Annex 30

Retrofit Heat Pumps for Buildings

Final Report

Operating Agent: Germany

IEA Energy Technology Network

IEA Heat Pump Programme

2010

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Preface

This project was carried out within the Heat Pump Programme, HPP which is an Implementing agreement within the International Energy Agency, IEA.

The IEA

The IEA was established in 1974 within the framework of the Organization for Economic Cooperation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among the IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration, currently within the framework of over 40 Implementing Agreements.

The IEA Heat Pump Programme

The Implementing Agreement for a Programme of Research, Development, Demonstration and Promotion of Heat Pumping Technologies (IA) forms the legal basis for the IEA Heat Pump Programme. Signatories of the IA are either governments or organizations designated by their respective governments to conduct programmes in the field of energy conservation.

Under the IA collaborative tasks or "Annexes" in the field of heat pumps are undertaken. These tasks are conducted on a cost-sharing and/or task-sharing basis by the participating countries. An Annex is in general coordinated by one country which acts as the Operating Agent (manager). Annexes have specific topics and work plans and operate for a specified period, usually several years. The objectives vary from information exchange to the development and implementation of technology. This report presents the results of one Annex. The Programme is governed by an Executive Committee, which monitors existing projects and identifies new areas where collaborative effort may be beneficial.

The IEA Heat Pump Centre

A central role within the IEA Heat Pump Programme is played by the IEA Heat Pump Centre (HPC). Consistent with the overall objective of the IA the HPC seeks to advance and disseminate knowledge about heat pumps, and promote their use wherever appropriate. Activities of the HPC include the production of a quarterly newsletter and the webpage, the organization of workshops, an inquiry service and a promotion programme. The HPC also publishes selected results from other Annexes, and this publication is one result of this activity.

For further information about the IEA Heat Pump Programme and for inquiries on heat pump issues in general contact the IEA Heat Pump Centre at the following address:

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Final Report

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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. 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 fossile 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.

In order to reach the targets of the Kyoto-protocol, the energy utilization in the built environment has to go through a transition. Until now, our space conditioning systems are major contributors to the global warming. Environmentally benign heating systems have to be introduced on a large scale in order to reduce the emissions of green house gases.

Electric heat pumps are one of the energy efficient ways to provide space heating and hot water generation. Even though this technology is well developed and has proven to be very reliable in practice, it has not yet reached public recognition worldwide. In Europe, an established market only exists in Sweden, Switzerland and parts of Austria. In other countries, the market share of heat pumps has remained small, and the heat pump is not considered a first choice when installing or replacing heating and hot water equipments.

In addition, with the exception of Sweden, the heat pump market in Europe until 2006 has been mainly concentrated on new buildings and in particular one- and two-family houses. There is, however, a much larger potential in the retrofit market which since 2007/2008 is already growing in the major European heat pump countries.

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
Two current problems are supporting the retrofitting of existing buildings:
The required reduction of greenhouse gas emissions and related global warming in accordance with the Kyoto protocol and the ever increasing oil and gas prices.
Both problems encourage the replacement of fossil fuel burners and the introduction of heat pumps in existing buildings
Because the ownership of existing buildings is highly dispersed, the retrofit market cannot easily be reached by governmental policy instruments, other than legislation. There is a great hesitation and uncertainty at what to do in this field. A clear strategy for tackling the high energy consumption in the existing building stock is lacking in most of the European countries.
From the beginning, the IEA Heat Pump Program (HPP), as most national programmes in the various IEA-countries, has been mainly concerned with the development and application of heat pumps for new buildings. Recognising the potential of the retrofit market, the IEA-HPP added Annex 30 on international collaboration on Retrofit Heat Pumps for Buildings 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 German/Swedish company (Attachment I)

The programme has been subdivided into four tasks:

Task 1: Overview Europe, State of the art – market analysis (Attachment II)
Task 2: Matrix of Heat Pumps (Case studies: Attachment III; R&D projects: Attachment IV)
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 workshops and eight expert meetings (Attachment V)

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.

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 or air-to-water), in buildings without centralized heat distribution systems.

From the viewpoint of the renovation process, there is a clear market split between collectively owned houses and private houses.
Collective houses owned by building corporations often face inner city problems with older impoverished quarters gliding down to a ghetto status. Strategic renovation of existing buildings can be used to increase the quality of these quarters, attracting new and young inhabitants. This type of strategic stock management of buildings is often a collaborative effort of building corporations, local communities and city councils.
This process can be used for introducing new energy systems. To upgrade these buildings to a higher level of comfort and a better energy performance, practical and economical solutions are needed. Usually this will include thermal insulation of the building envelope, double glazed draught free windows and lower temperature heat distribution systems. Heat pumps can then be installed as a natural solution at the same moment. But other energy conservation technologies also become possible through this type of upgrading as the experience in Germany shows, competing with heat pumps.

For the large market of privately owned buildings large refurbishments upgrading the building envelope to a modern standard are not common practice. The penetration of existing energy conservation technologies and heat pumps will only take off when the technology can be bought off the shelf as a standard cost effective solution for replacing the existing heating technology at the end of its life time. For this market innovative solutions must be developed and are already under development.

This report surveys the market potential and technological possibilities for several types of renovation. A first route is sketched to attain the goals

2. Heat Pump technology

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 vapor 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 as well as ground and surface water 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 ^{o}C supply / return temperatures, whereas conventional radiator systems, still dominated in the existing building stock, require high distribution temperatures, typically 60-90 ^{o}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. As the present market is still dominated by heat pumps with low temperature distribution systems, the main development stage is directed to economic competitive and energy-efficient heat pumps for the retrofit of heating systems in existing buildings.
The aim is mainly directed to economic ground-coupled and air-to-water systems with around 60 ^{o}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 ^{o}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.

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3. The domestic buildings renovation market in Europe

3.1 Market potential

The existing housing stock in Europe is estimated at approximately 150 million dwellings. 30 % are built before 1940, 45 % between 1950 and 1980 and 25 % after 1980.
The annual refurbishment rate for heating systems is relatively high. Eurostat reports a total annual refurbishment rate of almost 4,9 million units in the EU 25, Norway, Switzerland and Liechtenstein. The UK is top of the list, with an annual replacement 1.0 million units, followed by France with 0,88 million units; Germany 0,7 million and Italy 0,4 million units. The total stock of one/two family houses in the EU 25, Norway, Switzerland and Liechtenstein is almost 98 million. The end use of energy in existing residential buildings varies from over 300 kWh/m2a down to 30 kWh/m2a, with a weighted average of around 180 kWh/m^2a. Today, there are several different definitions for low-energy buildings, and different actions have started at national levels to encourage further construction of low-energy buildings, both for the new and for the retrofit market. In Germany, Austria, Norway, Sweden and Denmark, low energy building been more or less synonymous with 'passive houses'. 'Passive House' is a trade mark of the Passive House Institute, and passive buildings aiming to comply must have a heating energy consumption that should not exceed 15 kWh/m2a. Preheating of ventilation air and heat recovery are necessary, but final heating can be provided by any desired system. In Switzerland, the MINERGIE definition is used both for retrofitting and for new buildings. For retrofits, energy consumption should not exceed 80 kWh/m^2a, while for new buildings it should be 40 kWh/m^2a or lower

The majority of dwellings have to renew their fossil-fuel based heating systems in the next years. With an average energy use for space heating of 1000 m^3 – 2000 m^3 of natural gas per domestic unit in existing buildings and a total number of over 150 million units, the market in existing buildings however seems to be an excellent opportunity for heat pumps and other types of alternative heating systems or renewable energy systems.

More than 80 % of the energy used in these dwellings is used for space heating, cooling and hot water generation. Heating of buildings is needed in all European countries, and hydronic heating systems dominate even in countries that also require cooling.
For the European countries in the northern climate zone, especially in the Benelux countries, France, UK and Germany, the major heating systems are based on systems on the gas grid or are oil fired systems.
In Nordic countries a substantial proportion of residential buildings have direct electric heating with no in house heat distribution system. But also a substantial part of the market in these countries is equipped with heat pumps, increasingly with ground source heat pumps in Sweden and air-to-air heat pumps in Norway. In Norway and Sweden several district heating systems in urban areas are fitted with large heat pumps.

Fig 1 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.

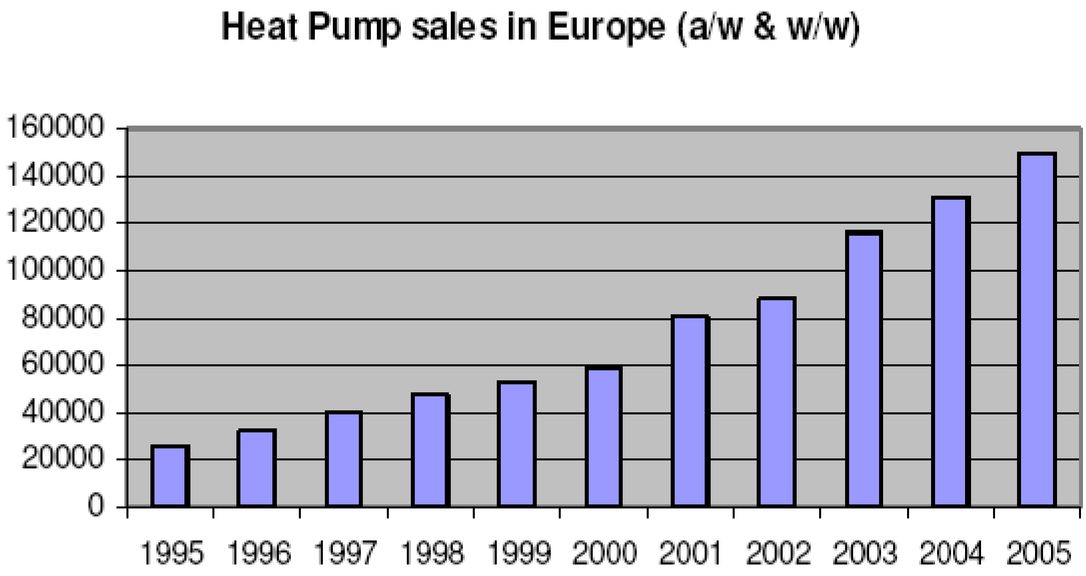

Fig. 1: Heat pumps sales in Europe beween 1995 and 2005 [1]

There is, however, 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.

Fig.2: shows the estimated longterm market growth of heat pumps in Europe with an estimated growth rate of 10 % per annum up to 2015, which, however, require much larger retrofit market shares compared to the present situation.

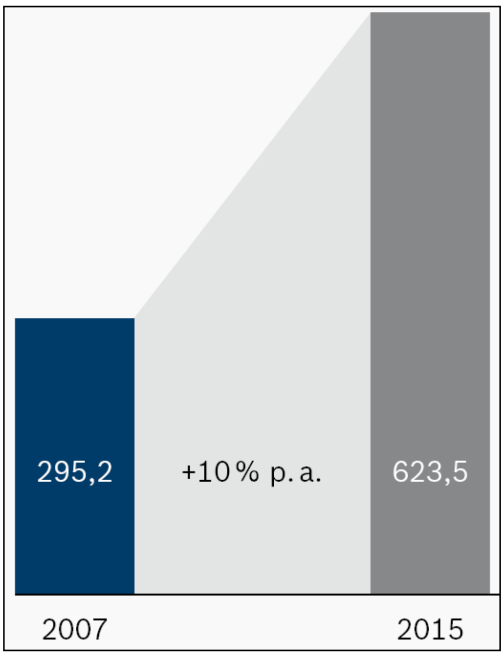

Fig.2: Long term market growth of heat pumps in Europe (sales units x 1.000)
(For further details see attachment II: Overview Europe: State of the art, market analysis and [2])

3.2 Existing buildings and heating systems in European countries.

The greatest challenges, and also the greatest potentials, are presented by the retrofit market: for example, France there is 28 million homes, of which 14 million are single-family houses, The new building construction rate is only 1-2 % of new single family houses, while 300 000 owners per year renovate their heating systems in existing single-family houses. 60 % of single-family houses in France have hydronic heating systems.The situation is more or less the same in Germany, the challenge is that most of the older buildings have high-temperature hydronic systems Another challenge is the relatively large number of houses in Europe without central heating systems.
The market of existing domestic buildings, building standards and heating systems in the heat pump related important European countries are summarized as follows:

Austria

In Austria, hydronic heat distribution systems are common practice. Since the late nineties, low temperature heating systems with floor or wall heating become increasingly important, especially in the new building sector. Common supply temperatures for floor heating systems are between 30 °C and 35 °C. However, there are still a number of new buildings equipped with radiator systems, mostly because of the system costs. In the existing building stock (before 1990), radiator systems are the most common heating systems. The supply temperatures depend on the building quality and on the type of radiators; common supply temperatures are in the range of 45 °C and 70 °C. In the past, air heating systems (mostly combined with air conditioning) were only common in large commercial buildings. In addition to these applications, there are nowadays a few air heating systems in low-energy houses with controlled air conditioning, combined with heat recovery from the exhausted air.
The following chart shows the specific heating load [W/m^2], the consumption of heating oil per year and square meter and the heat demand per square meter and per year for typical buildings of the fifties and seventies for conventional new buildings, for low energy houses and for passive houses. As shown in Tab.1 in Austria there has been an essential increase in building quality from 1970 to the present. The heat demand of the buildings decreased at 40 % of the heat demand during the seventies. Reasons for this development were the first and the second oil price shock, the increasing building regulations in cooperation with subsidies for the compliance with these regulations, the improved technologies in the field of building engineering and the rising awareness of alternative and energy efficient technology. Due to these changes the conditions for using heat pumps are now much better than in the past

	Heat demand kWh/m^{2}a	**Heating oil Consumption l/ m^{2}a**	**Specific heating Load W/ m^2**
Old building (till 1950)	>450	**>45**	**>300**
Old building (1950-1970)	**<400**	**<40**	**<250**
Old building (since 1970)	**<250**	**<25**	**<165**
Conventional new building	**<100**	**<10**	**<65**
Low energy house	**<40**	**<4**	**<27**
Passive house	**<15**	**<1,5**	**<10**

Tab. 1: Building standard now and in the past (ARSENAL RESEARCH 2002)

As shown in Tab. 2 centralized hydronic heating systems dominate the market, but 45 % of the dwellings use district heating, singlestorey heating or single or multi-room stoves. Natural gas and heating oil are the most used type of energy but wood and other renewable energies still play an important role, mainly in rural areas (Tab. 3)

Type of Space Heating	No of Units
District (remote) heating	454.940
Central (centralized) heating	1.651.830
singlestorey heating	457.370
single or multi-room stoves	387.730

Tab.2: Type of heating in dwellings, status 2001

Type of Energy	No of Units
District (remote) heating	494.940
Gas	1.072.000
Electricity	259.030
Heating Oil	893.100
Briquettes, Brown Coal	96.500
Coke, Brown + Hard Coal	
Wood or other reneable energies	516.600
not indicated	73.640

Tab. 3: Type of energy used for space heating, status 2001

Heat pump market

The heat pump market in Austria is presently concentrated on new buildings, because these buildings offer ideal conditions for using heat pumps. Due to high building standards and the installation of low temperature heat distribution systems ground coupled heat pump systems achieve high SPFs. But, there is a large market potential available in the retrofitting sector, which is presently not that much used for heat pumps. Reasons for that might be the existing high temperature hydronic systems, the lower SPF due to the higher heat pump outlet temperatures.

In 2006, 8.855 units of heat pumps for space heating were sold. With regard to the heat sources utilised, the following developments are to be seen:
Most popular, with a market share of 71 % are the ground-coupled heat pumps. Thereof represent the brine/water heat pumps 53 % and heat pumps with direct vaporization18 %. Water/water heat pumps covered 10,7 % of the market followed by the air/water heat pumps with 18,3 % market share.
The thermal capacity of all installed heat pumps in 2005 was 80 MW_{th} which is corresponding to an oil equivalent of 237.459 tons. The CO_2-reduction counts for

641.139 tons if green-electricity is used and counts for 493.149 tons, if a traditional electricity generation mix is used

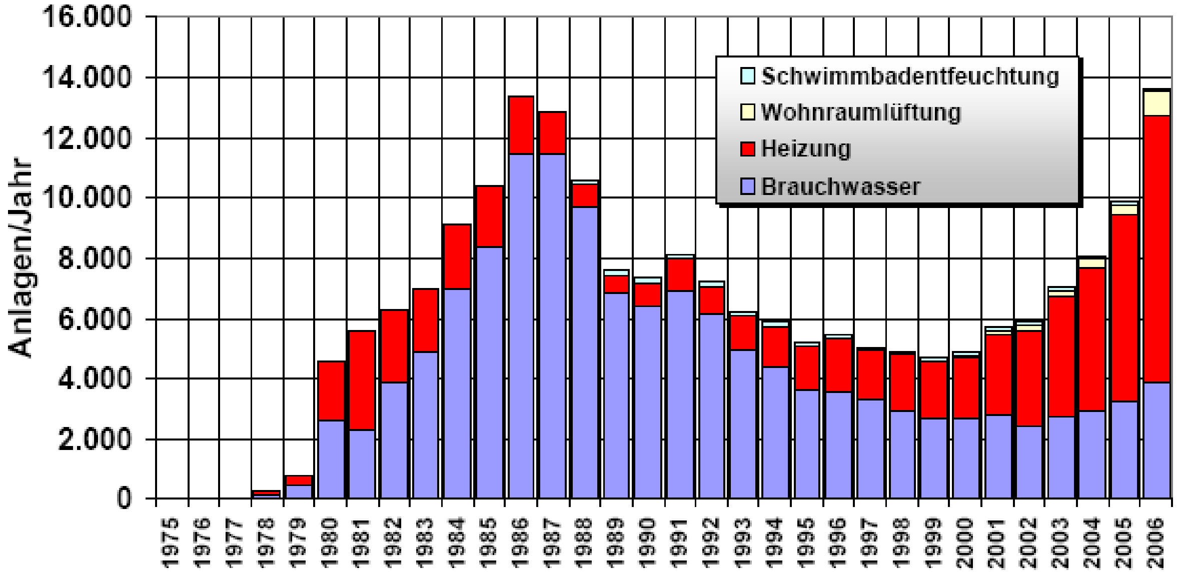

Fig.3: Austrian heat pump market 1975 – 2006 [3]

For further information see G. Fanninger "Present status of heat pump technology in Austria" (Aktueller Stand der Wärmepumpen-Technik in Österreich) [3]

Germany

In the year 2002 in Germany the total number of dwellings was nearly 39 million. Around 29 million have been built until the end of the seventies. (see Tab.4).

Germany	
	(x 1000)
Total No of dwellings	**38 689,8**
Until 1900	**3 267,4**
1901 - 1918	**2 629,4**
1919 - 1948	**4 970,8**
1949 - 1978	**18 094,5**
1979 - 1986	**4 189,7**
1987 - 1990	**1 236,9**
1991 - 2000	**4 003,6**
2001 and later	**297,4**

Tab.4: Number of dwellings and age of the building, status 2002

At that time the heating systems were comparable to the Austrian systems. There were hydronic heat distribution systems with supply temperatures of 90 °C /70 °C common too. Energy sources were predominately oil, coal or gas. In some new buildings lower supply temperatures were possible and in rare cases there were floor heating systems used. Air heating systems or air conditioning were also only common in large commercial buildings. Since the early 90's there was a clear structural change indicated by:

- increased use of natural gas instead of heating oil
- increased use of gas burners instead of boilers
- significant reduction of noxious emissions because of improved processes of combustion
- reduction of energy consumption by improved condensing technology and increasing of efficiency by use of condensing technology.

As shown in Fig. 4 a clear improvement in building standards took place in Germany between the 80's and the 90's. The building-guideline of 1995 asked for clearly higher standards on the insulation of buildings and on the quality of windows. In the year 2003, the private building construction sector has been subdivided as follows: 30 % new one- and two-family houses, 5 % multi-family houses and 65 % renovation and maintenance.

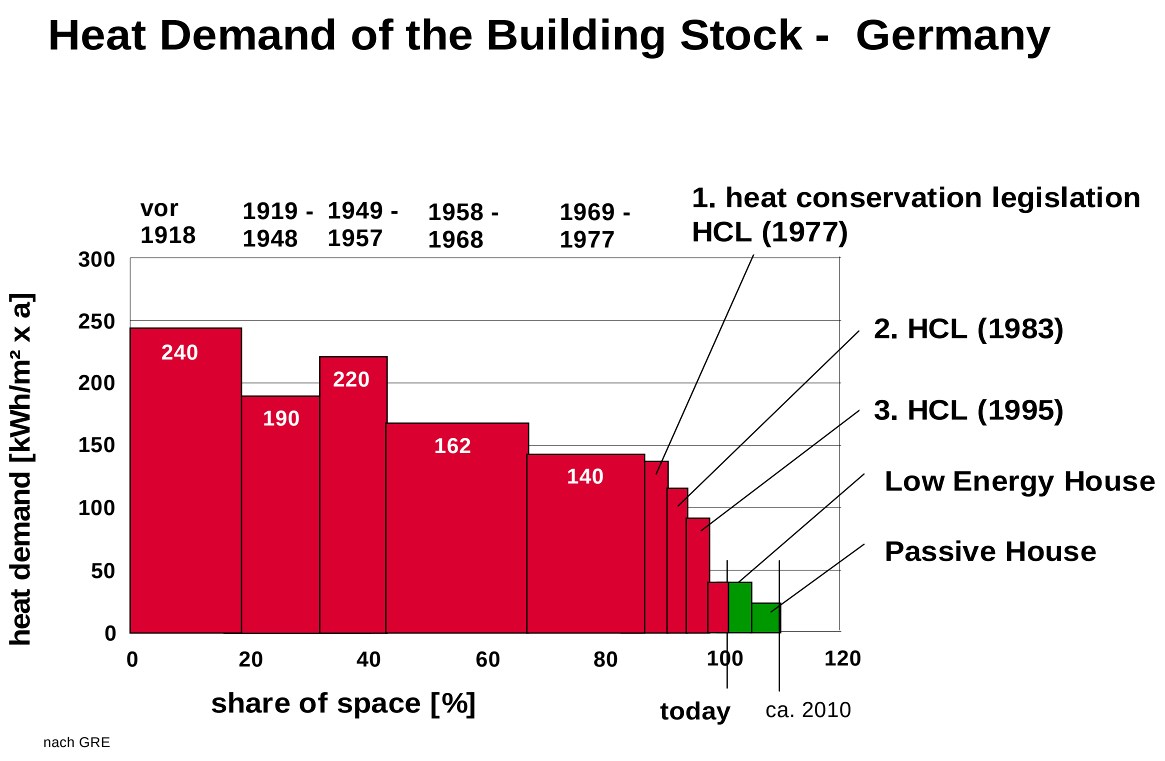

Fig.4: Heat demand of the building stock in Germany [4]

Because of those strict conditions it was possible to decrease the average heat demand from 250 kWh/m²a down to less than 110 kWh/m²a. This means that the half of the earlier required heat demand is now enough for heating a building. This again means that it was suddenly possible to reduce the supply temperature of heating systems and to facilitate the heat transfer via floor heating with surface temperatures fewer than 28°C.

