chart 1: Selection chart for selection of heat pumps



4. Summary of each Task:

OVERVIEW EUROPE, STATE OF THE ART – MARKET ANALYSIS (TASK 1):

Task 1 has been concentrated on the collection and analysis of statistical information on the present status of existing residential buildings and the present heat pump market and potential technology economically applicable for retrofit of existing buildings in the different climatic regions in selected European countries. As an example Tab. 1 shows the type of space heating in Germany in the year 2002, dominated by centralized hydronic heating systems which are especially suitable for heat pump application.

Table 1 Type of space heating in residential buildings in Germany 2002

	x 1 000
Total No. of dwellings	35 127.7
Type of heating	
District heating	4 804.7
Central heating	24 308.7
Single store heating	2 777.8
Single and multi-room stoves	3 197.9

CASE STUDIES AND DEMONSTRATION PROJECTS (TASK 2):

Task 2 presents 20 practical applications of heat pumps in existing buildings, analysing the present generation of heat pumps and possible improvement of components and systems for retrofit application, as well as Research & Development (R&D) projects directly related to the objectives of the annex, subdivided in systems, components and refrigerants from selected European countries.

IEA HPP Annex 30 distinguishes four categories of heat pumps for retrofitting (see Chart 1 above):

Standard Heat Pump Systems

Available standard heat pump systems will only be economically feasible in buildings with centralized heating systems that are well insulated, have double glazing or better, have an air-tight envelope* and use a low temperature heat distribution system.

Bi-Valent Heat Pump Systems

Furthermore available standard heat pump systems can be used to upgrade an existing heating system by using installed boiler to cover peak demand.

High Temperature Heat Pump Systems

The replacement of conventional heating systems in existing residential buildings with centralized distribution temperatures up to 70-90 °C require the development and market introduction of new high temperature heat pumps. An additional ideal application for high temperature heat pumps is domestic hot water preparation.

Direct Heating Heat Pump Systems (air-to-air)
However, standard buildings without centralized heat distribution systems are suitable for the general use of reversible (heating-cooling), modern standard heat pumps (air-to-air).

At this moment the major retrofit of systems in Germany, the Netherlands, France and Austria is mainly restricted to replacing the gas or oil boilers, except for some solar hot water and space heating systems, which are installed in a highly governmental subsidized niche market (Austria). However, due to rising oil prices, anew attitude towards environmentally sound energy is developing in Europe.

There is no general definition of an existing house which is the target group for retrofit with heat pumps. It could probably be agreed upon that a dwelling which is over 20 years of age is the primary target, because at that stage many materials need replacement or maintenance In order to survey the possibilities of retrofitting with heat pumps, the first step is to look into the renovation process and the frequency in which the several steps of the process occur.

In Germany overall sales of heat pumps grew at rate of 42% from 2004 to 2005 and145% from 2006 to 2008. Out of a total of 62 452 sold heat pumps in 2008 29 993 ground source heat pumps and 28 002 air to water heat pumps were installed. The air to water heat pump had the biggest growth in 2008, followed by the ground source heat pump. This trend may indicate the increasing number of heat pumps used for retrofitting. Experts estimate, however, that around 80% of all heat pumps in Germany sold are installed in new houses. The remaining 20% are divided into 5% 1st time and 5% replacement installations and about 10% non-housing, which is mainly represented by multiple high performance systems installed in public buildings.