Tab. 5 shows the energy consumption for central heat and hot water generation with district heating, gas and heating oil boilers of the building stock with until 2002.

Type of building		Living area (million/ m²)	Specific energy consumption (kWh/ (m²a)		
			District heating	Gas	Heating oil
One-family house	Until 1978	0,598	167	231	241
	1978 - 1990	0,200	146	198	217
	1991-2002	0,173	106	139	160
Two-family house	Until 1978	0,362	208	250	297
	1978 - 1990	0,067	166	219	236
	1991-2002	0,053	129	169	184
Multi-family house	Until 1978	0,736	134	188	265
	1978 - 1990	0,140	109	166	219
	1991-2002	0,124	68	156	171
All houses	Until 1978	1,696	120	213	279
	1978 - 1990	0,407	86	198	245
	1991-2002	0,350	71	148	174
Grand Total		**2,453**			

Tab.5: Specific energy consumption of the building stock with central heating and hot water generation

In Germany more than half of all inhabited dwelling units are located in buildings comprising three or more dwelling units. A clear majority of inhabited dwelling units are equipped with some form of centralized heating system. These include remote heating, block/central heating and single-storey heating (see Tab.6). The occurrence of single- or multi-room stoves has continually declined in Germany. Gas and heating oil are the main types of energy used for heating, with the use of gas even surpassing that of heating oil as compared with former years. Statistics showing how one-family houses are heated are not directly available

	X 1000
Total No of dwellings	**35 .127,7**
Type of heating	
District heating	**4. 804,7**
Central heating	**24. 308,2**
Single-storey heating	**2. 777,8**
Single and multi-room stoves	**3.197,9**
Not indicated	**39,1**

Type of energy	
Districht heat	**4. 804,7**
Gas	**16. 750,4**
Electricity	**1 .440,4**
Heating oil	**11 .177,1**
Briquettes, brown coal	**451,6**
Coke + hard coal	**117,1**
Wood or other reneables	**347,3**
Not indicated	**39,1**

Tab.6: Total Number of dwellings and type of space heating and energy in Germany, status 2002

2006 around 43.900 heat pumps for space heating have been sold, still dominated for new one- and two-family-houses. This is more than a doubling compared with the last year and the highest results in the heat pump history in Germany

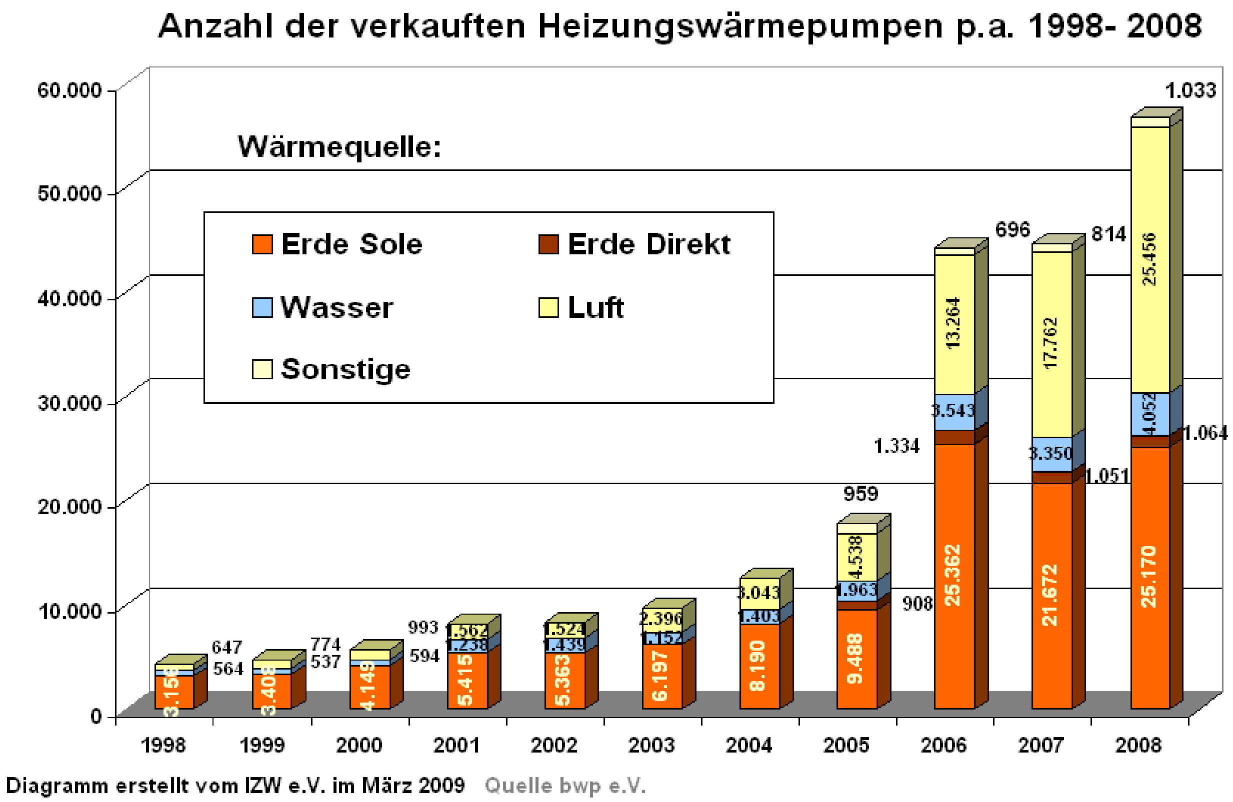

Fig.5: Number of sold heat pumps in Germany 1998 - 2008

Switzerland

The Swiss government has signed the Kyoto protocol. Therefore, CO_2 emissions should be reduced to the level of 1990. This is quite a challenging aim and requires a lot of effort. The Swiss government wants to reach the reduction first on a voluntary basis, but intends to force the emissions down with a special CO_2 tax if all else fails. Of course, it was noted that heat pumps could have a very strong impact on CO_2 reduction especially when replacing older gas or oil burners in heating installations of the existing building stock

The situation of the domestic heat sector in Switzerland was similar to the situation in Austria and Germany. During the eighties the heating market was dominated by hydronic heat distribution systems with radiators and high supply temperatures. The heat preparation was mostly done by heating oil, gas or wood pieces.
There was also an essential increase of the building quality between the seventies and the nineties, from about 20 kWh/m²a before the eighties to about 87 kWh/m²a in the year 2001. In Fig 6 there is an overview given about the development of the building standards during the last 20 years.
New houses built up to the Minergie standard have a yearly heat demand of 44 kWh/m²a, which is approximately half of the heat demand of conventional new buildings. In Switzerland there is also a building standard for renovated houses. A house which is renovated according to the conventional building standards has a yearly heat demand of 128 kWh/m²a. If the building is renovated according to the Minergie Standard the house would have a demand of 89 kWh/m²a, which is about 70 % of the conventional heat demand. In average new Minergie buildings have higher investment costs of only 6.3 %. Because of the ecological and economical facts and professional promotion the Minergie standard became more and more important during the last few years.

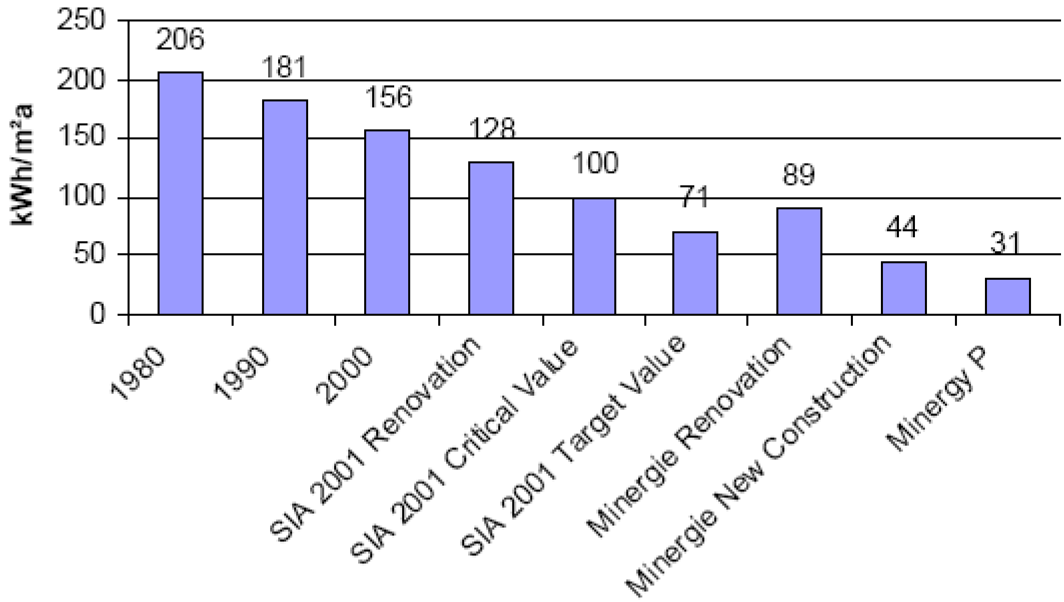

Fig.6: Building standard in Switzerland [5]

Switzerland has a surface area of 42,000 km², 7.4 mio inhabitants and consumed in 2006 888’330 TJ of end-energy [SFOE, 2006]. This was a decrease of 0.5 % compared to 2005.
The energy was used by

Households	259’870 TJ	29.3 %
Industry	177’350 TJ	20.0 %

Tertiary Sector	144'780 TJ	16.3 %
Traffic	292'030 TJ	32.9 %
Agriculture	4'300 TJ	1.5 %

In the household sector, the energy was supplied by the following energy sources:

Coal, wood and solid fuels	18'830 TJ	7.2 %
Liquid petrol fuels	124'620 TJ	48.0 %
Gas	41'080 TJ	15.8 %
Electricity	63'730 TJ	24.5 %
District heating systems	5'860 TJ	2.3 %
Renewable energy	5'750 TJ	2.2 %

Although, there is a remarkable amount of oil products for heating purposes and there is an increasing amount of heat pumps in Switzerland, see Fig 7 2006 around 70 % of new built residential houses were equipped with a heat pump [Rognon, 2008]. Mostly compressor heat pumps with electric drives are sold. There are only few absorption heat pumps which use gas as primary energy.
Recent years have seen an increase of air to water heat pumps compared to earth probe heat pumps. There are only a small number of water to water heat pumps in Switzerland. The 100'000st heat pump was installed in autumn 2006. The types of heat pumps sold in 2008 were 58,3 % air to water, 39 % brine to water and 2,7 % water to water. The evolution of sales is shown in figure 6.
There are many heat pumps in the range of 5 to 30 kW therm. The number of sold heat pumps 2008:20670. In 2007 4.2 % had a thermal capacity less than 5 kW, 43.8 % between 5 and 10 kW, 41.6 % between 10 and 20 kW and 10.4 % between 20 and 30 kW. [FWS, 200]

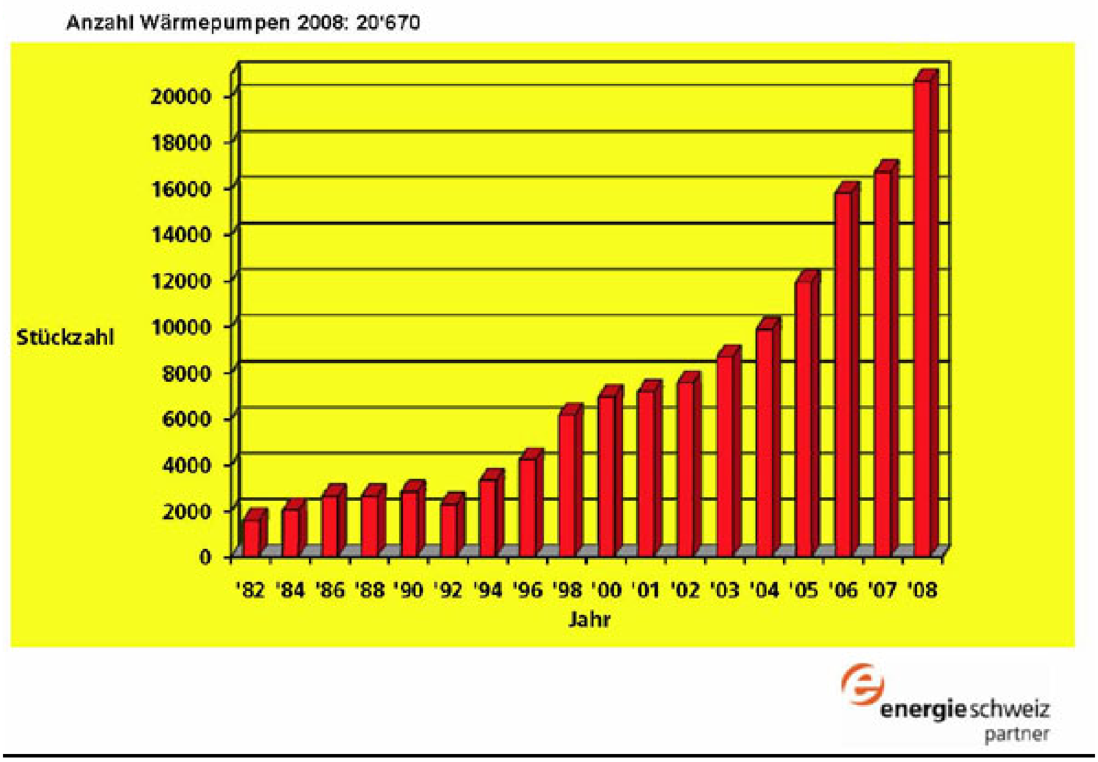

Fig.7: Sales figures of heat pumps in Switzerland from 1982 to 2008 [6].

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Table 7 shows the distribution of numbers of built-in larger heat pumps in existing buildings in function of thermal power.

Year	50 – 100 kW	100 – 300 kW	300 – 900 kW
2002	68	21	5
2003	90	34	7
2004	104	43	12
2005	110	59	16
2006	215	45	34
2007	213	43	34
2008	350	115	34

Tab. 7: Thermal power of larger heat pumps for recent years

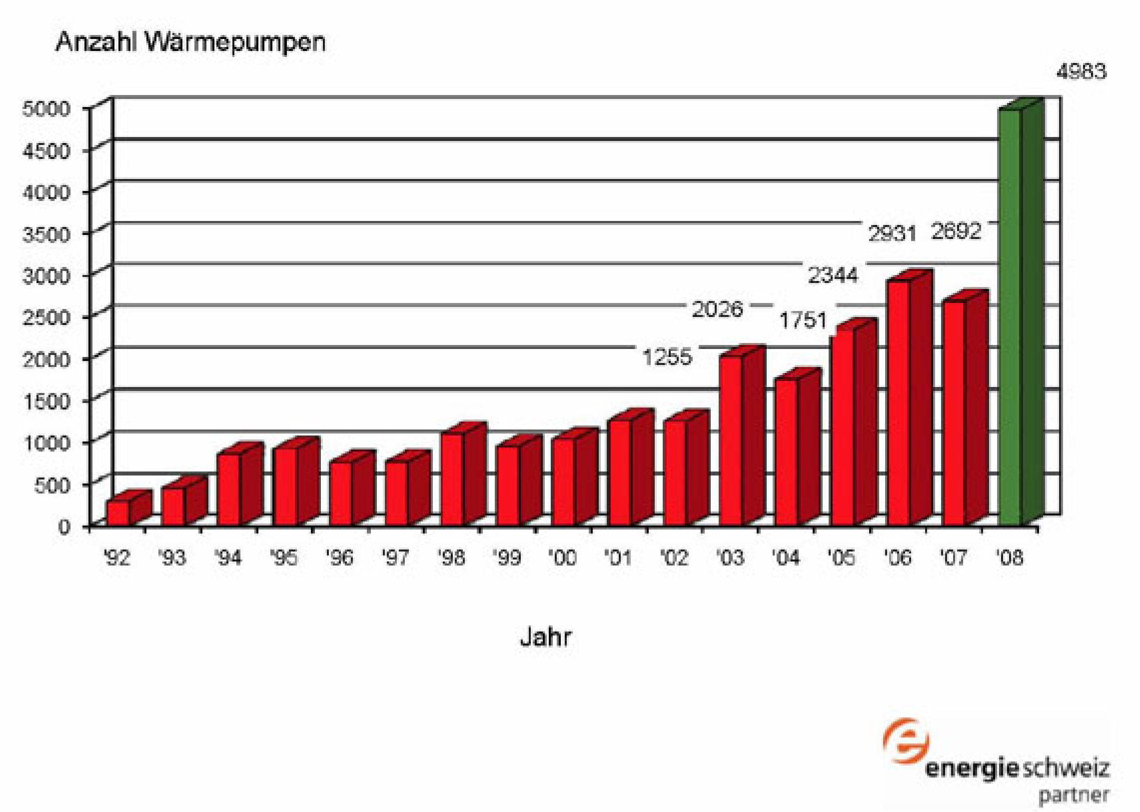


Fig.8: Sold heat pumps for retrofitting <20 kW from 1992 to 2008 [6]

Fig. 8shows the number of sold heat pumps with a capacity smaller than 20 kW in retrofitted buildings. In 2008 only 4.983 or 24 % of all sold heat pumps were used for retrofitting

More detailed information on Swiss heat pump statistics see [6]

France

The total number of dwellings in France is estimated to 28 Millions and single-family houses represent 14 Millions of total dwellings. The new building construction rate per year is just 1 % - 2 % of new single-family houses and 300,000 owners renovate their heating system per year in existing single-family houses, so 180,000 boilers have to be retrofitted each year (8.4 million oil/gas boilers).

Presently, for dwelling houses, energy consumption for heating is 317 TWh in 2002. The hydronic system is mainly used (88 %) for radiators (most cases) and floor heating. Oil and gas heating systems represent 60 % of the heating energy and are distributed in most case by hydronics systems. Electricity represents 28 % of heating energy and is distributed mainly by radiators (convectors first, and then radiants). In new buildings, which are heated with electricity, the ratio tendency is 33 % for convectors, 27 % for radiant and 24 % for heating floor (almost nil for heating ceilings). Only a few percent (5 % in 2000) of electrical systems in new houses were heat pump systems.

In France, dwellings are classified by their surfaces and their year of constructions. An important point is that before 1975, there was no thermal regulation in France and then these houses present a very poor performance in terms of thermal insulation. In most cases, due to the form of heat delivery systems and the standard of building insulation which can only be modified marginally, hydronic heating distribution with temperature supply up to 65°C or more are very common on the coldest days. So, the HSPF (heat seasonal performance factor) is the most appropriate parameter that represents the actual heating energy bills. HSPF is the ratio of the total heat delivered over the heating season to the total energy input over the heating season.

The French heat pump market grew by 112 % in 2006, to a total number of 53 510 Installations (Fig.9)
There are different reasons of the market grow. We can first explain that by the required reduction of greenhouse gas emissions and related global warming potential and also by the high oil and gas energy prices according to the high efficiency of the new heat pumps we can find in the market. Moreover, as we can see in Fig.9, there is a change of slope between 2005 and 2006, it is mainly due to subsides of the French government when you buy a heat pump. Finally, all these reasons lead to a very dynamic market
As mentioned, heat pumps that are sold today are mainly for the new buildings market.

Air/water heat pumps show the largest growth, at 139 %, and it is expected that this segment will overtake ground-source heat pumps quite soon (Fig.10). Since 1997, a new market impetus has been initiated by EDF (Electricité de France), in association with ADEME (French Environment and Energy Management Agency) and BRGM (French Mining and Geological Research Board). The emphasis has been on a controlled development of the market, based on quality, in order to avoid repeating the mistakes of the past. In 2005, public authorities introduced a strong subsidy scheme, expected to run until the end of 2009.
There is also a dramatic increase in sales of small heat pumps for air conditioning purposes; 75 % of them are reversible. Among these 75 %, which of course are mainly bought for building cooling during summer, it is difficult to evaluate how many of them are used by customers for heating during late autumn, winter, or early spring. However, it is estimated that this number is growing.

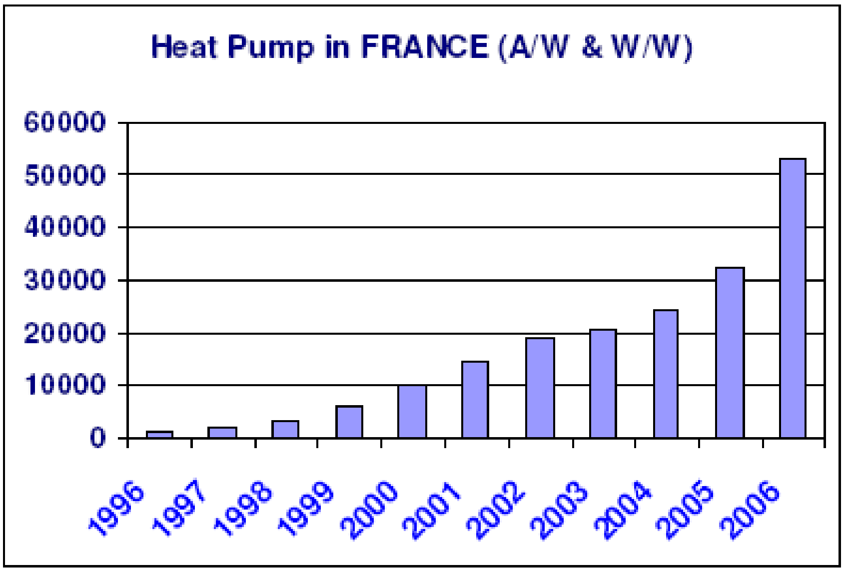


Fig.9: Development of the French heat pump market between 1996 and 2006 [7]

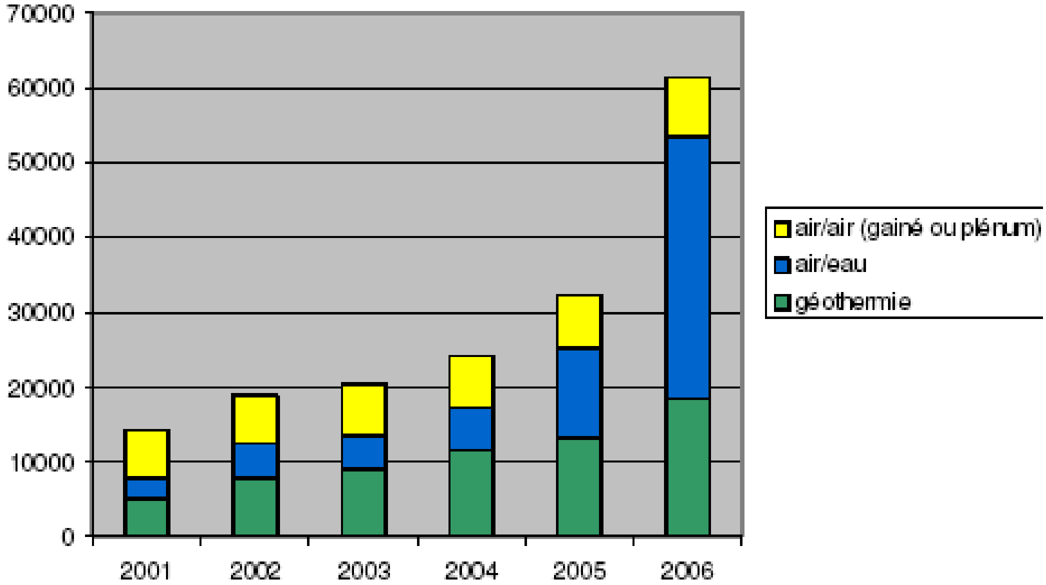


Fig.10: heat sources of french sold heat pumps btween 2001 and 2006 [7]

As a result of the building situation, the market potential of heat pump for existing buildings is much greater than for new buildings. The main barrier for the retrofitting in the existing buildings is the heat distribution systems using radiators
Nowadays, high temperature heat pumps account for an interesting alternative to boilers, with real advantages in term of CO_2 emission and energy efficiency. And other advantage of heat pump can be expressed by the energy that can be saved over a year.

Considering a retrofit approach where we have just to change the heating system, with no modification in the emitters nor important work on the house insulation, the common heat pump can not be used. A new generation of heat pump can respond to these requirements, they are called high temperature heat pumps

The Netherlands

In the Netherlands presently 70.000 new buildings per year are built, which will decrease 2010 to 50 % (35.000 houses) and increase 2020 again to 80 % (56.000 houses), which, however, would be low energy and passive houses.

The penetration of individual (hydronic) central heating systems has been increasing steadily and is now over 80 %, the remainder being split up under collective systems (just under 10 %, slowly growing) and room heating systems (just over 10 % and decreasing). Natural gas is by far the most used energy source.

Four different basic types of space heating are registered in the EBM-monitoring, being:

- Local room heating
- Central heating
- Collective block heating
- District heating

	2000	2001	2002	2003	2004
Local room heating	**10,3**	**9,0**	**8,3**	**8,2**	**7,7**
Central heating	**79,2**	**79,8**	**80,6**	**81,0**	**82,1**
Collective block- heating	**6,7**	**7,3**	**6,8**	**5,6**	**5,6**
District heating	**3,2**	**3,4**	**3,6**	**3,6**	**3,7**

Tab.7: Development of heating types (in %)

High efficiency boilers are the normal choice for new dwellings and refurbishments, leading to a steadily increasing partition in 2004 of 67 % of the installed base for dwellings with central heating and 50 % of all dwellings.

	2000	2001	2002	2003	2004
Before 1980	7%	7%	7%	4%	5%
1981 - 1990	29%	27%	25%	22%	17%
1991 - 1995	58%	48%	49%	37%	21%
>1996		15%	19%	34%	50%
Unknown	6%	3%	1%	3%	6%

Tab.8: Age distribution of installed gas-boilers in 2000 through 2004 (the Netherlands)

Space heating

In 2004, 50 % of the gas boilers were installed after 1996, the average age being about 10 years. Less than 22 % or about 1 million of the gas boilers is over 15 years old. Every year 250.000 new gas boilers are installed from which roughly 50.000 are installed in newly built houses. This can be compared to the 10.000 new houses that are equipped with heat pumps or connected to district heating.

Hot water heating
The installations for tap water heating show a trend from individual gas instantaneous water heaters (so called geysers) towards combi flow through gas boilers. With these developments the use of gas for water heating is decreasing as gas boilers are more efficient than geysers. An overview of the types of water heating is given in Fig. 11 Because in some dwellings there are more than one installation the total number sums up to over 100 %. In 2000 it was 116 % and in 2004 111 %.

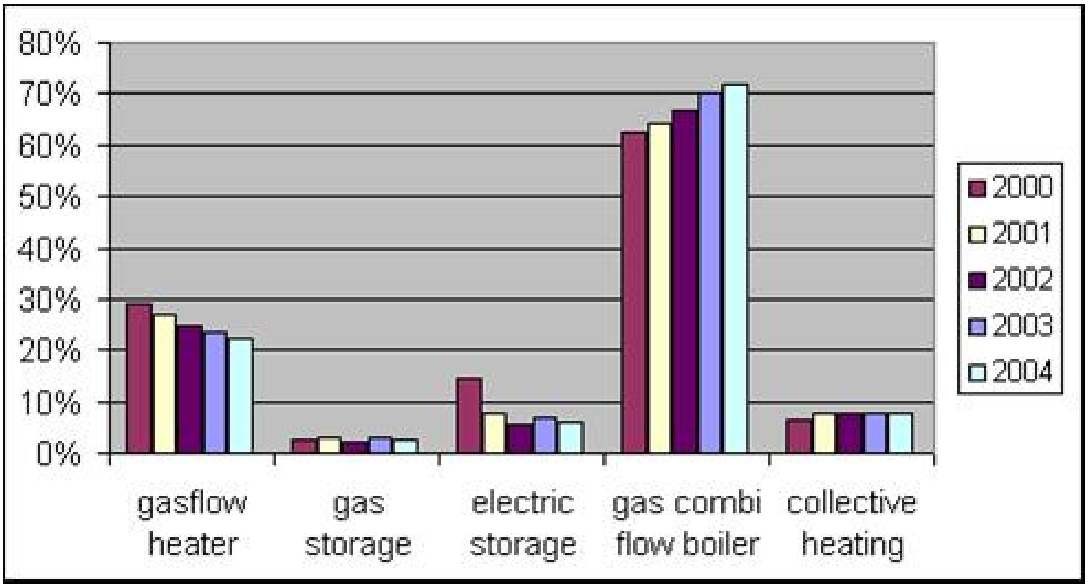


Fig.11: Penetration of the type of water heaters

In 2005 21.176 heat pumps were in operation in the residential sector (source: CBS). The turnover has shown an increase from virtually none in 1994 to 3.468 in 2005. The market consists mainly of heat pump water heaters (air to water) and heat pumps for room heating or combined room and water heating. The market share of heat pumps for room heating and cooling combined with water heating is increasing rapidly, and is expected to surpass that of heat pump water heaters only in 2006. No data on the division of heat pumps for the new and the retrofit market is available.

Sweden

The most common heating systems for domestic use in Sweden are hydronic heating systems and direct-acting electric radiators. Previous to 1980 radiator systems used high temperatures, typically 80/60, i.e. a supply temperature of 80 °C and return temperature of 60 °C at the design outdoor temperature. In 1984 new building regulations were issued where it was prescribed that hydronic heating systems must be designed in such a way that the supply temperature at the design outdoor temperature does not exceed 55 °C. Many of the old systems could also be adjusted to these temperature levels because they were oversized. Other actions such as extra insulation of the house also helped to decrease the temperature levels. Thus the most common temperature levels today are 55/45 at the design outdoor temperature. At present under floor heating systems are gaining market share, probably due to comfort and aesthetical reasons. These systems are typically designed for 35/28 at design outdoor temperature. When a direct-acting electric heating system is changed to hydronic systems, a fan-coil system is the most convenient choice. These systems also work with low temperatures and will probably be more common in the future since the Swedish policy is to decrease the use of direct-acting electric heating.

In Sweden there are altogether 1 775 000 single family houses. The building stock is fairly old, 43 % of the dwellings were built before 1961. New construction has been extremely low ever since the last recession in the beginning of the nineties. The total number of new constructed single-family houses 2002 was 7227. In comparison, the total number of new single-family houses in 1975 was 47 057. Strict building regulations combined with a high degree of energy awareness have led to the fact that those new constructed buildings are well insulated, thus leading to low heating demand. The tight envelope of the new buildings raises the demand for controlled ventilation. As a result exhaust air heat pumps are prevalent in new dwellings. The majority of the building stock though, still relies on natural ventilation. Except for the buildings heated by direct electricity, hydronic radiators are still the dominating form of heat distribution within the building. Air distribution systems in dwellings are very rare. Heat pumps are today installed in more than 90 % of the new single family houses. The low rate of new construction however, implies that the biggest market potential stems from the existing building stock.
Tab. 9 shows the heat demand per square meter and year for buildings, which were typical for their construction year..

Year of building construction	Heat demand kWh/m²a
till 1950	176
from 1950 till 1965	164
from 1965 till 1975	152
from 1975 till 1980	128
from 1980 till 1990	120
since 1990	108

Tab.9: Average annual heat demand in Sweden Data provided by The Mid Sweden University

In Sweden close to one third of Swedish single family houses are heated with electricity only, and direct electric heating is more common than electric boilers in a water-based system. More than 20 % apply a combination of bio-fuels and electricity. Bio-fuels have become more common than oil for heating Swedish single family houses. District heating for single family houses is not so common in Sweden, only 8.6 % of the houses use district heating.

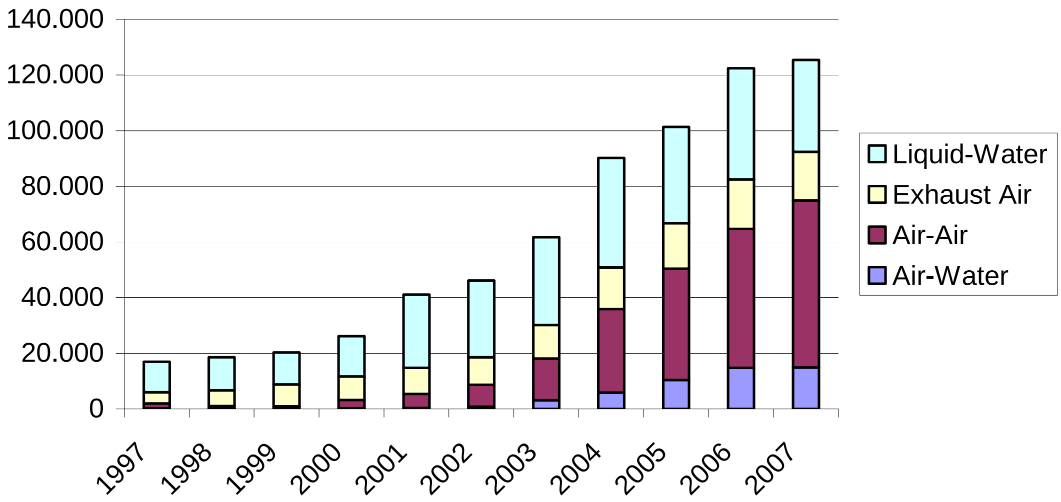


Fig. 12: Heat pump market development in Sweden 1997-2007 (est.) [8]

As seen in Fig. 12 Heat pumps are the first choice for heating in Sweden. However Sweden has only 9 million inhabitants and 1,744 million private homes. The Swedish market is a mature heat pump market**,** concentrated on the retrofit of the building standard.

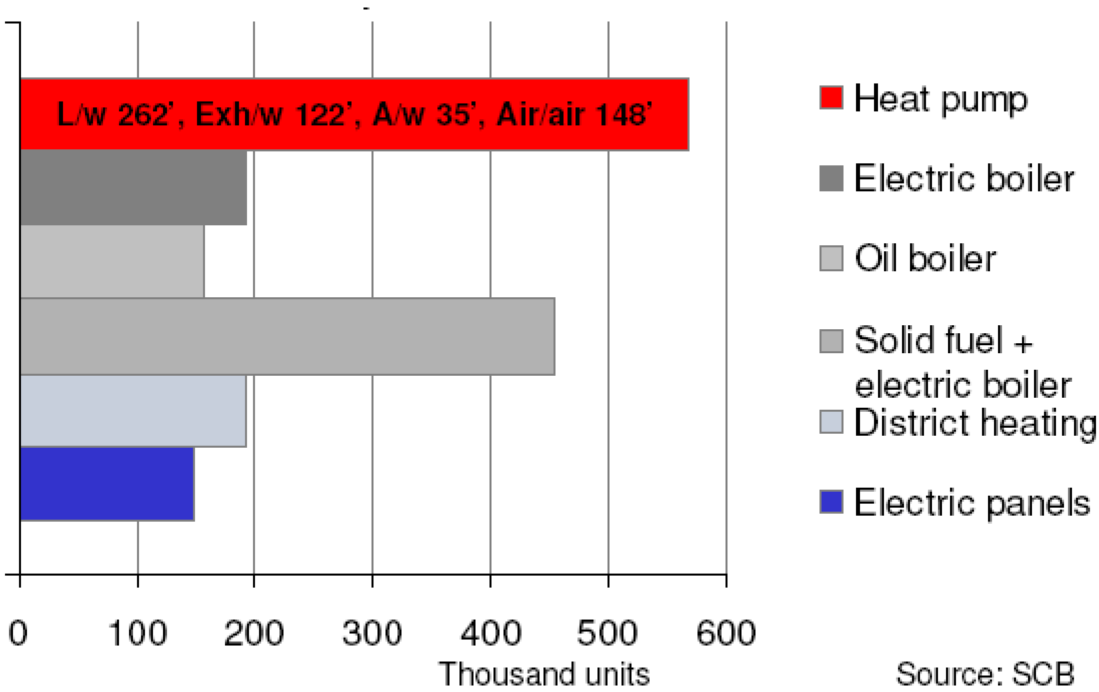


Fig. 13: Heating systems in Sweden 2007 [8]

United Kingdom

The UK market for space heating systems is dominated by natural gas fired boilers. This is because natural gas is very widely available in all populated areas (accessible to >90 % of the population) and is generally the least cost conventional heating option. Furthermore, very strong competition in the gas appliance market keeps the capital costs of boilers low. There is thus no economic incentive for existing gas consumers to move to a different heating technology.
Oil, LPG and electric heating are niche markets. Oil and LPG are mainly used in rural areas or remote sites where natural gas is unavailable. Electric heating is used in specific applications such as small apartments that are not connected to a central boiler system and some family houses that were typically built before 1970. Apartments and houses with electric heating utilise storage radiators to benefit from off-peak tariffs.

Although heat pumps have been available in the UK for a long time, very few have so far been installed specifically for space heating in residential and commercial buildings, and the market penetration lags far behind most other countries in Europe. The UK Government does however recognise the benefits of reduced carbon emissions from heat pumps and financial incentives are now available under several programmes. These incentives, coupled with increasing awareness of the benefits amongst potential installers and increasing choice of systems, have boosted the market for heat pumps, but it is still tiny compared to conventional gas boilers.

The most common form of heat pump in the UK is the reversible air to air split unit, but in reality the heating function is rarely used. “Real” heating systems include:
- water to water (in-building heating/cooling redistribution)
- air to air (condensing exhaust heat recovery)
- air to water (condensing exhaust heat recovery)
- open loop ground source
- closed loop ground source.

4. Present use of heat pumps as a retrofit

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, a new attitude towards environmentally sound energy is developing in Europe

In Germany overall sales of heat pumps grew at rate of 42 % from 2004 to 2005 and 140 % from 2005 to 2006 (see Fig. 4). Out of a total of 43.115 sold heat pumps in 2006 22.613 ground source heat pumps and 13.292 outside air to water heat pumps were installed. The air to water heat pump had the biggest growth in 2006, followed by the ground source heat pump.
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.

In Switzerland 2006 75 % of all new one-family houses are equipped with heat pumps, however, as shown in Fig14, the retrofit market in residential buildings is between 2003 and 2006 only around 25 % of the total, but 2008 already 37,5 %

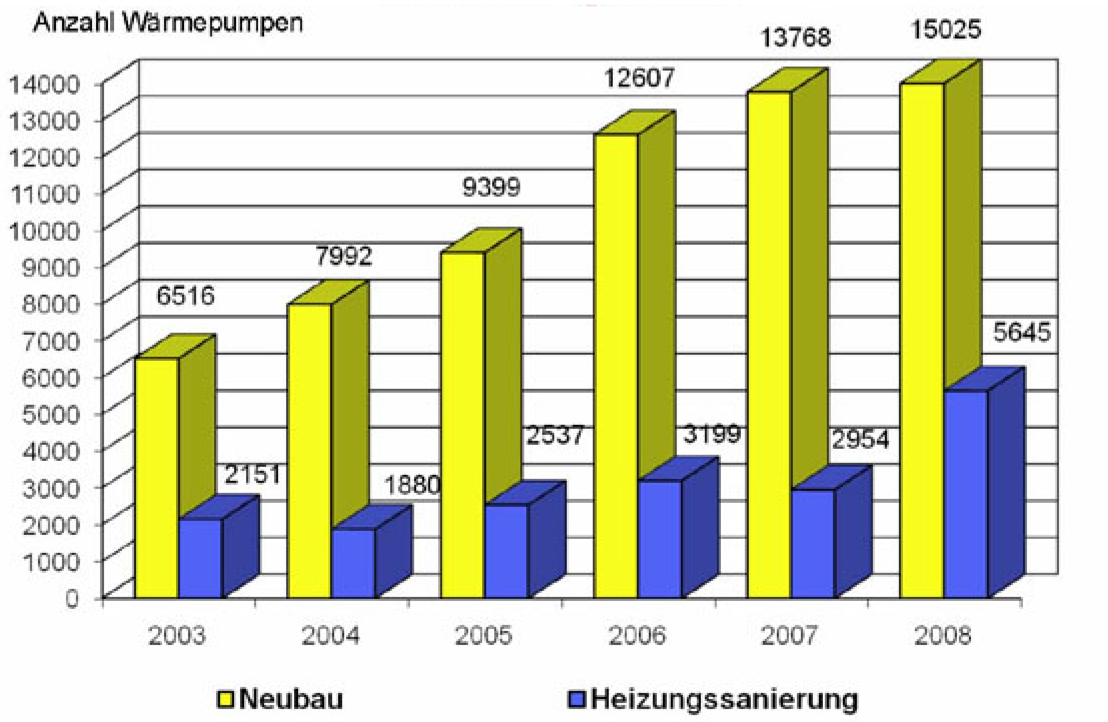


Fig. 14: Sold heat pumps related to the application (new or retrofit buildings)4

The Swedish heat pump market is the largest and arguably most dynamic in Europe.

Heat pumps are well recognised by most one-family households in Sweden today; between 350.000 and 400.000 Swedish dwellings are currently heated by a heat pump. Strict building regulations and high levels of energy awareness mean that new buildings constructed in Sweden require very high levels of insulation. 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

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 degree 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 heating

.

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. 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 boilers

Cooling is common in southern Europe in particular (southern France, Greece, Italy and Spain), and air is the common medium for distributing the cooling. Heat pumping technology in a reversible air based system is widely accepted in these areas also for retrofit.

Attachment III presents a total of twenty case studies and demonstration projects, collection of practical applications of heat pumps in existing buildings, analysises of the results for present generation of heat pumps and improvement of components and systems in different European countries.

5. **The renovation process**

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. A survey of the category of work and the average frequency of work on it shows:

Category of work	**Frequency of work (years)**
Decoration	7
Internal remodelling	10
Replacement of services	13
Stuctural alterations, conversions etc.	25
Replacement of external non-structural elements	29

Looking at the reasons for the renovation work:

Motivation	**%**
Statutory requirements	3
Update to current technologies	5
Follow fashion and trends	8
Improvement of building performance	9
Increase of economic value	11
Improve of appearance	16
Maintenance	20
Increase or improved use of space	30

The reasons for renovation differ greatly depending on the ownership of the house.
In the EU 56 % of the domestic dwellings (2000) are owner occupied, but figures vary between countries from 42 % in Germany to 80 % in Spain

	Owned	**Rented**
Germany	42	58

Netherlands	55	45
France	60	40
UK	67	33
Spain	80	20

Factors influencing the market for retrofitting heating systems vary a lot per market sector and can not be generalized for the complete market.

However, in general certain rules can be given as a guide line for energy upgrading of buildings. As a rule of thumb thermal insulation is the first renovation step for buildings more than 30 years old. This type of renovation is very fundamental and is mainly undertaken in larger restructuring processes.

The basic rules for renovation and creating a low-energy building are:
- firstly, to reduce the energy demand
- then use energy from renewable sources
- finally produce the remaining demand more efficiently.

This principle is called the “Trias Energetica”.

The energy consumption for the heating of buildings can thus be reduced by the appropriate combination of several measures:
- insulation of components: roof, wall and floor
- application of insulating glazing
- air-tightness of buildings
- orientation of buildings and rooms for the use of passive solar energy
- use of an efficient and environment-friendly heating system
- installation of comfortable and efficient ventilation
- use of renewable energy as heating support
- use of heat pumps as heating support.

Thermal insulation (combined with the application of energy saving windows) holds a key position among these measures, which lay the foundation of low-energy building.

The levels of renovation are however dictated by the market (in a broad sense). The motivation of the owner and the age of the building are not always rational. A further analyse of the barriers and the prime movers in the market will be made under chapter 5.

Thus the market for renovation falls apart in market segments which can be structured around the types of renovation, building structures, design and ownership:
- Drastic renovation in which the buildings are demolished and rebuilt.This is mainly taking place in the segment of rented buildings in ownership of corporations or town councils. This type of renovation projects for multi family houses as well as one- and two-family houses are executed together with town councils and the owners on a large scale in inner city renovation projects. The freedom of design makes it possible to use ‘any’ type of individual or collective heating system and heat pumps.
- Large scale refurbishment where the standard of the building is brought up to present standards with better insulation and heating systems.