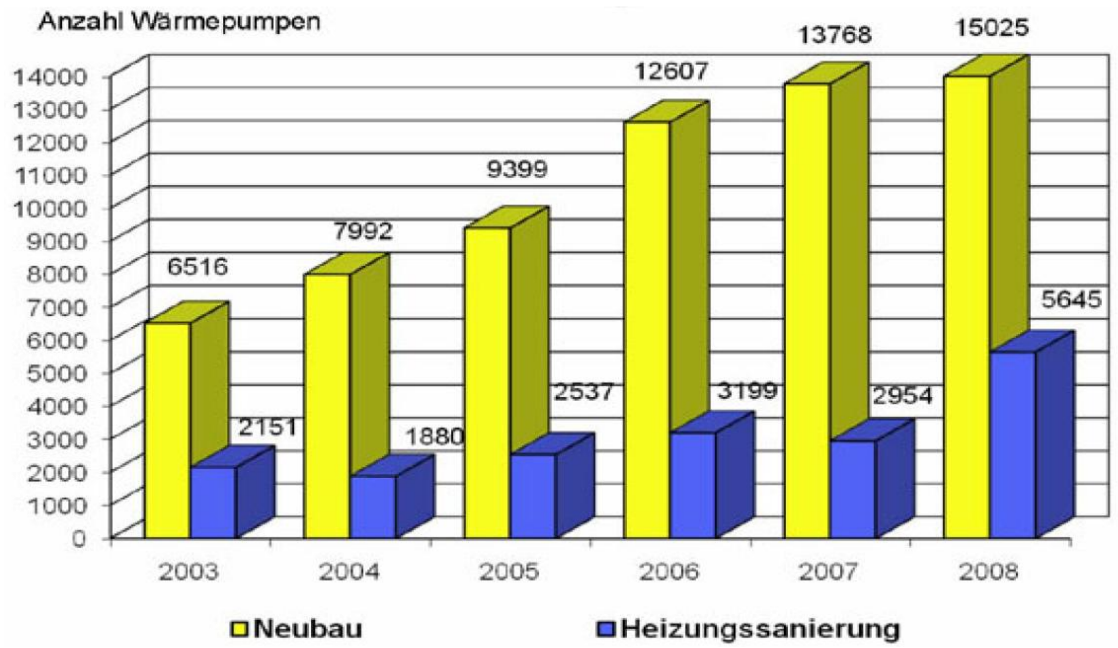


Figure 5. Sold heat pumps related to the application (new or retrofit buildings)

In Switzerland 2006 78% of all new one-family houses are equipped with heat pumps, however, as shown in Figure 5, the retrofit market in residential buildings is between 2002 and 2007 only around 25% of the total, but 2008 already 37.5% of all sold residential heat pumps, due to the governmental support programme but also the lower construction rate in the residential building sector.

The Swedish heat pump market is the largest and arguably most dynamic in Europe. Strict building regulations and high levels of energy awareness mean that new buildings constructed in Sweden require very high levels of insulation. The Swedish heating systems can be summarized as follows:

- 80% of houses have hydronic heating systems
- The rest have electric heating with electric panels
- Old houses have radiators, normal design temp 55-65 °C
- Oil boiler has been the dominating way of heating
- Gas is not available, except from southern Sweden
- New houses have mainly under floor heating
- New houses normally have heat pumps or district heat

The major market for heat pumps is single-family houses, where most units range in output from 1 kW to 10 kW and no more than 25 kW. Sweden has 9 Million inhabitants and only 1 744 private buildings, but heat pumps are well recognised by most one-family households today. As seen in Figure 6 heat pumps dominate the heating market as 550 000 and 600 000 Swedish dwellings are currently heated by a heat pump. But more than 85% of all heat pumps are used in the building stock, as the retrofit market in Sweden is very open to heat pumps as the standard of building and insulation is basically better than in other parts of Europe.

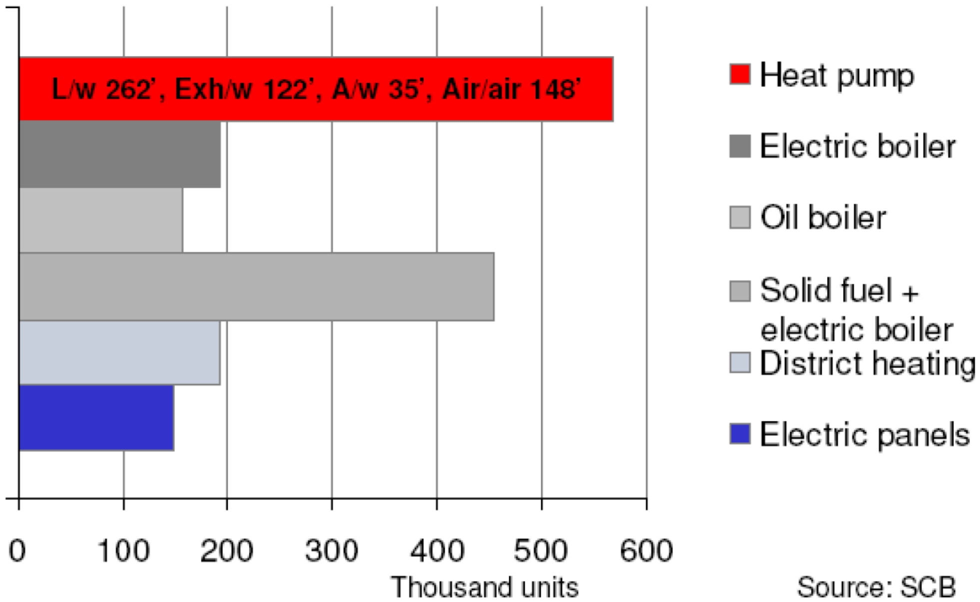


Figure 6. Heating systems in Sweden, status 2007 [6]

The situation therefore is not completely comparable. In Sweden 80% of geothermal heat pumps are sold for modernisation/conversion purposes as replacements of old boiler systems as consumers become increasingly aware of the running cost advantages of heat pumps over boiler.