- This is also taking place in the segment of rented buildings in ownership of corporations or town councils. The envelopes of the building as well as the energy installation are renewed. There is some freedom of design. Leaving the high temperature heating system in the building narrows the possibilities for heating technology.

6. Overcoming ecomomic, enviroммental and legal barriers

Analysing the barriers for the market introduction of retrofit heat pumps
- advanced technical solutions
- economy of the system
- ecology (energy-efficiency and reduction of greenhouse gas emissions)

have to be considered.

The first step should be a collection of main barriers and problem areas for the use of heat pump for the retrofit of heating systems for further discussion as well as problem solutions:
- High distribution temperature of conventional heating systems in existing residential buildings.
- Present generation of heat pumps has a maximum economical heat distribution temperature of 65 °C
- Ratio of the nominal capacity of the heat pump and the heating system

Long term use of the refrigerants: flammable / F-Gases / CO_2

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 and environmental issues leading to lower greenhouse gas emissions, particularly by the use of low or zero GWP working fluids.

A summary of the present status of R;D&D projects for advanced heat pumps, subdivided in systems, components and components and refrigerants, is presented in Attachment IV.

- **High investment cost**
  - 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.
  - A Swedish study shows that the investment costs can be devided into
    - Heat source, normally vertical or horizontal ground loops 35 % - 40 %
    - Heat pump 40 %
    - Installation 20 % - 25 %

- The investment cost of the heat pump in an eighty years old house [9] – installed July 2006 –are devided as follows
  - o Heat pump source (ground water) 30 %
  - o Heat pump 40 %
  - o Installation 30 %

- Costs of earth-probes up to 100 m for an installed heat capacity of 20 kW may reach up to 50 % of the total investment and the installation cost up to 40 % of total, depending on the specific condition of the individual house. Besides the cost of the earth coupled heat source, availablity and legal regulations are of specific importance. As an example the hydro-geological conditons and related regulations of earth-coupled heat sources in the city of Karlsruhe are shown.

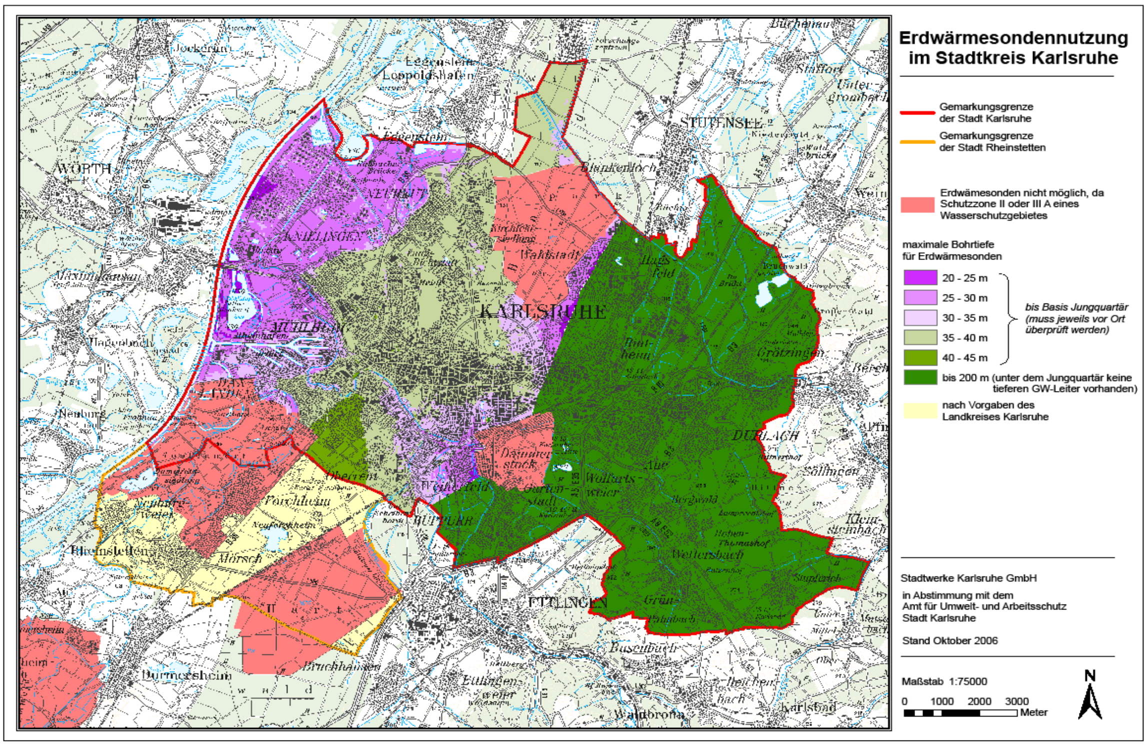


Fig. 15: Hydrogeological conditions and regulations of earthprobe use in the City of Karlsruhe /Germany [9]

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 below, comparing the natural gas costs 2005 to 2006 with the actual electricity costs 2006 to 2008. A comparison of the actual natural gas costs 2006 to 2008 would increase the difference to nearly 65 %

08.07.05 - 07.07.06 (natural gas 2005-2006): € 3.637
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 = - 50 %**

- Those promoting and marketing heat pump systems may here be facing a pedagogical, or educational challenge. In addition to marketing arguments, environmental and comfort benefits of heat pumps should be stressed and valued.

- **Electricity tariffs**
  In some countries utilities offer special heat pump tariffs, which are generally between 30 and 50 % below the normal residential electricity tariffs. However, up to two hours interruptions up to three times per day have to be accepted and additional technical solution foreseen, e.g. bumper-storage,.

- **Low energy prices**
  Low energy prices, which do not fully reflect the external cost of the different energies, are a significant barrier in some European countries. This is often related to the fact that even if a heat pump system is economically competitive, the energy cost difference may be too small to decide for the heat pump system. This is in spite of other benefits that a heat pump system offers, such as reduced CO_2-emissions, more comfort etc. This barrier can only be overcome by offering incentives, grants, renewable energy tax benefits for heat pumps, exempted or reduced CO_2-taxes etc.
- Long term price development oil and gas compared with kWh electricity
- Energy performance of the building
- Heat pump manufacturer still prefer new buildings

- **Interaction of the heat pump in the building**
  Several heat pump manufacturers already offer heat pump units that can produce water at temperatures up to 65 ^{o}C. While the product offer should become broader, the biggest issue is not “product” related. There is the lack of practice and competency to integrate such heat pumps in the existing building stock.
  While replacing a boiler by another boiler is more or less a plug & play exercise, replacing a boiler by a heat pump will require:
  – a thorough understanding of the heat demand of the building
  – a thorough understanding of the heat distribution system (temperatures, circuits, regulating valves)
  – the design of a circuit and controls that enables the heat pump to operate under all weather conditions; in particular when the weather is mild (high heat supply versus low heat demand)
  –

- **Poor perception**
  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.

If initiatives aimed at increasing the future use of heat pumps in Europe are to be successful, steps must be taken to avoid that such situations are repeated. These steps include the training and certification of installers and marketing personnel. They should also include the establishment of a heat pump labelling programme, as a guarantee of energy efficiency performance and environmental benefits.
It is believed that a simple method of calculating heat pump system savings in terms of energy and cost could be a useful tool for heat pump sellers, who should be able to give a heat pump buyer reliable and relevant information. The development of such a method should therefore be considered
– Support programmes of local communities, utilities, government
– Incremental value of the building /dwelling

- **The limited awareness**
  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

7. Successful factors for the marketing of retrofit heat pumps

Analysing 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 a retrofit heat pumps can be summarized as follows [8]:

- Suitable heating systems
- Temperature level below 65 degree 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, 10-12000 Euro, same prices as 1985
- Low running cost
  - Annual saving on running cost is 1.500 Euro in new built house
  - Annual saving on running cost is 2.500 Euro in an old house
- Reasonable pay off time, 5-8 years
- The end customer have one partner only
- Good comfort

- Neighbor 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.

Heat pumps are an old technology, which has not been extensively used as long as both energy prices and the efficiency of electricity generation have been low, taking into account that the drive energy is most commonly electricity. For the future improved power generation systems based on renewables and fossil fuels have to be taken into consideration, e.g. the efficiency of gas-fired combined-cycle power plants available on the market is already about 58 %, with oil-fired systems similar values are possible.

First of all basic conditions such as the price of the primary energy can considerably impact the market of heat pumps. For instance countries with low oil- and gas-prices consider less environmentally-friendly heating solutions**.**

.

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 are 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.

The following facts may underline this statement:

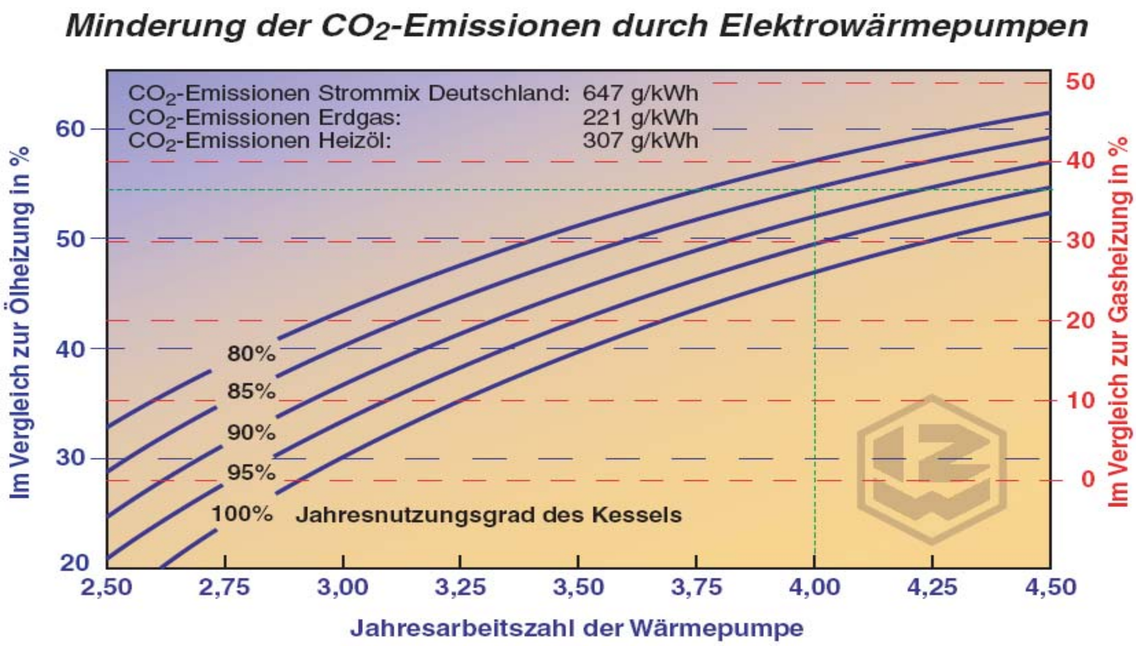
Tab. 10: shows the weighted emission-factor of a “weighted average” heat source for each country.

Fig 16 shows the Greenhouse gas emissions (kg CO_2/kWh) of heat pumps compared with conventionalnatural and oil heating systems

Table 11 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.

	Electric heaters		Gas burners		Fuel oil burners		A/W heat pumps		W/W heat pumps		Weighted indicator
Country	Emission factor (kg CO_2/kWh)	(%)	Emission factor (kg CO_2/kWh)	(%)	Emission factor (kg CO_2/kWh)	(%)	Emission factor (kg CO_2/kWh)	(%)	Emission factor (kg CO_2/kWh)	(%)	kg CO_2/kWh
Austria	0,233	15	0,2172	50	0,2962	30	0,078	0	0,051	5	**0,2349**
Belgium	0,276	10	0,2172	50	0,2962	40	0,078	0	0,060	0	**0,2547**
France	0,032	15	0,2172	50	0,2962	30	0,009	5	0,007	0	**0,2027**
Germany	0,517	5	0,2172	57	0,2962	35	0,173	0	0,112	3	**0,2567**
Netherlands	0,421	0	0,2172	70	0,2962	25	0,141	0	0,092	5	**0,2307**
Norway	0,003	70	0,2172	0	0,2962	20	0,001	0	0,001	10	**0,0612**
Sweden	0,014	40	0,2172	0	0,2962	20	0,006	20	0,003	20	**0,0666**
Switzerland	0,011	10	0,2172	35	0,2962	45	0,004	0	0,002	10	**0,2107**
United Kingdom	0,442	5	0,2172	60	0,2962	35	0,148	0	0,096	0	**0,2561**

<u>Tab.10</u>: Greenhouse gas emissions (kg CO_2/kWh) of different countries**:**



<u>Fig.16</u>: Greenhouse gas emissions (kg CO_2/kWh) of heat pumps compared with conventional heating system

<u>Tab. 11</u> shows in 1977 a saving by heat pumsp of already 0.5 % of the total global CO_2-emissions and 2001 of 0,6 %. Presently more than 130 million heat pumps with a thermal output of 1300 TWh/a are in operation world-wide, reducing CO_2-emissions by about 0,13 Gt/a.
The results of the potential savings in the third column can be summarized as follows:
The potential for reducing CO_2-emissions assuming a 30 % share in the building sector using technology presently available is about 6 % of the total world-wide CO_2-emissions of 22 Gt/a.
These 6 % are one of the largest contributions to CO_2 reduction a single technology available on the market can offer. The fourth column is based on greatly advanced future technologies of heat pumps and power plant efficiencies. It yields a 16 % saving of global total CO_2- emissions.

Residential	1977	2001	Savings potential	
			Present	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	1.550
CO_2-Emissions				
From oil-fired boilers Mt CO_2/a	204	215	1672	3500
From heat pumps "	140	140	1022	1500
Savings by Heat pumps "	64	75	650	2000
Savings commercial "	30	35	350	1100
Savings industry "	20	22	200	600
Total Savings	**114**	**132**	**1200**	**3700**
% CO_2-savings by heat pumps	**0,5 %**	**0,6 %**	**6,0 %**	**16.0 %**

Tab.11: Present and estimated future savings of CO_2-emissions by the use of heat pumps [10]

Time	System	CO_2-Emissions (kg CO_2)		
Average 2002 - 2006	Natural gas	13,909*		
		D (0.562)	KA (0.481)	EU (0.48)
		(kg CO_2/kWh)		
20.7.06 – 19.07.07	HP-electricity	6,859	5,870	5,858
08.07.07 – 07.07.08	HP -electricity	7,912	6,772	6,757
Reduction in %		47	55	55

Tab: 12: CO_2-emissions of a Juli 2006 installed heat pump in an eighty years old one-family house after two years of operation compared with the previous gas heating [9].

Tab. 12 shows around 50 % reduction of CO_2-emissions of a water/water heat pump, installled in an eighty years old one-family house compared with the previous natural gas heating system. [9].

Tab.13 below shows the longterm potential of different renewable energies for heat generation, resulting in the highest contribution of geothermal energy, corresponding with earth-coupled heat pumps.

Heat generation	Present use	Longterm potential
	TWh	TWh/a
biomass	59,8	200
geothermal energy	**1,6**	**330**
solarenergy	2,6	290
total	**63,9**	**820**
Percentage related to the final energy consumption for heat 2003	**4,2 %**	**55 %**

Tab.13: Longterm potential of renewable energy for heat generation

The forecasts take into account an extensive retrofitting with heat pumps in the building stock. The present heat pump market in existing buildings, with the exception of Sweden, is small compared with the present dominating market in new buiklings.

Therefore, heat pumps are one of the key technologies for the reduction of fossil fuel consumption and CO_2-emissions and the market potential for retrofitting is much larger than in new buildings

However, successful marketing of retrofit heat pumps is more difficult.The retrofit market heating systems are characterised by high supply temperatures and low thermal inertia of the existing heat distribution systems. In comparison to a conventional heat pump, a successful retrofit heat pump must have a smaller drop of heating capacity, a lower compressor outlet temperature, and a higher performance factor at higher temperature lifts. Furthermore, a more sophisticated control strategy of the heat pump heating system is needed in order to minimize the size of the heat storage tank or to avoid it completely if possible. This has to be based on a dynamic model of the whole heat pump heating system including the heat source, the heat pump, the heat storage tank, the hydronic heat distribution and the building.
.
Retrofit heat pump requires therefore much more sales processes compared to new buildings. The sales procedure consists of several stages, which have different impact factors. In that sense, installers, engineers as well as boring companies play a very important role. Nevertheless, also the power-supply company has to be considered in this process. For example, a privileged heat pump tariff can give the heat pump an advantage with respect to the operational costs among its competitors. However, it is a win-win situation since in turn the power-provider can sell energy for the next 20 to 30 years
Another important aspect is the building design whereby a city building with heavy walls has other requirements on the heating system than a blockhouse with light walls. Finally drilling boreholes in a well-tended garden seldom elicits much enthusiasm.
For retrofit heat pumps air and well water remain in most cases the possible heat sources. Furthermore, heat pumps are only accepted if they provide comfortable room temperatures even in the coldest days without any backup heating system.

With respect to the price of heat pumps, a considerable price drop occurred over the last two decades in the market. In Switzerland the heat pump prices dropped by 50 % over the last 24 years (price of a brine/water-7,6 kW heat pump: 1981: 41.100 SF, 2005: 19.060 SF). As a result, the heat pump has become more competitive against conventional heating systems such as oil- and gas-fired boilers.

Even more 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.

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Information Centre on Heat Pumps and Refrigeration

Attachment I

Annex 30
Retrofit Heat Pumps for Buildings

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Attachment II

Annex 30
Retrofit Heat Pumps for Buildings

Overview Europe
State of the art – market analysis

1. Housing Statistics

		Norway	Sweden	Switzerland	France	Germany
	×	**2001**	**2002/03**	**2000/02**	**2001**	**2002/03**
Population	1.000	4.503	8.976	7.400	61.044	82.828
Households	1.000	1.875	~4.000	~1.900	24.407	38.718
Housing Stock	1.000	1.874	4.364	1.180	29.367	38.370
single-family	1.000	1.530	1.998	822	16.647	10.779
two-family	1.000			130		6.975
multi-family - flats	1.000	344	2.366	228	12.720	20.616
Age						
< 1948		22%	27%	38%	33%	28%
1949 - 1980		54%	56%	36%	35%	49%
1980 - 2000		24%	17%	26%	32%	23%

Tab.1: Statistics, housing stock in selected European countries

	2001	2002/03	2000/02	2001	2002/03
Type of Energy					
District Heating		+++		+	
Gas			++	+++	++++
Electricity	+++	+	++	+++	
Oil		+	+++	++	+++
Hard-Brown Coal, Coke		+			
Wood, renewable energies		+	++	+	
Housing completion	24.500	19.986	26.500		252.602
single-family	15.500	8.143	10.000		135.246
two-family					37.628
multi-family - flats	9.000	11.843	16500		79.728
Yearly sales Heat Pumps	~35.000*	~60.000	~10.000	~25.000	~20.000

Tab.2: type of energy, housing completion, heat pump sales in selected countries

2. Heat Pump statistic

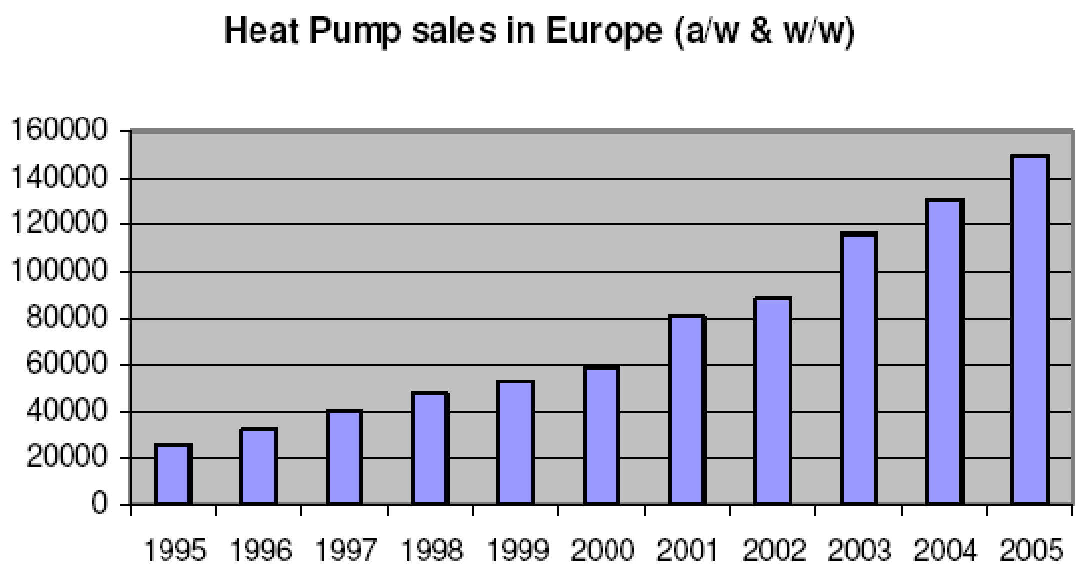


Fig.1: Heat pumps sales in Europe between 1995 and 2005

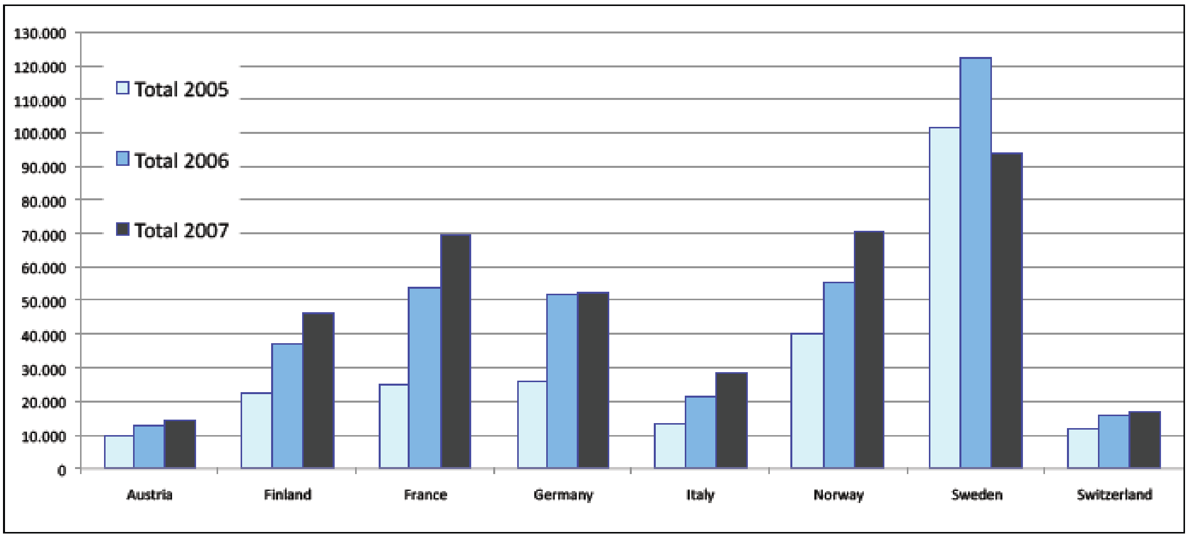


Fig.2: Heat pump statistic in selected European countries

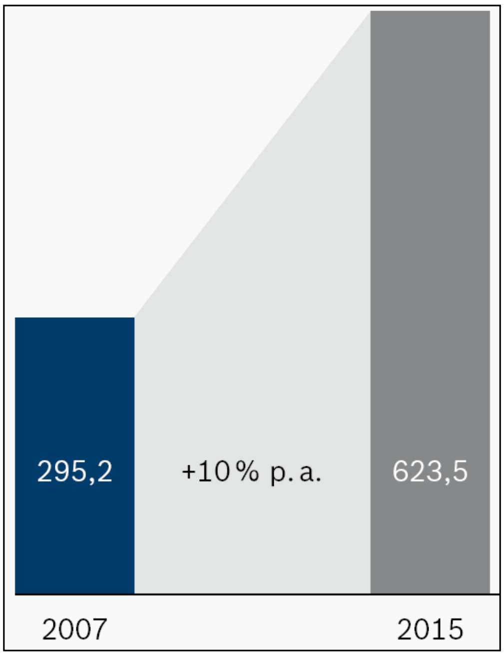


Fig.3: Long term market growth of heat pumps in Europe (sales units x 1.000)
(Source: Marktreport 2007 Bosch Thermotechnik)

3. Heat pump application overview

Heat pumps can successfully be 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 (see tab.3 below).

	New buildings	Renovation
Residential: single/double family house	**Mass market currently developing**	**Largely undeveloped (besides Sweden & Switzerland)**
Residential: multi-family residency	**Small market developing**	**Initial development steps**
Non-residential/commercial	**Minority share in currently sold heat pumps. Several demonstration projects, potential for heating and cooling projects unexploited.**	**Initial steps, increasingly important with owners that value low operating cost**

Tab.3: Market segments for heat pumps (Source: EHPA)

4. Heat Pump contribution to EU energy goals

Heating & cooling consume at least 40% of all primary energy within the EU. The widespread replacement of oil and gas boilers as well as of direct electric heating systems with heat pumps could contribute significantly to the renewable energy strategy of the European Union in terms of

- **primary energy savings (energy efficiency),**
- **renewable energy production**
- **greenhouse-gas-emissions reduction (GHG emission).**
-

However such support will require that »ambient heat« is recognized as a renewable energy source and its contribution is accounted for in the national energy statistics.
An important step in this direction was the adoption of the EU Directive on the promotion of renew able 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 on 17.December 2008 by the European parliament.

Equipping a new one family house with a heat pump instead of an oil burner saves (on average) more than 4 tons of GHG- emissions and around 50% of primary energy per year. Around 75% of the total required energy is produced from ambient heat In order to illustrate the potential contribution of heat pumps on a European level (EU-25 states) 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?«. The potential contribution to the EU energy strategy is impressive: Starting in 2008 more than 70 million heat pumps would be installed by 2020. They would reduce final energy consumption by 902 TWh, would produce 774 TWh of renewable energy and would save 230 Mto of GHG (see Tab. 4)

	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%

Tab.4: Contribution potential of heat pumps to EU energy goals (source: EHPA)

Information Centre on Heat Pumps and Refrigeration

IZW e.V.

Attachment III

Annex 30

Retrofit Heat Pumps for Buildings

Case Studies

Contents

0 Introduction

An important aim of energy policy is to reduce energy consumption; especially for heating. A key question is how to reduce energy demand of existing buildings. The two main ways to reduce the heating demand in buildings are constructional measures and/or improvement of the conventional heating system.

Heat pumps will play an important role in the building stock as long as the necessary technical, economic and ecological conditions are fulfilled.

Retrofit heat pumps already show their potential in Sweden, where around 80% of sold heat pumps are used for retrofit, whereas in Switzerland only around 20% of the total market is related to retrofit.

STANDARD HEAT PUMP SYSTEM

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 SYSTEM

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 SYSTEM

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.

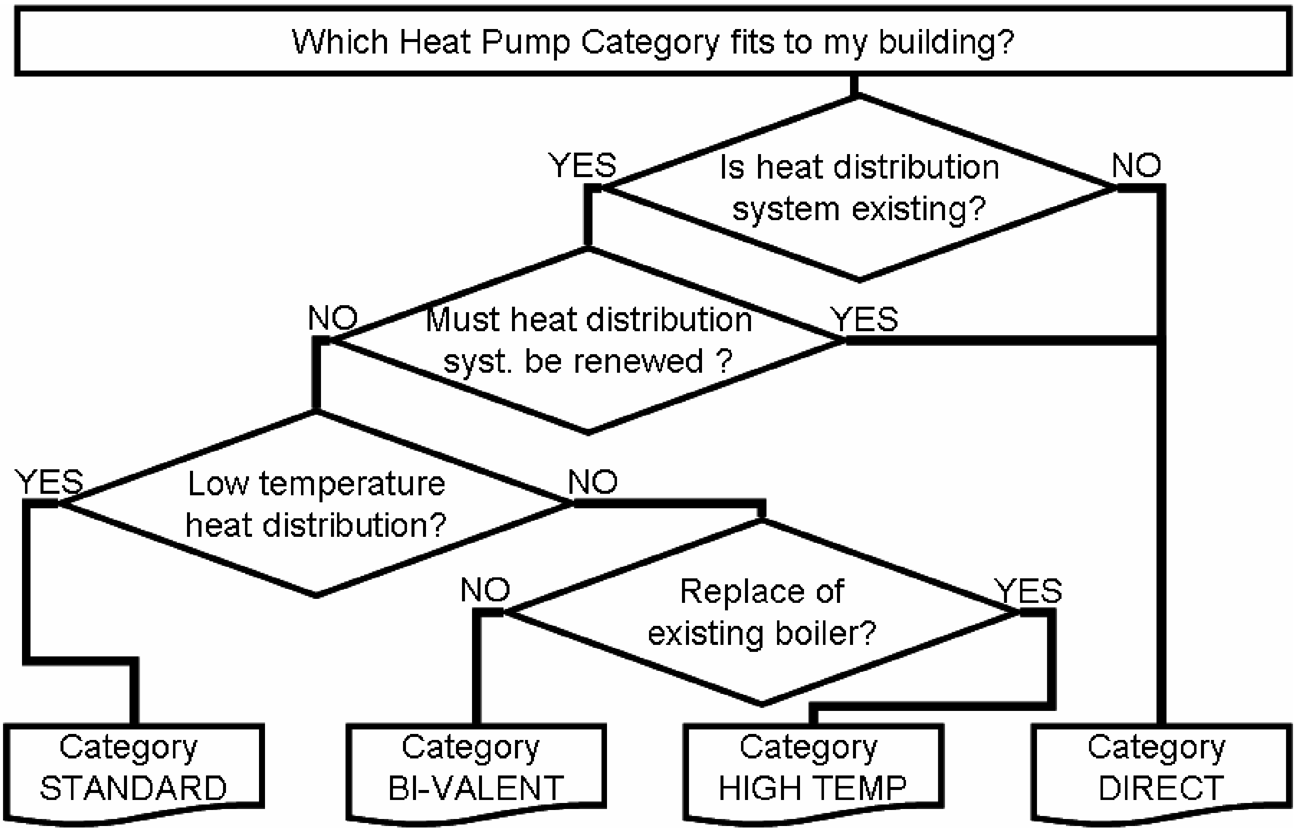
An additional ideal application for hight temperature heat pumps is domestic hot water preparation.

DIRECT HEATING HEAT PUMP SYSTEM (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).

However, the technical capability of heat pumps is able to meet today already an essential part of the heating and hot water demand in Germany, The Netherlands and France, as demonstrated in the following selected case studies of retrofit heat pumps. Each case study is indicated with its Category. For a guideline to analyze roughly which Category of heat pump is suitable in each case see flowchart on next page.

*Indoor air quality requires: ventilation system (may also include a heat pump to recover heat)


Which Heat Pump Category fits to my building?
Is heat distribution system existing?
YES
NO
Must heat distribution syst. be renewed ?
NO
YES
Low temperature heat distribution?
YES
NO
Replace of existing boiler?
NO
YES
Category STANDARD
Category BI-VALENT
Category HIGH TEMP
Category DIRECT

Case studies

In this chapter the examined case studies will be described.

1.1 Leeuwarden (STANDARD)

Project 01/NL - Achter de Hoven Gemeente Leeuwarden

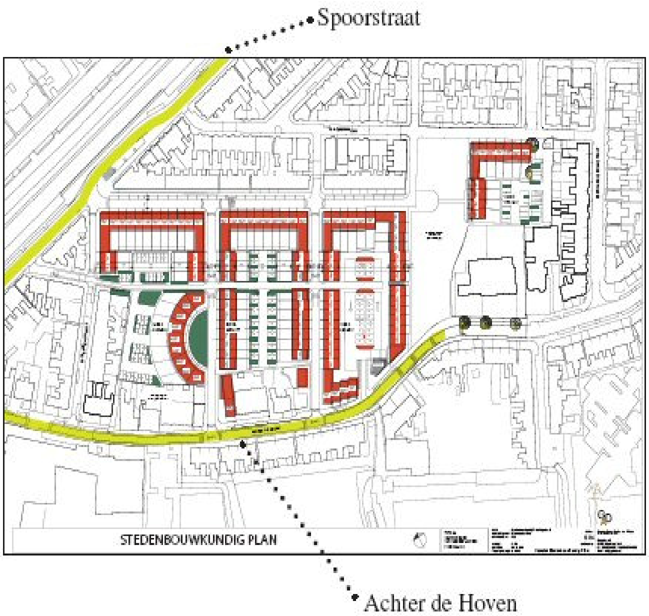
Rebuilding by a corporation

Source: O Kleefkens, SenterNovem

Number of inhabitants: 2.500

Location

Achter de Hoven/Vegelin is situated on the east side of Leeuwarden (NL).



Living, houses and environment

The quarter consisted of individual houses of which the western part de Vegelinbuurt dated from before 1914. The last decades the quality of living standards has deteriorated and the quarter got slummy.

Therefore the quarter has been nominated as priority target quarter in the policy for 'Stedelijke Vernieuwing' in the Netherlands.

The demolition of 160 dwellings has started in 2004, replacing these by 110 new houses. As the existing dwellings were used by families with a relatively low income these replacing new buildings had to be fitted to that particular market.

Initiative: Woonproject (CHF).

Commisioned: Corperation Friesland. te Grou

Architect Doeke van Wieren, Gunner Daan architects bv bna Jelle de Jong architects.

Minicipality Michiel de Boer Tel +31 (0)58 233 8871 m.j.boer@leeuwarden.nl

Project description

In 'De Vegelin' 160 dwellings, mainly built before 1914, have been replaced by 110 reasonably priced new dwellings. These new dwellings upgrading the whole quarter considerably in living standards have been designed by the architects Jelle de Jong and Doeke van Wieren. They have used the nostalgic characteristics for the outside but have equipped the houses with all main modern conveniences.

For the energy system it is the first project in which ITHO energy systems are used on a large scale for a renovation project. Each house is equipped with an individual electric heat pump, heat recuperation in the air ventilation system, low temperature floor heating and heat recuperation of the shower.

Summer cooling has also been installed increasing the living standards even more.

Projectbuilder: BAM woningbouw - Leeuwarden
Installer: P. de Vries bv Installatietechnieken - Leeuwarden.
Contact: Johan Meijer. 058-2880222
Servicing: P. de Vries bv Installatietechnieken – Leeuwarden

Realisation
Start: September 2004 - Finish: July 2005.

Economy:
Selling prices from € 125.000,- Renting from € 570,- /month.

Description of technology

As technology for heating, cooling and ventilation the ITHO-integrated concept has been used.

1.2 Rosenheim (STANDARD)

Groundwater heat pump unit - semi-detached house in Rosenheim/Germany

Source: Fachhochschule München, Prof. Dr.-Ing. W. Schenk

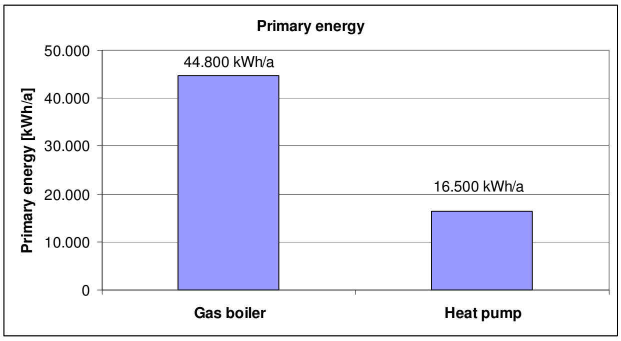
Heated area:	170 m^2
Year of construction	1984
Heat load	13.6 kW ≈ 80 W/ m^2

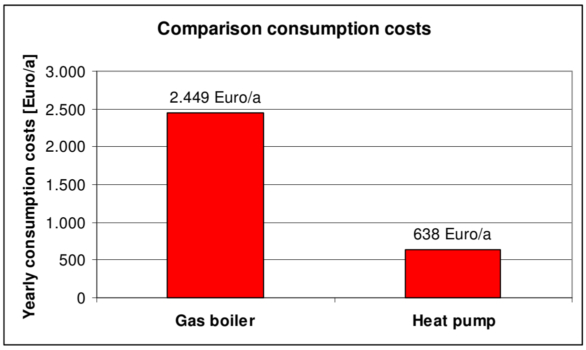
<u>Before redevelopment</u>

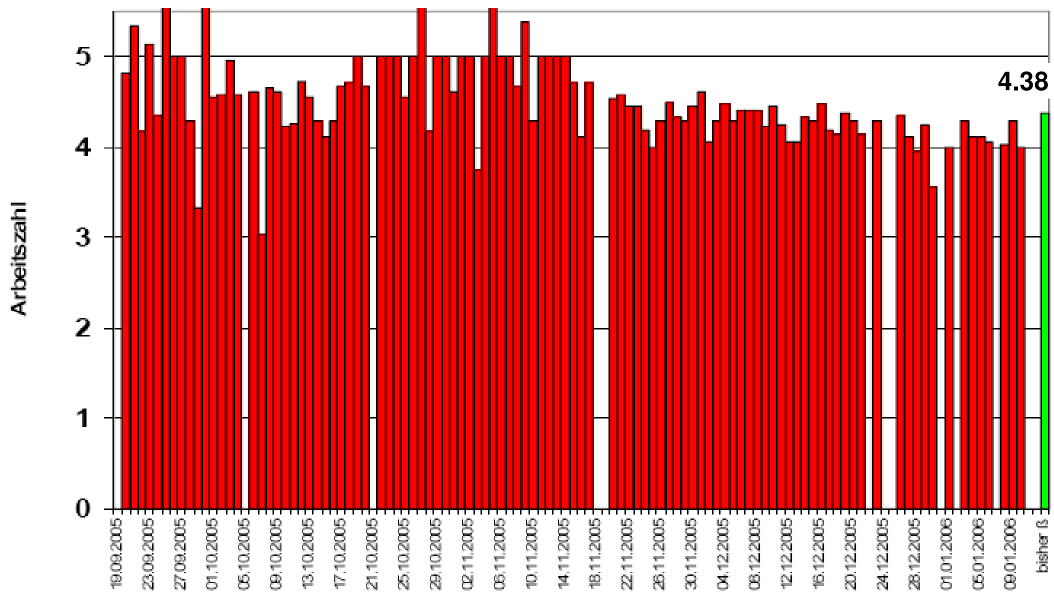
Gas boiler	21 kW
Gas consumption	38,000 kWh = 2,288 €/a
Electricity consumption	1,000 kWh = 161 €/a
Consumption costs	2,449 €/a
Primary energy consumption	44,800 kWh/a

<u>After redevelopment</u>

Heat pump	8.4 kW (W10/W55)
Freshwater system Electricity consumption	5,500 kWh/a
“Projected” Consumption costs	638 €/a
Primary energy consumption	16,500 kWh/a







Projected costs:

Full usage hours	2,400 h/a
Electricity consumption	5,500 kWh/a
Consumption costs	3.75 €/ m^2/a

Savings:

Consumptions Costs : 1,811 Euro/a

Primary energy: 63%

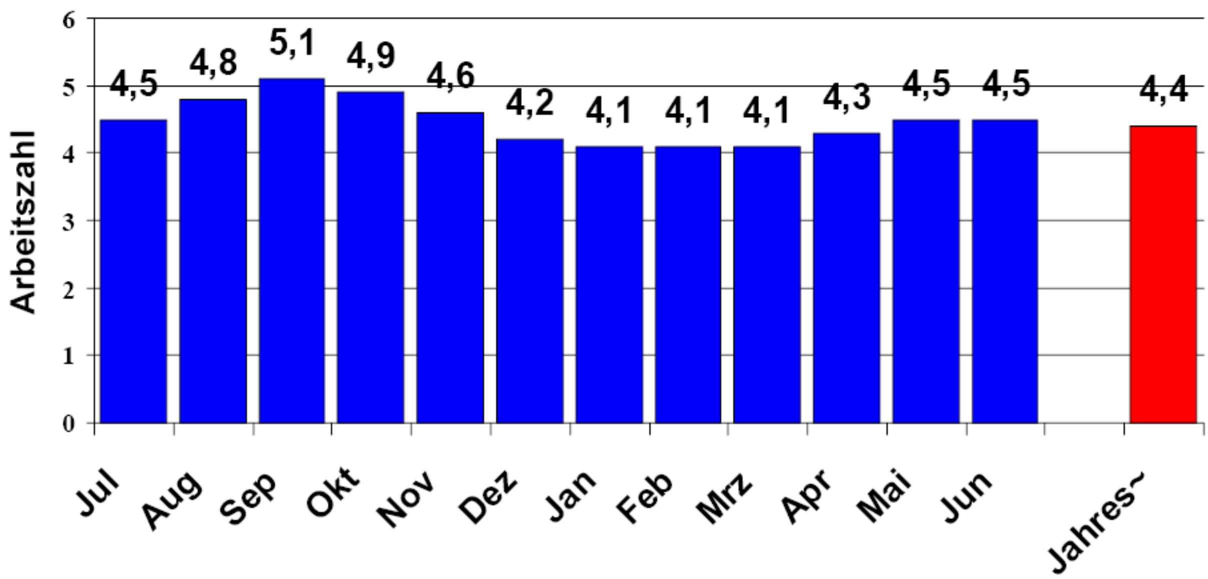
1.3 Halfing (STANDARD)

Earth-collector heat pump one-family house in Halfing

Source: Fachhochschule München, Prof. Dr.-Ing. W. Schenk

Data of the unit:

- heating area: 290 m²
- standard heat demand of the building: 12.9 kW
- power demand for tap water: 1 kW
- heat power of the heat pump: 12 kW
- cooling power: 9 kW
- **earth collector:**
- 5 circuits of 100 m
- area of the earth collector: 400 m²
- specific extraction power: 22.5 W/m²



Full usage hours:	3,200 h/a
Electricity consumption	9,800 kWh
Consumption costs	1,091 €/a = 3.76 €/ m²/a
	(for comparison only: 5,200 l oil = 3,100 €)

1.4 Karlsruhe (STANDARD)

Retrofit Heat Pumps for Buildings

Case Study

76133 Karlsruhe, Nördliche Hildapromenade 4

Source: Prof. Dr.-Ing. H.-J. Laue

Project description

Monument listed ("Bauhaus") building

Types and age of building

Year of construction: 1928

No. of dwellings: one

Total area: 300 m^2

Status before renovation:

Old hydronic central gas heating boiler with tap water generation

Owner of the building: Inge Laue

Participating companies

Installer MHK GmbH für Wärme- und Kältetechnik
68753 Waghäusel

Well builder Krämer Bewässerung GmbH
Gewerbering 6
76706 Dettenheim

Year of renovation: 2006

Duration of renovation : 3 weeks, July 2006

Technologies:

- Water / water heat pump with conveyor and sink well without intermediate heat exchanger
- 19,7 kW nominal heat capacity
- Single stage refrigeration circuit
- Refrigerant R407C
- Scroll compressor
- Enhanced vapour injection (EVI –Circle)
- Combined stainless steel – buffer for 300 l tap water + 650 l heating water
- Maximum heating temperature 65 °C
- Maximum tap water temperature 55 °C

Ecomomy

Total cost:

Heat pump	**40 %**
Wells, complete	**30 %**
Installation including electricity (meter etc.)	**30 %**

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 below, comparing the natural gas costs 2005 to 2006 with the actual electricity costs 2006 to 2008. A comparison of the actual natural gas costs 2006 to 2008 would increase the difference to nearly 65 %:

08.07.05 - 07.07.06 (natural gas 2005-2006):	€	3.637
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 = - 50 %**

*: average air temperature Germany:

year	winter	spring
2008	3,0	8,8
2007	4,3	10,8

Energetic and ecological results:

Start of operation: 20.07.2006

Result after two years of operation:

Seasonal Performance Factor

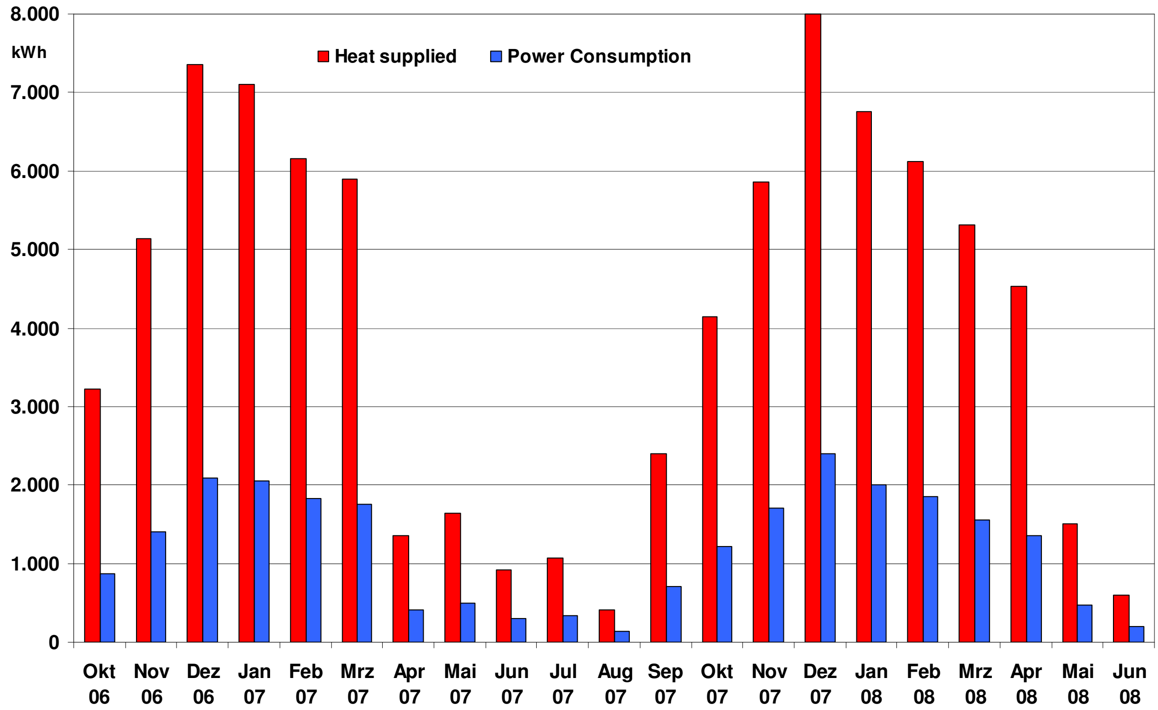
Heat pump condition	Time	Seasonal performance factor
Test run, only hot water	20.07.06 - 31.9.06	3.20
Test run, hot water and space heating	20.07.06 - 31.12.06	3.55
Hot water and space heating	20.07.06 -07.07.08	3.40
Space heating/hot water without water rotating pump	20.07.08 -07.07.08	3.53

Energy consumption

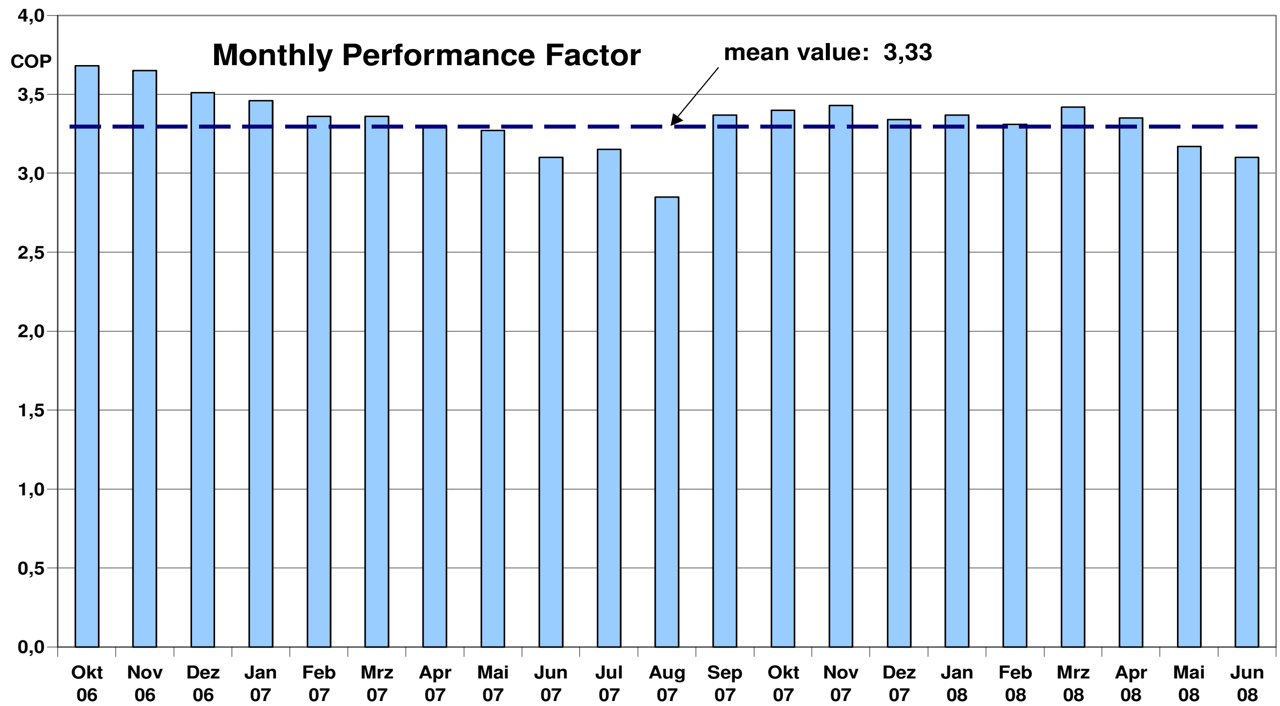
Time	System	Energy consumption			
		Final energy		Primary energy	
		kWh	kWh/m²a	kWh	kWh/m²a
Average 2002 - 2006	Natural gas	69.547	232	97,366	324
20.7.06 –19.07.07	HP-Electricity	12,205	41	32,953	110
08.07.07 – 07.07.08	HP – Electricity	14.078	47	38.010	127
Reduction (average) in %		89	89	63	63

Primary energy factor Natural gas: 1.4 Electricity: 2.7

Heat supplied and Power consumption



Monthly Performance Factor SPF (Oct.06 – June 08) 3,33



CO_2- Emissions

Time	System	CO_2-Emissions (kg CO_2)		
Average 2002 - 2006	Natural gas	13,909*		
		D (0.562)	KA (0.481)	EU (0.48)
		(kg CO_2/kWh)		
20.7.06 – 19.07.07	HP-electricity	6,859	5,870	5,858
08.07.07 – 07.07.08	HP -electricity	7,912	6,772	6,757
Reduction in %		47	55	55

***: natural gas: 0, 2 kg CO_2/ kWh**

Primary energy demand: [kwh/m^2 a]

Before (natural gas, average of five years): 324

After (heat pump electricity, 2006 – 2008): 118

The case has clearly shown that the real advantage of the retrofit heat pump is not demonstrated by a high SPF, but the absolute reduction of the primary energy consumption and the related CO_2-emissions in comparison with the earlier conventional heating system. Under the given conditions the heat pump has reduced the primary energy consumption and CO_2-emissions in comparison with the original gas-heating by nearly 60 %.

Comments

Special contract with the local utility:

Supply of electricity for a turn-off operated central-storage heating unit with heat pump. The reduced price electricity supply within and without the low load time with a cut down three times per day for two hours each proved as a disadvantage for the economic, energy-efficient and comfort related operation and has been cancelled after three months of experience.

1.5 Transvaal (STANDARD)

P- NL - 05 - Energy restructuring Transvaal (feasibility)

Source: Onno Kleefkens

Number of inhabitants: 8000

Location

Transvaal an old quarter lies in the South East of Den Haag in which a larger part of the houses is owned by the housing corporation of Staedion.

Living, houses and environment

The quarter is built between 1890 and 1935 and lies favourably between city centre and a large park in the vicinity of a sporting complex. It is one of the most densely populated areas with a low quality of life and safety. The population is multi racial and the last decades the quality of living standards has deteriorated and the quarter got slummy.

The housing corporations Staedion and Vestia have drawn a plan together with the Municipality of The Hague to revive the whole area of the South East of the city.

In the triangle of Transvaal 3000 dwellings are demolished and replaced by 1200 new houses. Through this exercise it is possible to create a new energy infrastructure increasing the energy performance.

Goal for Staedion is to sell a larger part of the houses (70%) to private owners. However seeing the profile of the area the houses will be relatively at the bottom end of the market not leaving too much room for high investments.

Initiative: Staedion Housing Corporation

Consultant: W/E Adviseurs Duurzaam Bouwen

Architect: ?

Municipality: City of The Hague

Project description

The project is set up as a study in two phases:

- Definition of ambitions and concepts
- Comparison of feasibility of concepts

First the boundary conditions were defined in which as a basis the standards of the energy regulation (EPC=0.8) were taken as a starting point. If the additional costs are within acceptable limits Staedion is willing to invest more. The problems here are twofold. Firstly the low profile of the area which doesn't allow high investments, although houses are sold to private owners. Secondly the fact that the higher costs for rented houses cannot be compensated, according to legislation, by a higher rent. The Ministry of Public Housing is working on this problem, which will be the task of the new government.

Therewith the decision was made to invest first in the envelope of the building and make the renovated building ready for future energy systems. Higher insulation and better glazing is chosen at a level normally used in standard building practice. Further a low temperature floor heating system is installed.

Based upon those starting conditions four heating concepts were compared for four types of houses:

- High efficiency boiler supported by thermal solar energy
- High efficiency boiler with mechanical ventilation and heat recovery
- Individual heat pumps
- Collective heat pump with distribution and supported by a high efficiency boiler

The concepts were compared on:

- Energy use and the consequences for the EPC in the Energy regulation. The heat pump systems were the best, although the collective system marginally better than the system with mechanical ventilation.
- Investment costs. With the standard high efficiency boiler as a reference the collective heat pump system can be installed at roughly the same costs per house. The individual heat pump is esteemed some € 6,000 more expensive.
- Costs for the occupant. Based upon an estimation of tariffs and service costs given by Eneco the individual heat pump is far the cheapest saving about 40% on the alternatives. In this the problem occurs of rented houses compared to sold houses.
- CO_2-emissions. This comparison causes some problems for the electric heat pump but still the individual heat pump is the best.

Further in the study other consequences of choices were looked into:

- Technical feasibility in which especially for heat pumps
    - Sources for the open ground source for collective as well individual heat pumps were favoured.

1.6 Gussago (STANDARD)

Source: N.N.

Renovation of an historical building in Gussago (BS) to built energy efficient offices

- Building type and size:
  - Offices
  - 425 m^2
- Main measures:
  - Ventilated roof and floor insulation
  - Low-E (Ar fill) glazing with external and internal shading devices
  - Ventilation with heat recovery
  - Heat pump with ground exchanger
  - Low temperature radiant panels
  - Zone control system
  - Solar thermal plant
- Primary energy consumption for heating:
  - **37 kWh/m^2/year**
- Annual primary energy saving for heating:
  - **68%**

http://www.eerg.it/greenbuilding/

1.7 Pforzheim (STANDARD)

Case study: Pforzheim-Senefelderstraße

Source:

This typical representative of the buildings of the fiftieth years with nine dwellings in three floors has been as a prototype energetically redeveloped in 2006.a 20 cm thick.

Combined thermal insulation system and an insulation of the basement and top floor supplemented the forefront reconstruction and roof new tiling. New windows took care for more homely comfort. The building has been heated with a heat pump. The heat source of the heat pump are two 85 m deep earth probes. The heat pump is also connected with exhaust air unit.

Technical data

Reconstructed multi-family house

Year of construction: 1951

Living area: 396 m^2

Old heating system: gas boiler

Result

New heating system**:** earth coupled heat pump with exhaust air unit

Primary energy demand:

Before: 358 kWh/m^2a

Afterwards: 47.6 kWh/m^2a

Reduction of primary energy consumption: 81 %

Final energy demand

Before: 303 kWh/m^2a

Afterwards: 30.9 kWh/m^2a

Reduction of final energy consumption: 93.6 %

1.8 Chemnitz (STANDARD)

Small art nouveau (Jugendstil) multi-family house

Source: dena Deutsche Energie-Agentur

Fig.: building before redevelopment

Data of the building

Place:	Mitschurinstraße 3, 09117 Chemnitz
Year of construction:	1911
Living area:	420 m2

Measures

- Insulation of the front with 20 cm combined thermal insulation system
- Insulation of the roof: 18 cm mineral bearing material
- Insulation of the basement: 12 cm polyurethane-hard foam
- Windows: heat insulation glazing (triple)
- Heating tap water: heat pump (brine-water) with low temperature floor heating
- Solar thermal tap water generation
- Ventilation: central exhaust air unit with heat recovery

Results after redevelopment

- Final energy demand: before /**afterwards**: 284 Wh/ma / **25.3 kWh/ma**
- Primary energy demand before / **afterwards:** 588.5 kWh/ma / **39.8 kWh/m2a**
- Reduction of primary energy demand around 03 %
- Reduction of heat lost of the building envelope: 82 %
- Reduction of CO_2-emissions: 116 tons per year

Final energy demand: energy amount from fuel, e.g. oil, wood pellets

Primary energy demand: total energy demand including transition, transport of the fuel

1.9 Zwolle-Zuid (BI-VALENT)

NL- 03 Renovation Shopping centre and new apartments in Zwolle-Zuid

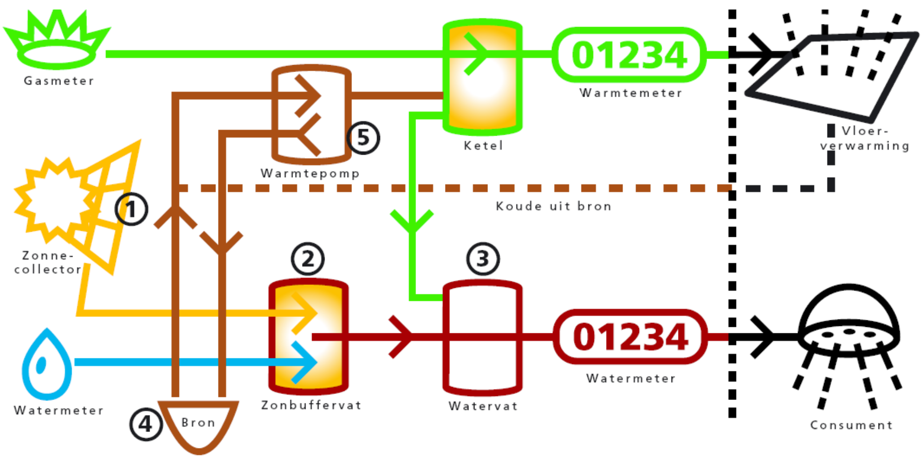
Source: Onno Kleefkens

Number of inhabitants: 500 (after renovation)

Location: Zwolle, The Netherlands

Description of the project

In Zwolle there an old shopping centre (1980) of about 10.000 square meters is going to be renovated. On top of this shopping centre 133 new apartments will be built. The overall project will use a sustainable energy system (about 50 % sustainable energy) based on a combination of several technologies: aquifer for cold and warm storage of the summer heat and the winter cold, heat pumps (about 400 kW), solar-thermal system of 300 m^2 for the production of domestic hot water and regeneration of the aquifer. The system I s backed up with high efficiency gas boilers for peak demands in heating. A scheme of the system is shown below.



Initiative	: Project developers: Provast from Den-Haag and DLH from Zwolle
Commissioned	: Altera Vastgoed N.V. and housing association SWZ from Zwolle
Architects	: RPHS from Voorburg
Minicipality	: John Braakman, ZON Energie B.V. johnbraakman@zonergie.nu
Project builder	: Trebbe bouw from Zwolle
Installer	: Unica from Zwolle
Advisor	: Cauberg Huygen from Zwolle
Development energy	: ZON Energie from Spanbroek
Investor energy system	: Cogas Energie, from Almelo

Planning

Start January 2007

Finishing September 2009

1.10 Berlin (BI-VALENT)

Redevelopment of the space and tap water heating system with heat pump and earth coupled CO_2-heat pipe

Experiences of the heating period 2005 / 2006

Source: **Christian Felix Scholz**

www.kaeltro.de

Data:

- freestanding one-family house,
- year of construction: 1936,
- no additional thermal insulation,
- saddleback roof

Heat demand has been calculated from the oil demand of the last ten years with

- **12 kW (around 80 W/m²)**

Test period 2005 / 2006 excellent due to many night/day temperatures of -16 / -2 °C

Mono energetic heating system

- heat pump capacity: 7.4 kW
- electrical resistant heater: 6.0 kW
- heating temperature between 35°C and 50°C
- heating surface: 149 m²
- tap water final temperature: 45°C (sporadic legionella set up: 65°C) ,
- 300 l buffer

Status before

- 9 rooms heated with cast iron radiators, heating temperature 70/75°C (outside temp. -5/-14 °C)
- 18 kW oil heating
- 3,000 l fuel oil underground tank

Status afterwards

- same number of rooms (9) heated with fan convectors with heating temperature 35/50 °C (outside temp. 18/-14°C)
- 8.1 kW heat pump and 6.0 kW electric buffer heater (mono energetic) 500 l heating buffer
- 300 l tap water connected with the heat pump
- 3 kW electric tap water heating (legionella set up)

Ascertained mono energetic heat demand 12 kW (DIN $T_{outside}$ -14 °C)

Medium term goal: reduction of the electric heating with additional roof- and building envelope-insulation

Critical factor of the exposition of the heating system is a selected low heating temperature. In the actual object radiators in a thermal / dynamic function have been selected. The result is a low heating temperature dependent of the outside temperature, small size radiators, same place of the old radiators and use of the existing tube system., all of them important factors for an economic redevelopment of the building.

The investment of the presented case is subdivided as follows:

Heat source: geothermal heat with 100 m CO_2-heat pipe (heat output: 60 W/m)

Heat generation: heat pump

Heat distribution: radiators, piping system, buffer (no underfloor heating)
Tap water buffer with well dimensioned heat exchanger

Control and electrical engineering: room controller (part of the heat pump), electric meter for heat pump power

Place of bore hole dependent of the position of the building and the area / garden.

Drilling requires conditions for entry of the driller of 2.5 m width to the bore hole. The distance of the bore hole to the site boundary should be at least 5 m, to the building 1 m

The drilling on site requires an area of around 20 to 25 m^2. After completion the planting has to be revaluated.

The heat pump, buffer and tap water buffer require an area of 4 m^2, the electrical distribution 1 m^2.

The total redevelopment of the heating system requires 10 to 12 working days.

Electric power consumption and costs

Heat pump tariff: € 0,09 / kWh

The tap water allocation of a two person household requires per day 4.3 kWh of € 0.09

The heat capacity of the heat pump with 6 kW heat output (to/tc: -8/45_to/W55 –8/55) is 8.1 kW, sufficient for a outside temperature of 0 °C. Lower temperatures require an electric resistance heating up to 6 kW.

.

Heating cost of the period 2005 / 2006 (238 days)

Tap water during the heating period: 1.28 KW x € 0.09	€	92.52
Tap water for the whole year (127 à 4.3 KW) 546.1 x € 0.09	€	49.15
Total tap water costs (365 days)	**€**	**141.67**

Total heating costs for the heating period 2005/2006,

11,590 KW x € 0.09	**€**	**1,043.10**
Total costs tap water and heating	**€**	**1,253.47**
Total costs of the old oil heating	**€**	**1,831.50**

(reference period 1983 to 2005 = 22 years, price of oil; € 0.55 /l

Annual savings **€ 646.73**

1.11 Frankfurt am Main (BI-VALENT)

Source: dena Deutsche Energie-Agentur

© ABG Frankfurt Holding GmbH

Frankfurt am Main saniert mit Passivhaus-Komponenten

Konsequent setzt die ABG Frankfurt Holding GmbH bei ihrem Sanierungsvorhaben im Gallusviertel auf Passivhaus-Komponenten. Hierzu zählen der Einbau von Passivhausfenstern und von dezentralen Kompaktaggregaten zur kontrollierten Wohnungslüftung. Geheizt wird ausschließlich mittels elektrischer Wärmepumpe.

Die Partner
Bauherr: ABG Frankfurt Holding GmbH
Architekt: faktor 10 GmbH, P Grenz/F. Rasch, Darmstadt
Fachplanung: Ingenieurbüro Baumgartner, Mörlenbach
Begleitung: Passivhaus-Institut, Darmstadt

Das Ergebnis

vorher: 234 kWh/m^2a
nachher: **28 kWh/m^2a** (–88 %)

Transmissionswärmeverlust nach Sanierung:
0,25 W/m^2K (63 % unter EnEV)
eingesparte CO_2: 51 kg/m^2a

Das Projekt
Adresse: Tevestraße 36–46, Frankfurt am Main
Baujahr: 1951
Wohnfläche: 1.746 m^2 (36 WE)

Das Ergebnis

vorher: 251 kWh/m^2a
nachher: **38 kWh/m^2a** (–85 %)

Transmissionswärmeverlust nach Sanierung:
0,24 W/m^2K (64 % unter EnEV)
eingesparte CO_2: 49 kg/m^2a

Das Projekt
Adresse: Tevestraße 48–54, Frankfurt am Main
Baujahr: 1951
Wohnfläche: 1.070 m^2 (24 WE)

Merkmale für beide Projekte
Dämmung: 20 cm Außenwand, 40 cm Dach, 10 + 6 cm Kellerdecke/Fußboden
Fenster: 3-Scheiben-Wärmeschutzverglasung, (U_W = 0,85 W/m^2K)
Lüftung/Heizung/Warmwasser: dezentrale Zu-/Abluftanlage mit Wärmerückgewinnung, Wärmepumpe und elektrischer Ergänzungsheizung, zus. Solarkollektoranlage (96 m^2)

Zusätzliche Modernisierungen: neue Maisonettenwohnungen im Dachgeschoss, Grundrissänderungen, Balkonvorständerung, Bäder, Küchen, Vollverglasungen der Treppenhäuser, verbesserter Schallschutz

1.12 Freiburg (Breisgau) (BI-VALENT)

Multiple family dwellings in the new Freiburg area Vauban

Source: Fraunhofer Institute ISE

A multiple family dwellings in the new Freiburg area Vauban was examined. The heating demand meets 10 kWh/(m²a). The apartment in the foreground is supplied by a newly developed compact heating and ventilation device with integrated exhaust air heat pump.