Figure 7 shows as an R&D example the so called cycle with economizer and vapour injection (EVI concept), a rather simple and cheap solution for the retrofit heat pump market up to outlet temperature of 65 °C.

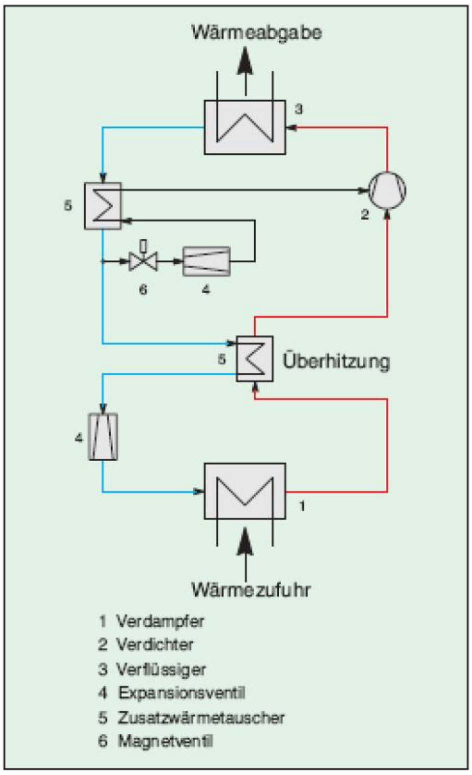


Figure 7. Economizer and vapour injection cycle (EVI concept) [1]

OVERCOMING ECONOMIC, ENVIRONMENTAL AND LEGAL BARRIERS (TASK 3)

Task 3 compares the economy and ecology (energy - efficiency and greenhouse gas emissions) of retrofit heat pump systems with conventional heating and cooling systems, presents recommendations of governmental or utility promotion and support programmes as well as demonstration and dissemination projects.

The main barrier for the use of heat pumps for retrofitting is the high distribution temperature of conventional heating systems in existing residential buildings with design temperatures up to 70-90 °C which is too high for the present heat pump generation with maximum, economically acceptable heat distribution temperature of around 55 °C. Besides the application of existing heat pumps in already improved standard buildings with reduced heat demand, e.g. with thermal insulation of the building envelope and hence lower temperature heat distribution systems, the development and market introduction of new high temperature heat pumps is a mayor task for the replacement of conventional heating systems with heat pumps in existing buildings. Specific emphasis should be paid to higher heat distribution temperatures, see Figure 7 above, and environmental issues leading to lower greenhouse gas emissions, particularly by the use of low or zero GWP working fluids.

High investment costs are in many cases a barrier, in spite of the fact that the overall lifetime cost of the system is very satisfactory. Experiences have shown that in the cost break down of the heat pump system for individual and semi-detached houses (one- and two-family houses) the highest costs are related to the ground source, in particular earth-probes.

The high investment costs are more than compensated by the low operation costs, which would correspond with a payback period of around 10 years as shown with comparison of the operation costs of a water/water heat pump with the former natural gas boiler below: [6], whereas the much higher natural gas prices in 2006 to 2008 would further improve the economic advantage of the heat pump.

08.07.05 - 07.07.06	(natural gas 2005-2006):	€ 3 534
20.07.06 - 19.07.07	(hp electricity, 2006-2007):	€ 1 569
08.07.07 - 07.07.08	(hp electricity 2007-2008):	€ 2 030
Difference (average 2006 – 2008)*		**€ 1 799,5 = - 49%**

*: average air temperature Germany:

year	winter	spring
2008	3.0	8.8
2007	4.3	10.8

Poor perception has occasionally a detrimental effect on the retrofit heat pump market, which has tempted incompetent vendors and installers to enter. This has, in some instances and in combination with some brands not meeting a reasonable efficiency and quality standard, led to frustrated buyers and a setback in sales. This situation has arisen in several European countries, often in conjunction with energy saving initiatives and programmes.