1.13 Flers (North of Paris) (BI-VALENT)

High temperature heat pump for the retrofit market in France
Field test in Flers located in the North of Paris

Source: J.-B. Ritz, EdF

Location: Field test in Flers located in the North of Paris (France)




Project description:

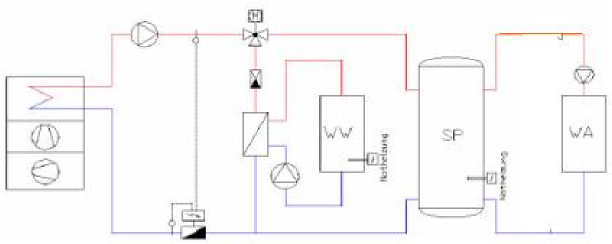
EDF R&D has selected a house and equipped it with a high temperature heat pump. We have refurbished an old gas propane boiler. The heat pump has been instrumented. The consumption and the heating capacity of the heat pump have been measured

Type and age of building

Built in 1770

- Heat requirement of 12kW at -15 °C
- Surface of 130 m^2
- Heating (65°C) by static emitters and hot water production (55°C) (Parallel storage for heating)
- Alternate production with priority to tap water (Design temperature T= -6°C)

Parallel storage for heating and Sanitory Hot Water



Owner of the building: Ms. Michu

Participating company

Installers: local electrician

Duration of renovation: October to November 2002

Renovation processes and technologies

No renovation of the building, only a refurbishment of the exiting boiler

Technology

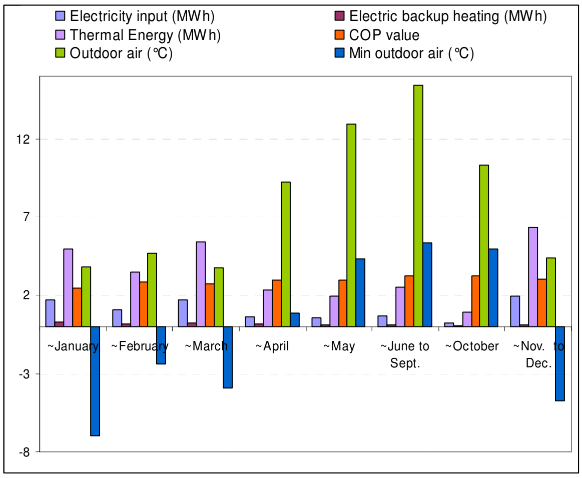
The heat pump installed is a Viessmann heat pump AWH110 equipped with a compressor with a vapour injection port EVI.

Economy

Divided by two the bill every year since 2002.

Results (only heating part):

- **the seasonal COP is 2,95**



Energy demand (heating and DHW) (kWh/m² a): 200 kWh/m^2 a

Customers satisfaction in term of comfort and energy is quite good when the HP is properly installed. No problem concerning the compressor and all components of the HP.

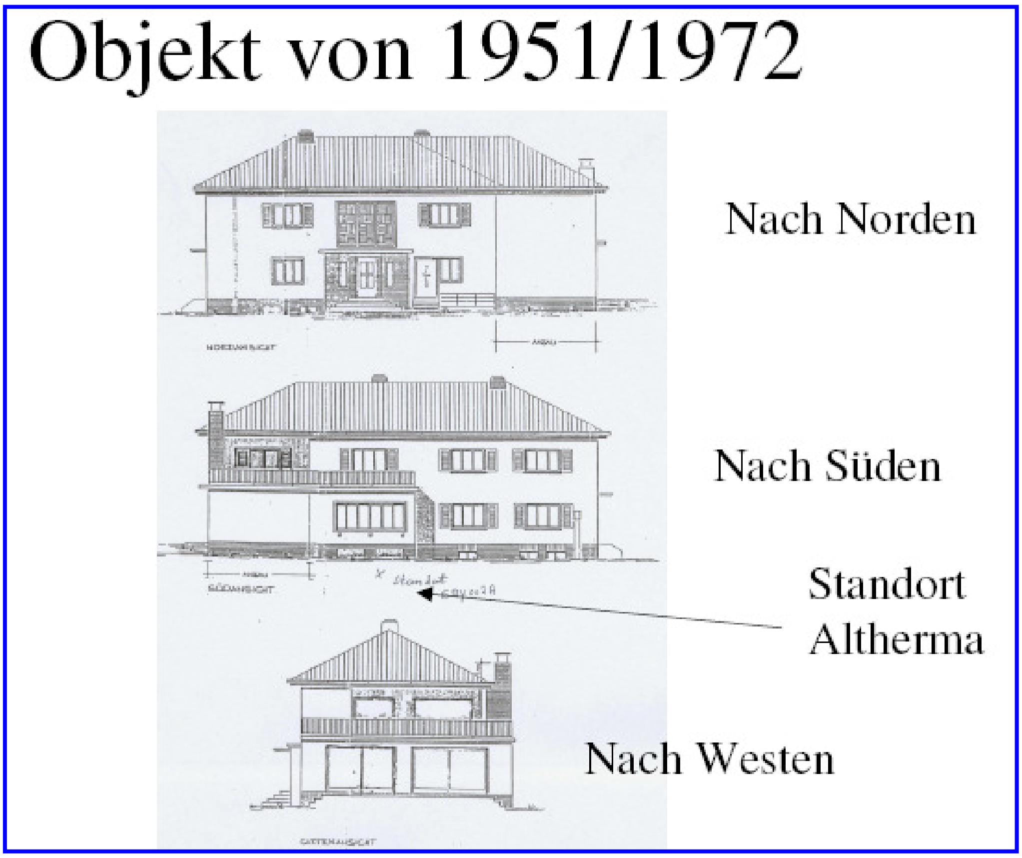
The HT HP is a good product for heating and tap water production with high potential: relevant and reliable

1.14 Breuberg (BI-VALENT)

Altherma heat pump system "Split air /hydrobox / water heat pump" in Breuberg/Germany

64747 Breuberg, Kreuzfeldstr.10a

Source: Dr.-Ing. Rainer M. Jakobs



Project description

One family house with separate office

Types and age of building

Year of construction: 1951 Extension 1972

No. of dwellings: one ~280 m²

No. of offices: one ~ 65 m²

Total area: ~345 m²

Renovation Heating system (Oil boiler) 1999

Hydronic central oil heating boiler;

Domestic hot water HP (300 l tank)

Owner of the building: private

2 Participating companies

Installer

Eichhorn Kälte Klima Elektro

D-63911 Klingenfurth-Trennfurth

Heat pump

Daikin Airconditioning Germany GmbH
Office

Saaläckerstr. 8

D-63801 Kleinostheim

Installation: January 2007

Duration of work : 3 days

Technologies

- Air / water heat pump 8,43 kW nominal heat capacity
- Single stage refrigeration circuit
- Refrigerant R410A
- Maximum heating temperature 55°C
- Ambient Temperature: –20 to +25 °C

Economy

Total cost:

Heat pump	**70 %**
Installation	
including electricity (meter etc.)	**30 %**

Results

Heat pump condition	Time	
Space heating thermal energy	1.3.07 - 1.3.08	33.982 kWh
Electricity HP + E-Heater	1.3.07 - 1.3.08	12.232 kWh
"Seasonal" performance factor	1.3.07 - 1.3.08	2,8

Comparison of Energy consumptions

time	system	Energy consumption			
		Final energy		Primary energy	
		KWh/a	kWh/m²a	kWh	kWh/m²a
1999-2005	Oil	45.000	>130	51.300	> 149
10.2.07 -12.02.08	HP-electricity	12.387	>36	33.445	> 97

Primary energy factor:

Oil: 1,14

electricity: 2,7

CO_2-emissions:

time	system	CO_2-Emissions (kg CO_2)		
1999-2005	Oil (0,306)	13.770		
10.2.07 -12.02.08	HP-electricity	D (0,520)	Breuberg (0,314)	E (0,483)
		(kg CO_2/kWh)		
		6.441	3.890	5.983

<u>Energy costs</u>:	**€**	
1999 - 2006 (Oil): (~4500 l average p. a.)	**~ 2.925**	**(0,65 €/l)**
2007/2008 (heat pump-electricity):	**1.795**	**(0,145 €/kWh)**

Comments

The heat pump is designed as a bivalent system. The existing oil boiler could be used below ~ -7 °C; during the reported period the boiler was used less than 3-4 days (not automatically, change has to be done manually).

Special contract with the local utility:

Supply of electricity for a D-HW-HP and a Air/Water HP with electrical direct heater.

The reduced price electricity supply with maximum cut downs three times per day for two hours is part of the contract, but not used by the utility.

1.15 Neunkirchen-Seelscheid (BI-VALENT)

Multiple family house Neunkirchen-Seelscheid

Source:

Owner:	Dieter Wölfel
Year of construction:	1900
Addition and conversion:	1962
Thermal insulation and windows:	1998
Heat pump:	11.2004
Air/water heat pump	
Inside installation	
Manufacture:	Tecalor
Bivalent with existing oil boiler	
Heating temperature:	55°C
Heat capacity:	18.0 kW

<u>Oil consumption</u>

Before heat pump installation:	7,000 l
After heat pump installation	1,000 l
Electricity heat pump:	18,000 kWh/a

<u>Operating costs</u>

Before heat pump installation:	10.87 €/m^2 a
After heat pump installation:	6.23 €/m^2 a

1.16 St. Agnes (UK Cornwall) (BI-VALENT)

Air to Water Heat Pump Field-test of a building office in Cornwall (UK) by EDF R&D

Source: Jean-Benoit Ritz, EDF

Location: St Agnes (UK Cornwall)

Project description:

Equipment of an individual house with 2 floors

Type and age of building

- Year of construction: after 1980
- N° of dwelling: 1 semi detached house
- Total area of the house: ~120 m²
- Status before renovation: see project description

Owner of the building: Carrick House

Participating company

Installers: local electrician

Others: EDF Energy (part of funding)

Year of renovation: 2005 (HP equipment)

Technology

- Heating cooling system: air/water heat pump, P_{th} 6 kW at 7/50, supplying water at 50℃ max to new huge radiators; not reversible.

- Ventilation system: unknown,
- Drinking water: heated in electric storage tank
- Miscellaneous:

Results (only heating part):

- Yearly consumption : 3.200 kWh_{el} for a supplied thermal of 7.745 kWh
- **the seasonal COP is 2,49**
- HP permits to save 900 kg carbon during one whole year, compared to an oil boiler with 85% efficiency GCV

1.17 London Newham (BI-VALENT)

Air to Water Heat Pump Field-test in a warm zone of London by EDF R&D

Source: Jean-Benoit Ritz, EDF

Location: London Newham

Project description:

Tower block (20 floors) recently refurbished (internal insulation, double –glazed windows, carpet, new sanitary water distribution, new heating system: central heating by oil replaced by individual gas boiler, except for 1 flat with heat pump)

Type and age of building (

- Year of construction: before 1980?
- N° of dwelling : only 1 flat equipped with a HP
- Total area of the flat : 50 m²
- Status before renovation : see project description

Owner of the building: London Borough of Newham

Participating company

Architect: N.N.

Installers: local electrician

Others: EDF Energy (part of funding)

Year of renovation: 2004

Duration of renovation: ~1 year

Renovation processes and technologies

- Wall insulation: external walls are 225mm solid Concrete which was clad with 35mm Thermal Board , internal walls are 100mm Lightweight Blocks no thermal Board .
- Ceilings insulation: ceilings are 225 mm Concrete with 50 mm sand & cement screed no insulation as there is on floor above our flat.
- Windows: All windows are double glazed.

Technology

- Heating cooling system: air/water heat pump, P_{th} 6 kW at 7/50, supplying water at 50° max to new huge radiators; not reversible.
- Ventilation system : ventilation at this time is natural ,
- Drinking water: heated in electric storage tank
- Miscellaneous:

Economy

No data available

Results (only heating part):

- Yearly consumption : 2.470 kWh_{el} for a supplied thermal of 6.320 kWh
- **the seasonal COP is 2,56**
- HP permits to save 827 kg carbon during one whole year, compared to an oil boiler with 85% efficiency GCV, what gives carbon saving around 16 kg CO_2/m^2/year. For gas comparison, carbons savings is 7 kg CO_2/m^2/year. The data measurements period (June 2005➔ May 2006) was a rather mild year.
- Comments : HP power was a little bit oversized

Energy demand (kWh/m² a): 49.4 kWh/m² a

1.18 Truro (UK Cornwall) (BI-VALENT)

Air to Water Heat Pump Field-test of a building office in Cornwall (UK) by EDF R&D

Source: Jean-Benoit Ritz, EDF

Location: Truro (UK Cornwall)

Project description:

Refurbishing of a building office: house with 2 floors recently

Type and age of building

- Year of construction: before 1980?
- N° of dwelling: 1 single house
- Total area of the house: 90 m² on 2 floors
- Status before renovation: see project description

Owner of the building: Carrick House

Participating company

Installers: local electrician

Others: EDF Energy (part of funding)

Year of renovation: 2005

Renovation processes and technologies

- Wall insulation : 2 Durox Superblock panels (100mm width) separated a cavity filled with fibre insulation (width 50 mm)

- Roof : 150mm rock wool between ceiling joists and 100 mm rock wool above
- Windows: Double –glazed windows,

Technology

- Heating cooling system: air/water heat pump, P_{th} 6 kW at 7/50, supplying water at 50°C max to new huge radiators; not reversible.
- Ventilation system: unknown,
- Drinking water: heated in electric storage tank
- Miscellaneous:

Economy

No data available

Results (only heating part):

- Yearly consumption : 3.730 kWh_{el} for a supplied thermal of 8.758 kWh
- **the seasonal COP is 2,43**
- HP permits to save 940 kg carbon (dioxide) during one whole year, compared to an oil boiler with 85% efficiency GCV, what gives carbon saving around 11 kg CO_2/m²/year. For gas comparison, carbons savings is 4 kg CO_2/m²/year. The data measurements period is 2006.
- Comments : HP power was a little bit undersized

Energy demand (kWh/m² a): 41.4 kWh/m²a

1.19 Nijmegen (HIGH TEMP)

NL – 04 Renovation Energy System for 270 apartments in Nijmegen

Source: Onno Kleefkens

Number of inhabitants: 1000

Location: Nijmegen, The Netherlands

Description of the project

Wezenhof is an existing apartment complex of 270 apartments with a standard gas heating system, a large energy consumption (2000 m^3 per apartment!) and since 1998 and additional cogeneration system. This combined heat and power system has never worked according to specification and is shut down since 2002.

The complete infrastructure (heat exchangers, distribution) is still available and the renovation strategy is to introduce a high temperature heat pump as substitute for the not functioning CHP-system.

In the apartments an additional thermostat and another type of radiators will be it introduced, to be able to handle the lower temperature regime.

Initiative : Talis Woondiensten, Housing association from Nijmegen

Municipality : John Braakman, ZON Energie B.V.
johnbraakman@zonergie.nu

Installer : ?

Advisor : ?

Developer energy system : ZON Energie from Spanbroek

Investor energy system : Talis Woondiensten

Planning

Start study January 2007

Start renovation April 2008

Finish September 2008

1.20 Essen (DIRECT)

Retrofit inverter heat pumps instead of electrical storage heating in a dwelling house in Essen, Germany

source: Ansgar Thiemann, DAIKIN Airconditioning Germany GmbH, Unterhaching
in BundesBauBlatt 11/2003, Bauverlag, Gütersloh, Germany

Project: multi-flat-house, rebuild after war, exchange of electrical over-nightrecharged storage heating system installed in the 70ties

Facts:

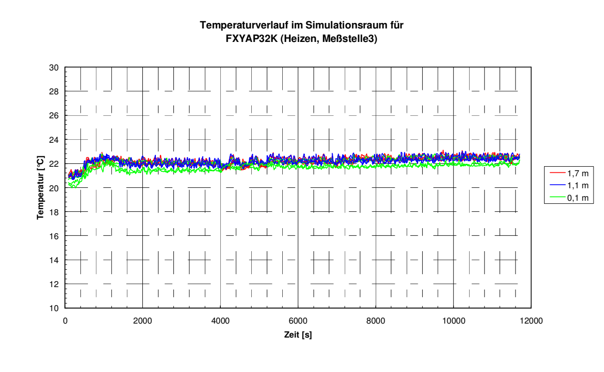
Building	3 floors dwelling house incl. garden
Location	only residential district; side street
No. of flats	10
Heated floor area	ca. 600m²
By HP heated floor area	heat pumps are the only heating system
No. of heat pumps	26
Used models	DAIKIN FTXD25/RXD25+FTXD35RXD35

Problem: exchange of heating system but flats without heat distribution system

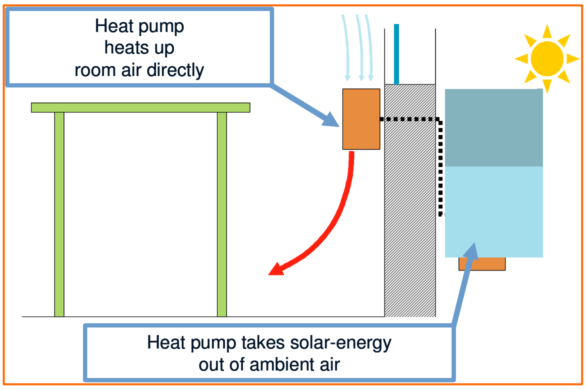
Solution: decentralized air-to-air heat pumps

Advantages:
-using existing electrical infrastructure
-saving space (indoor heating units are much smaller than electrical storage heating)
-necessary piping work has only a small distance from inside to outside to overcome
-very continuous temperature distribution in heated room (pic1)
-warm air is brought down to lower layer of air (pic2)
-optimized position of indoor heating units below window takes advantages from cold air draft that is flowing down the window (pic2)
-air cleaning function included: air will be filtered and smell will be destroyed
-cool function included: this heating system offers air conditioning function
-quick heat up function: short time running at 115% offers very high boost capacity
-no heating room and no oil or gas tanks necessary: additionally saved space
-clean installation: fast and no difficulty to co-ordinate (in case of many flats) the installation of a heat distribution system (installation room by room)
-small invest costs: all-inclusive ca. euro 52,000 for 600m² heated surface
-small energy consumption and energy costs: in 2002/3 average 26kWh/(m²·a)* electrical energy means 72% savings (in 2001/2 average 94kWh/(m²·a) electrical energy for storage heating)
-28 t CO_2 savings each year

*Average consumption of 26kWh/(m²·a) is confirmed by average of 5 heating periods (2003-2008).



pic1: Room temperature using inverter HP [source] Andreas Gernemann, Universität GH Essen, Germany, Institut für Thermodynamik und angewandte Energietechnik in KKA Februar 2001



pic2: heat pump below window [source] Ansgar Thiemann, DAIKIN Airconditioning Germany GmbH, Unterhaching at IKK Fachforum 2005, Hannover, Germany

1.21 Munich (DIRECT)

source: Ansgar Thiemann, DAIKIN Airconditioning Germany GmbH, Unterhaching
Hotel: Holiday Inn Munich City Center, Germany

Air-to-air heat pumps for 603 hotel rooms (design temperature -20°C)

Facts:

Building	in 2005 refurbished tall building of 1973
Location	Munich city centre
No. of rooms	603 at 11 stories
Heated floor area	ca. 17000m²
By HP heated floor area	heat pumps are the only heating system
No. of heat pumps	65
Nominal heating capacity	1.55 MW in total
Used models	DAIKIN VRV RXYQ12M+FXDQ25M

Problem: to fulfill fire protection requirements
Solution: air-to-air inverter heat pump as the only heating system for 603 rooms
Advantages:
-Air-to-air heat pump system could be installed step by step:
only one third of hotel rooms could not be used during construction
-small piping diameters are fulfilling German fire protection standards
-R410A system is conform to German tall building standards
-Safe heating system (65 heat pumps): there will be rather an influence on hotel in case of operation stop of one circuit
-No back-up heating system required because heating design temperature of air-to-air inverter heat pumps covers -20 °C

Story about the hotel:
(refurbishment)
• Holiday Inn Munich City Center was build in 1973 as 'Penta' hotel. Later it was transformed into 'Forum' hotel. Since summer 2004 it is 'Holiday Inn'. It is located in the center of Munich and good connected to subway and trains towards airport. There are 603 rooms, 25..30 square meter each.
• It is largest in Germany an third largest in Europe within hotels of Holiday Inn Brand.
• Before refurbishment it was installed a two pipe system which was used for steam heated warm water in winter time and for chilled water in summer time. Originally the four buildings of the hotel were supplied with chilled water by steam driven absorbtion engines.
• This system was very old and has produced high running and maintenance costs.
• Additional new German standards for fire protection made a complete renovation necessary regarding fire protection of the building. Especially old piping was not meeting requirements anymore.
• Airconditioning was a 'must' for Holiday Inn and decision was made to use a heat pump system which could be used for cooling in summer time for guest rooms, offices and small conference rooms.
• An inverter air-to-air heat pump system was able to fulfill all expectations.
• Installation began in July 2005 end ended in January 2006 (only half a year for 603 rooms)

2 Overview Case Studies

A. Thiemann: "Retrofit inverter heat pumps instead of electrical storage heating in a dwelling house in Essen, Germany

O. Kleefkens: Project 01/NL - Achter de Hoven Gemeente Leeuwarden Rebuilding by a corporation

W. Schenk, FH München: Groundwater heat pump Rosenheim (in German)

W. Schenk, FH München: Earth-collector heat pump one-family house Halfing (in German)

H.J. Laue: Groundwater heat pump Karlsruhe/Germany

O. Kleefkens: NL- 03 Renovation Shopping centre and new apartment Zwolle-Zuid

O. Kleefkens: NL – 04 Renovation Energy System for 270 apartments in Nijmegen

O. Kleefkens: P- NL - 05 - Energy restructuring Transvaal (feasibility)

NN: Renovation of an historical building in Gussago, Italy to build energy efficient offices

A. Thiemann: Holiday Inn Munich City Center, Germany: Air-to-air heat pumps for 603 hotel rooms

Dena Zukunftshaus: Pforzheim-Senefelderstraße

Dena Zukunftshaus: Small art nouveau (Jugendstil) multi-family house Chemnitz

Ch. Scholz: Space and tap water heating with heat pump and earth coupled CO_2-heat pipe

Dena Zukunftshaus: German retrofit project with heat pumps

Fraunhofer Institute ISE, Freiburg: Multiple family dwellings in the new Freiburg area Vauban

J.-B. Ritz: High temperature heat pump for the retrofit market in France

Field test in Flers located in the North of Paris

R. Jakobs: Altherma heat pump system "Split air /hydrobox / water heat pump" in Breuberg/Germany

NN: Multiple family house in Neunkirchen-Seelscheid, Germany

J.-B. Ritz: Air to Water Heat Pump Field-test in a warm zone of London Newham **by EDF R&D**

J.-B. Ritz: Air to Water Heat Pump Field-test of a building office in Truro/ Cornwall (UK) by EDF R&D

J.-B. Ritz: Air to Water Heat Pump Field-test of a building office in St. Agnes /Cornwall (UK) by EDF R&D

Information Centre on Heat Pumps and Refrigeration
IZW e.V.