The limited awareness by decision makers, the public, authorities and politicians dealing with energy matters is due to a lack of professional information at all levels. It is worth mentioning that whereas such renewable energy sources as wind, solar, biomass and photovoltaic are well known alternatives, because of effective information campaigns and authority support, only modest emphasis has been placed on the energy saving and environmental potential of heat pump systems in particularly for the retrofit market.

SUCCESSFUL FACTORS FOR THE MARKETING OF RETROFIT HEAT PUMPS (TASK 4):
Task 4 has analysed the marketing situation in the different European countries. There is no general trend of the energy demand and supply situation in general and the building sector in particular, e.g. types and standard of the building stock, heating only or and heating and cooling as well as the energy policy including extent and type of heat pump promotion and support. With other words each country has to develop its own marketing concept.

The reasons for the Swedish success in retrofit heat pumps and the driving forces for the end customers to install retrofit heat pumps can be summarized as follows:

- Suitable heating systems
- Temperature level below 65 °C
- Low electricity prices
- High oil prices
- Good geological conditions
- No focus on “super COP”
- High temperature heat pumps simplified the retrofit installations
- Simple and reliable systems ("one day installation")
- Network of drilling companies
- Reasonable investment, € 10-12 000, same prices as 1985
- Low running cost
    - Annual saving on running cost is € 1 500 in new built house
    - Annual saving on running cost is € 2 500 in an old house
- Reasonable pay off time, 5-8 years
- The end customer has one partner only
- Good comfort
- Neighbour effect
- Strong marketing
- Environmental, renewable energy

So far Europe has been concentrating on heating-only hydronic heat pumps and heat recovery systems, but sales of air-to-air dual-mode units for both heating and cooling are now growing, not only in the southern part of Europe.

The oil crises have changed this situation, and Kyoto is a further reason for the increasing market deployment of this technology. It is well known that heat pumps significantly offer in the building sector the possibility of reducing fossil energy consumption and their related global emissions of greenhouse gases.

Basic second law thermodynamics show the advantages in energy consumption:
While a condensing boiler can reach a primary energy ratio (PER) of 105% (the theoretical maximum would be 110% based on the lower calorific value), heat pumps achieve 200% PER and more, with hydro or wind energy even 400% PER and more.

According to the Kyoto Agreement, the global emission of greenhouse gases, in particular of industrialised countries, is supposed to be reduced. Of the six greenhouse gases mentioned in the Kyoto Agreement, CO_2 is the most important one (it is responsible for considerably more than 50% of the global warming effect) and at the same time it is the one of the emissions which is most difficult to be reduced world-wide. However, it can be shown that the heat pump is one of the key technologies for energy conservation and reducing CO_2-emission.

Table 2 shows present and estimated future savings of CO_2-emissions due to the utilization of heat pumps in the residential and commercial sector as well as in industry.

Table 2 : Present and estimated future savings of CO2-emissions by the use of heat pumps

Residential	1977	2001	Savings potential Present	Savings potential Future
Annual heat demand per residence	10.00	10.00	9.00	8.00
Specific CO_2-emissions				
From heat pump (kg CO_2/kWh heat)	0.215	0.2	0.18	0.12
From oil-fired boiler "	0.713	0.7	0.67	0.64
Number of residential HP 10^6	65	70	670	1.55
CO2-Emissions				
From oil-fired boilers (Mt CO_2/a)	204	215	1 672	3 500
From heat pumps "	140	140	1 022	1 500
Savings by Heat pumps "	64	75	650	2 000
Savings commercial "	30	35	350	1 100
Savings industry "	20	22	200	600
Total Savings	**114**	**132**	**1 200**	**3 700**
% CO2-savings by heat pumps	**0.5%**	**0.6%**	**6.0%**	**16.0%**

Table 3. CO_2-emissions of a water/water heat pump installed in July 2006 in an eighty years old one-family house compared with the previous natural gas heating (see page 10 average air temperature Germany)

Time	System	CO2-Emissions		
		(kg CO2)		
average	Natural gas	15 077		
		D (0.562)	KA (0.481)	EU (0.48)
		(kg CO2/kWh)		
20.7.06 – 19.07.07	HP-electricity	6 859	5 870	5 858
08.07.07 – 07.07.08	HP-electicity	7 912	6 772	6 757
average Reduction in %		**51**	**58**	**58**

Table 3 shows a 60% reduction of the CO_2-emissions of a groundwater heat pump in an eighty years old one-family house compared with the previous natural gas heating.

The specific conditions of the building stock should not only favour the development of energy-efficient high-temperature heat pumps (higher heat distribution temperature, but also simple and reliable systems for installation in existing buildings without modifications and improvements of the building itself.

The Swedish philosophy of marginal conditions of retrofit heat pump, e.g. "installed in one day" or the Dutch proposal "to be transported in a Mercedes Vito" are of specific importance for the broad market introduction of retrofit heat pumps and the related reductions of primary energy consumption and CO2-emissions.

In this context economic solution are also air/water systems (bi- or monovalent, mono-energetic) as well as centralized and decentralized air/air systems. The requirements of the new building sector for heat pumps with high seasonal performance factor (SPF) are not the precondition of retrofit heat pumps. The real advantage of the retrofit heat pump is demonstrated by the absolute reduction of the primary energy consumption and the related CO_2-emissions in comparison with the earlier conventional heating system (see Table 3 above).

To compare the CO_2-emissions of heat pumps with conventional heating systems in Germany a so called CO_2-coefficient has been developed, using the actual CO_2-factor for electricity (heat pump) and fossil fuel (natural gas and oil):

g CO_2/kWh thermal heat = $F_{CO2\ el}$ / ε

F CO_2 el = CO_2-emission per kWh electric Energy = 562 g CO_2 / kWh_{el} using the actual German CO_2-factor, calculated with Global Emission Model for Integrated Systems (GEMIS) Version 4.42)

ε = COP manufacturer information measured according to DIN EN 14511 at a testing centre, e.g. Buchs, Switzerland at the following conditions:

	New building		Retrofit
Brine	B0 / W35	or	BO / W55
Groundwater	W10 / W35	or	W10 / W55
Air	A7 / W35	or	A7 / W5

The results of the above formula for a new building are shown in Figure 8. Even with a COP of 2.5 the heat pump has a lower CO2-emission compared with fossil fired boilers (oil- as well as gas condensing boiler).

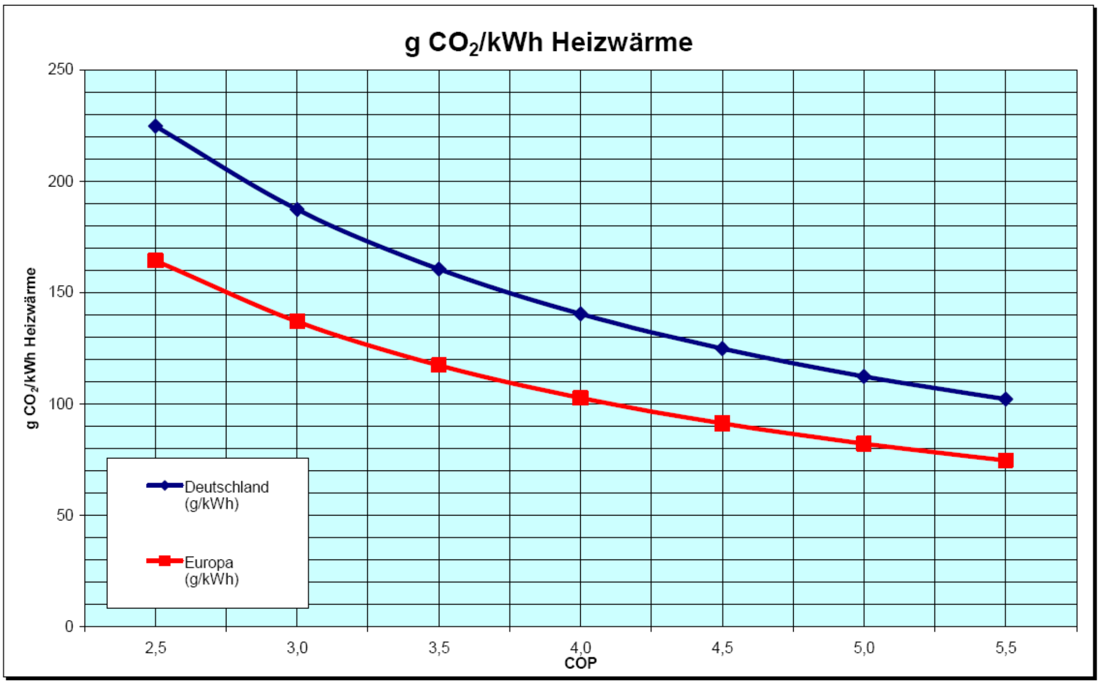


Figure 8. CO_2-emission Factor Heizwärme (thermal heat) in relation to the COP

Last not least, but not less important for the marketing of retrofit heat pumps are highly experienced installers and drilling companies, quality assurance and the training of specialists are of specific importance. In the case of the heat pump manufacturers, they have, in cooperation with installers, to operate a reliable and responsive customer service in order to maintain and repair heat pumps. This guarantees a reliable and satisfying heat pump operation.

5. Summary and Perspectives

Annex 30 "Retrofit heat pumps for buildings" has analysed the development of the building sector and market situation of heat pumps (Task 1), collected case studies of good practice as well as investigated the state of the art in technology along with technological developments (Task 2), detected barriers which explain why potentials of heat pumps are not yet recognized (Task 3) and collected successful factors for the marketing of retrofit heat pumps (Task 4).

Heat pumps can principally be successfully employed in residential buildings (single and multi-family housing), commercial buildings and industrial applications. While the market for heat pumps in new residential buildings has picked up momentum and is even self-sustaining in some countries, their application in the retrofit segment as well as in commercial and industrial buildings is just starting.

With the exception of Sweden, until 2006 the heat pump market in Europe has been mainly concentrated on new buildings and in particular one- and two-family houses, dominated by heat pumps with low temperature distribution systems, whereas economic competitive and energy-efficient heat pumps for the retrofit of high temperature heating systems in existing buildings were still in the development stage.

However, the existing European building stock shows largest potential to contribute to Europe's challenge in reduction of fossil energy consumption and greenhouse gas emissions. Case studies and field tests of the annex have shown that heat pumps are able to use this potential.

Since 2007/2008 the heat pump market is increasingly influenced by the retrofit of the building stock in particular in Germany, Switzerland and France.
The reasons are as follows:

- The drastic reduction of the construction rate of new residential buildings inmost European countries negatively influenced the heat pump market for new buildings
- Heat pump manufacturers directed their increasing R&D activities to economic ground-coupled and air-to-water systems with around 60 °C heating temperature and high COP. Possible solutions are CO_2 as working fluid, multi cycle systems or speed regulated compressors
- Heating and cooling air-to-air heat pumps, the most common types in residential applications in the mature heat pump markets of Japan and the USA, are of increasing interest for the retrofit market in Europe, The output temperature of an air distribution system is usually in the range of 30-50 °C
- The governmental support to reduce primary energy consumption and the related CO_2-emissions in buildings with heat pump was more and more directed towards the existing building stock in the major European heat pump countries.

An important step in this direction was the adoption of the EU Directive on the promotion of renewable energy sources, which for the first time recognised that besides geothermal energy (earth coupled) also aerothermal (energy in the air) and hydrothermal (energy stored in surface- and ground-water) as renewable energy late 2008 by the European parliament.

With other words for the first time the EU legislation accepted heat pumps, besides wind and solar power, as a technology using geothermal, aerothermal and hydrothermal as renewable energy source. As a result of this work, it is clear today that in many cases heat pumps already can or will soon allow to be used as a preferable retrofit choice. The use of heat pumps is leading to drastically improved efficiency in heat generation, reduction in use of fossil energy and, at the same time, to enable people to use geothermal, hydrothermal and aerothermal renewable energy.

EHPA has crafted a vision along the question which impact would the employment of heat pumps in all new and renovated one-family houses until 2020 have for the European economy [8]. The potential contribution to the EU energy strategy is impressive: Starting in 2008more than 70 million heat pumps would be installed by 2020. They would reduce final energy consumption, would produce renewable energy and would save greenhouse gas (see Table 4). It means that heat pumps are contributing to all three targets of European Commission's 20-20-20 policy in particular with the existing building stock.

Table 4 : Contribution potential of heat pumps to EU energy goals [8]

	EU target	Change required to reach target	Potential contribution by heat pumps	as a share of the EU target
Primary energy consumption	reduction by 20%	4 385 TWh (20%)	902 TWh	20.6%
Renewable energy production	contribution of 20% by RES	3 508 TWh	774 TWh	22%
Greenhousegas-emissions	reduction by 20%	1 073 Mto (20%)	230 Mto	21.5%

6. Literature

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