Attachment IV

Annex 30

Retrofit Heat Pumps for Buildings

Research & Development (R&D) Projects

Contents

0 Introduction

Accordingly to heat pump systems differentiated in attachment III (case studies) there are STANDARD HEAT PUMPS ready to use for retrofitting in already improved standard buildings with reduced heat demand, e.g. with thermal insulation of the building envelope and hence the heat distribution system is modernized (low temperature).

DIRECT HEATING HEAT PUMPS (air-to-air) can be installed for spaces without usable heat distribution system.

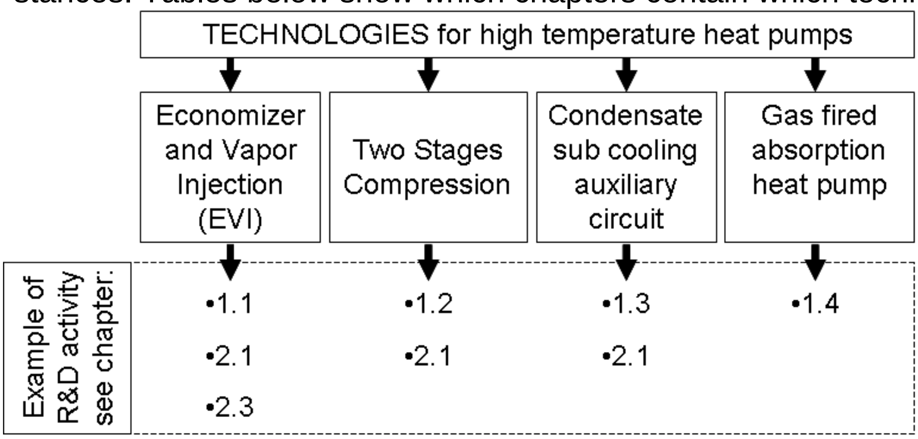
Furthermore a heat pump can be added to a boiler and used as BI-VALENT heating system in case of an existing heat distribution system with higher temperatures.

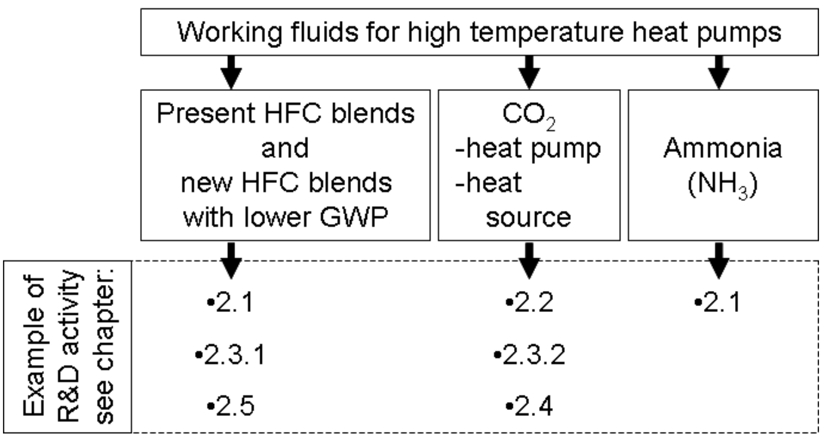
Those systems are proved in various field tests (see chapter 3).

But remaining barrier for the use of heat pumps for retrofitting as a stand-alone solution 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.

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 and environmental issues leading to lower greenhouse gas emissions, particularly by the use of low or zero GWP working fluids.

Current research and development (R&D) activities accommodate these circumstances. Tables below show which chapters contain which technology:





1 R&D projects

1.1 EVI Heat pump with higher outlet temperatures

The market of retrofit heat pumps for outlet temperature up to 65°C is presently dominated by a simple and cheap solution, the so called cycle with economizer and vapour injection (EVI concept) as shown in Figure 1. This cycle is well known from larger heat pumps with screw type compressors: a part stream of the condensate is expanded to a middle pressure level. The created liquid-vapour mixture is then brought to saturation by sub cooling the - rest of the condensate is injected into the compressor.

This cycle has the following advantages:

1. Higher mass flow rate at the compressor outlet = higher heating power.
2. Reduction of the compressor outlet temperature = meeting the temperature limits of the compressor.
3. Sub cooling the condensate = increasing the COP, if a suitable compressor is available

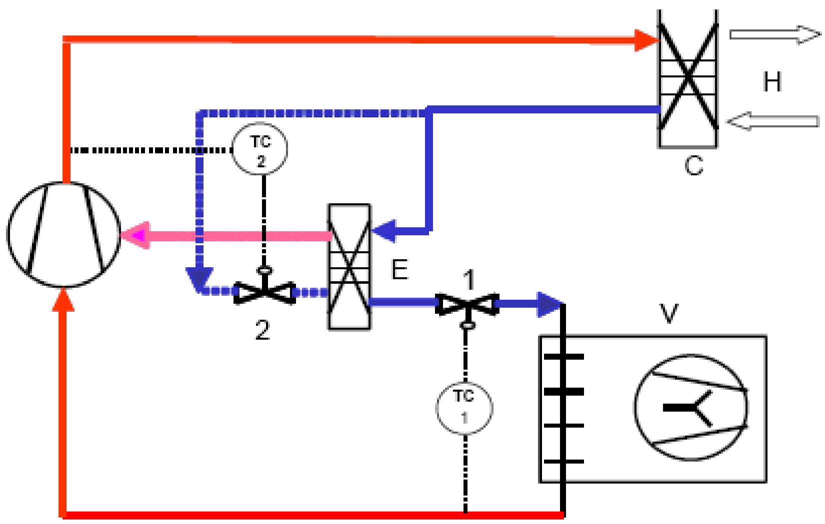


Figure 1: Heat pump cycle with economizer/vapour injection.
Commercial scroll compressor with liquid injection port;
R407C as refrigerant; C - condenser, E - economizer, V - evaporator,
H - hydronic heating system, 1 - main expansion valve,
2 - expansion valve for the injected stream.

Heat pumps with die EVI concept have been installed at different locations during a research project in Switzerland and France (BFE 2002). In the measured data and the theoretical analysis the EVI cycle reached the best results concerning COP.

Compared to a one-step compression cycle the seasonal performance factor (average seasonal COP) improved by 18%. The EVI scroll compressor has shown a high potential in a heat pump. The improved temperature and heating power characteristics may help to overcome barriers towards a retrofit system and are also helpful for other applications like domestic hot water production.

A similar system has been developed in an agreement of collaboration between SATAG Thermotechnik, CH, Viessmann, Germany, EPFL, University of Lausanne and EDF R&D, France, as well as Copeland for the technical break of the enhanced vapour injection scroll compressor technology.

A first prototype of heat pump was built and tested in 2000-2001 in France and the pilot production was ready for field tests since end of 2002.

Together with Copeland the German heating system manufacturer Viessmann developed a heat pump with an economiser cycle and hot gas injection in the compressor.

For retrofit Viessmann encountered several challenges:

- The older heating systems require an outlet temperature of 65°C to 70°C.
- The heat source for a retrofit heat pump should be ambient air. So the requirement is a high COP and a temperature lift from –15°C ambient air to 65°C outlet temperature.

The heat pump should be interesting from an economical point of view which excludes multistage heat pump and other solutions.

A Viessmann heat pump with the EVI concept has been installed in an 80 years old monument listed building ("Bauhaus") in Karlsruhe/Germany in July 2006.

First results are presented in the final report of the Annex (Attachment III: Case studies).

1.2 Two stages compression for high temperature

The thermodynamically most promising solution to the retrofit problem is a two stage heat pump with two compressors as shown in Figure 2. This cycle has been built and investigated [Zehnder et al. 1999]. Compared to a simple one stage cycle it attained a 50% increase in heating power and a 14% increase of the COP at the highest temperature lifts. But it turned out that the oil migration in the circuit prevented a proper lubrication of both compressors after a few hours of operation. Furthermore a heat pump of this type is too complex to compete with the much simpler boiler, which a retrofit heat pump should replace. [source: Swiss Federal Office of Energy]

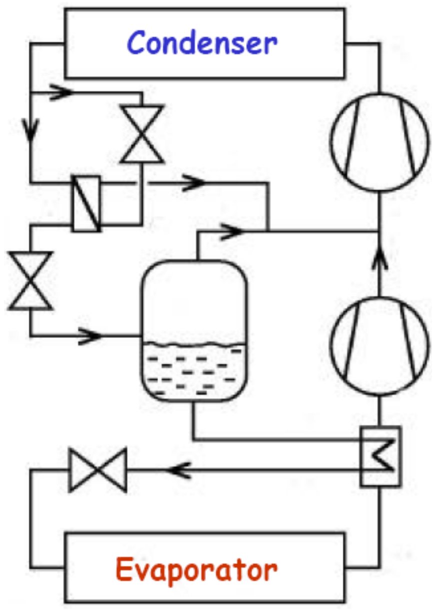


Figure 2: Heat pump cycle with two compressors and an intermediate injection. Reciprocating compressor in the first and scroll compressor in the second stage. R407C as refrigerant [Zehnder et al. 1999].

1.3 Condensate sub cooling auxiliary circuit

A further research project [Reiner et al. 1998] investigated a cycle with a separate auxiliary heat pump loop. This uses the condensate subcooling as heat source and delivers the heat at the loop of the hydronic system coming from the main heat pump (Figure 3). This prototype heat pump has been tested with R407C and R417A (Isceon 59). For high temperature lifts an increase of the heating power by up to 20% and of the COP by up to 5% compared to a simple one stage cycle was achieved. With R417A there were no problems with the compressor outlet temperature.
R407C lead to a too high compressor outlet temperature and is therefore not suitable for this cycle in retrofit applications. For a small heat pump this cycle is rather complex. But it should be taken into account for larger heat pumps. [Source: Swiss Federal Office of Energy]

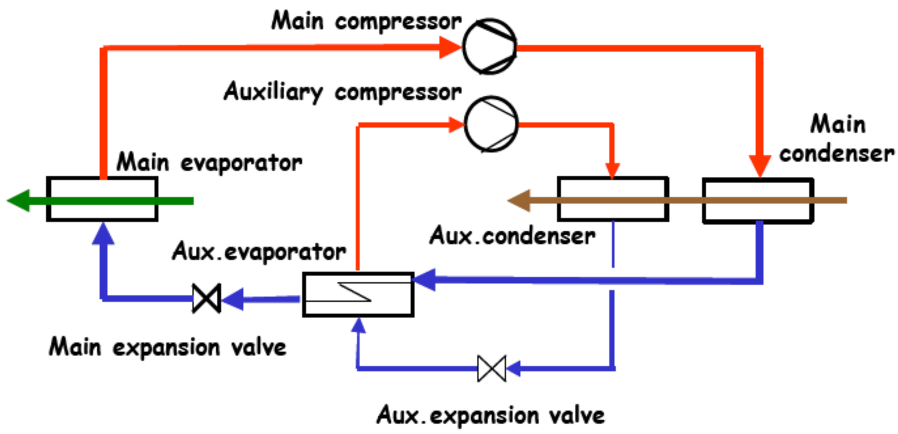


Figure 3: Heat pump cycle with a separate auxiliary heat pump loop for subcooling the condensate of the main heat pump loop [Reiner et al. 1998]. Refrigerants R407C and R417A; main heat pump with a scroll compressor, auxiliary heat pump with a reciprocating compressor.

1.4 Gas fired absorption heat pumps

Position of gas fired absorption heat pumps for existing dwellings

Fit with existing energy infra-structure (natural gas)

Heat source with small capacity will do

Less troubled by non-low temperature system

Deliver same comfort as high efficiency boilers

In sound pressure comparable to HE-boilers same location

No moving parts, long lifetime, low maintenance, low noise

Ambitions

Substantial part (>50%) of boilers in existing dwellings to be replaced by sorption heat pumps

Sorption hp installed within 2 hours at the same location as old boiler

No need for extra provisions

Housing Corporations or Energy Companies are owner of the systems: inhabitants pay for convenience only

Transfer of results to dwellings in private property

2 R&D projects in European countries

The status of examples of R&D projects in European countries is summarized as follows:

2.1 Switzerland

The *Swiss Retrofit Heat Pump* project

While larger retrofit heat pumps are already available on the market (for example the above mentioned heat pump with economizer and screw compressors), optimal solutions do not yet exist for heating powers below 25 kW.

In order to change this situation the *Swiss Federal Office of Energy* launched a competition “Swiss retrofit heat pump” in 1998 to develop an air to water heat pump with high temperature rise to replace oil and gas burners.

The thermal capacity should be 15 to 20 kW with an air temperature of – 12 °C and a water temperature of 60 °C. Four project teams started their planning in order to develop a new type of retrofit heat pumps which would meet the following requirements:

1. Ambient air has to be used as heat source.
2. The heat pump must provide the required heating power at an ambient air temperature of –12°C and a supply temperature of the hydronic heating system of 60°C without any backup heating systems.
3. The retrofit heat pump has to produce hot tap water at 55°C as well.
4. For high temperature lifts the retrofit heat pump needs to have a considerable smaller drop in heating power than the heat pumps tested so far.
5. For the highest temperature lifts from –12 °C ambient temperature up to 60 °C supply temperature the compressor outlet temperature has to be kept below 85 °C.
6. For ambient air as heat source the second law efficiency with all losses included (according to the standard EN 255) has to be maintained above 0,375 under all operational conditions and above 0,425 for the test point at air 2°C to water 50°C.
7. The liquid refrigerant hold-up has to be kept at a minimum.
8. The control system has to assure a minimal volume of the heat storage tank.
9. The heat pump has to fulfil the requirements of the DACH quality label as well as all European standards.

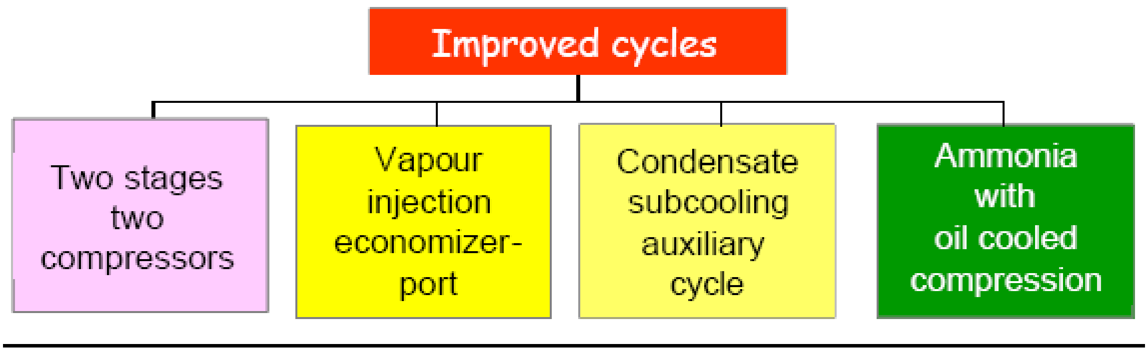


Figure 4: Heat pump cycles for small retrofit heat pumps (< 25 kW heating power) investigated in the *Swiss Retrofit Heat Pump* programme

2.2 Austria

- **CO_2 Heat Pump for combined space heating and tap water production**

  Aim: Design, Test, system optimization

  Status: on-going

  Cooperation: EU-RTD performer + SMEs

  Funding: EU FP6 Collective research project

  (Arsenal Research)

- **Ground coupled horizontal CO_2-Loop with forced circulation as a heat source for heat pumps**

  Aim: Design, Test, system optimisation

  Status: on-going

  Cooperation: EU-RTD performer + SMEs

  Funding: FP6 Collective research project

  (Arsenal research)

2.3 Germany

2.3.1 High-temperature air-to-water heat pump

Glen Dimplex Deutschland GmbH

- Installation location: Outdoors
- Flow temperature max 75 °C

  High temperature air-to-water heat pump for outside installation with external temperature controlled heat pump manager; sound-optimised through the use of low-noise crescent wing axial-flow fans and air deflection covers; energy-efficient defrosting by reverse circulation and inclined evaporator. Integrated soft starter; return flow sensor and external temperature sensor included in the scope of supply. In the summer a maximum heating flow-temperature of 58 °C is available for domestic hot water preparation.

2.3.2 CO_2 Research**:**

- HP with ejector (Stiebel Eltron)
- Domestic Hot water HP (Stiebel Eltron - CH)
- Compressor (University Braunschweig)
- Retrofit heat pump with high energy- efficiency and an eco-friendly refrigerant (R&D Project from Viessmann)

The intention of this R&D project is the development of an electric driven heat pump with the refrigerant CO_2 for the retrofit market, which is reaching the demand of existing houses. Today, most of the sold heat pumps are installed n new buildings. The main barriers for using heat pumps for the retrofit of old buildings are the high inlet temperatures of 70 °C up to 90 °C, which is too high for the present commercial heat pumps

Another motivation of this R&D project is the possibility to use the eco-friendly refrigerant CO_2, with lower global warming potential GWP compared with the presently used HFC blends.

The heat pump with electric heating permits to cover the heating demand of a house with 20 kW max. capacity at design temperature. The seasonal performance factor (SPF) target is 3.3. Space heating (90%) and tap water heating (10%) will be realised with an economiser cycle and hot gas injection in the compressor. The bivalent point is fixed at -7 °C (13 kW). The annual energy consumption of the electrical heater amounts to 5% (calculation result)

Also a prototype of a CO_2 compressor will be developed within this project with the necessary capacity, high efficiency, high condensing temperatures, a perspective of low production costs and a long lifespan. First compressors have been built and Copeland is testing them in time. Probably in September Viessmann will get one finished compressor for building the first CO_2 heat pump prototype.

All evaporator measurements are finished. The gas cooler measurements are still running. Viessmann has ordered all necessary components like valves, tubes, heat exchangers, to build the first prototype machine and is making all the necessary 3D-constructions.

End 2008 the first prototype has been built and successfully operated. After early problems a stable and safe heat pump operation has been reported.

First measurements have shown a 30 % higher oiltrasnport, related to the tital mass flow rate. The highest COP was in the order of 1, 95. After a modification of the heat pump the oiltransport has been reduced by 66 % and the COP increased to 3, 2. For more information see Attachment VI Literature "Zwischenbericht April 2009"

- **The FKW CO_2 Heat Pipe as Earth Probe for Geothermal Heat Pumps**

FKW has performed R&D work since 1998 on a CO_2 earth heat pipe system with patent application already on December 24, 1998. That work led to the development of a special CO2 earth heat pipe with flexible stainless steel pipes, covered by the German Patent No. DE 10327602. At the end of the R&D work in 2004, field tests have been performed with this innovative heat pipe in order to investigate the feasibility of handling and inserting it into the earth and to measure the performance in comparison to a conventional brine earth probe.

Tests with both 100 m deep earth probes each in parallel continuously operated by two identical heat pumps showed a 25 % better energetic performance of the novel system, still not taking into account the around 15 % extra energy needed for the brine pump. This substantial energetic advantage is based on the better heat exchange behaviour in the CO_2 condenser and heat pipe than in the brine cooler and earth probe and confirms a theoretical Swiss BfE study.

In order to gain experience with the new system around ten FKW CO_2 heat pipes were installed as pilot systems for heating of one-family-houses at various locations in Germany and Austria. In summary, it could be stated that the individual pilot systems, having now worked already since 2005 during between three and one heating seasons, have not shown any problems so far.

In 2005, FKW decided also to start a continuing research and development project for further improvement work on the developed heat pipe.

In 2007, this project started at FKW, supported by its partners Viessmann, ThyssenKruppEdelstahl, Brugg Pipe Systems and Gea-WTT Plate Heat Exchangers, and sponsored by the German Federal Ministry of Economy.

For the research and development work, and also energetic comparisons with conventional systems, FKW installed two different CO_2 heat pipes and one brine earth probe, close to its building.

For the market introduction, first development work had been done already at the CO_2/refrigerant heat exchanger for an industrial low cost production of the heat pipe system.

In 2008, the market introduction will start in order to improve the energy efficiency of geothermal he at pumps with pump less CO_2 earth heat pipes for greenhouse gas reduction

- **EIfER – Research-Project**

During the year 2005 the EIfER, European Institute for Energy Research in Karlsruhe, initiated a research project which was sponsored by the both utilities EnBW, Energie Baden-Württemberg, Karlsruhe and EDF, Éléctricité de France, Paris, in order to investigate a 250 m deep FKW-CO_2-earth heat pipe for providing earth heat to an old existing building from only one individual deep borehole.

Partners in this project were the University of Karlsruhe, FKW Hannover, Kaeltro Berlin, and the "systherma planning bureau for earth heat systems" in Starzach-Felldorf which performed the coordination, FKW the lay out of this first very deep heat pipe system, Kaeltro the installation between heat pipe, heat pump and heating system, and the Institute for Applied Geology of the University Karlsruhe the installation of the devices for measurements after the installation in order to evaluate together with FKW the operation of the whole system.

The drilling of the borehole at Triberg (Black Forest) was done in December 2006, the heat pipe was placed in the borehole in March 2007 and, after several preliminary tests with the whole heat pump system and the CO_2-earth heat pipe, the official starting of operation had been on January 23, 2008

2.3.3 Field Tests

- Field experience of existing heat pumps
  (Fraunhofer ISE financed by the utility company E.on Energie AG, München)

2.4 Norway

Trans-critical CO_2 heat pumping systems

Until now, most of the interest in CO_2 heat pumps has been for tap water heating. Especially the applications for tap water heating in Japan are very successful.

The application for space heating seems the next step in the development of CO_2 heat pumps.

Nekså from SINTEF Energy Research (2002) investigated several options within a system design to achieve a lowest possible return temperature from the heating system; radiator and air heating are connected in series. Tap water is pre-heated in parallel with the space heating and heat exchange against hot discharge gas is used to achieve the required hot water temperature. A comparison with a system using HFC-134a as working fluid showed favourable seasonal performance for the CO_2 system when more than 30% of the heating demand for space heating was from the air heating system, and the rest from the radiator system.

2.5 The Netherlands

Research and development *(Objective):*

To create compact heating/cooling systems using heat pumps that (exegetically) optimally meet (low-grade) energy requirements for heating and cooling in the built environment, which form the basis for heat neutral concepts**.**

Needed focus *(application areas)*:
Retrofit market to replace the high temperature gas-boiler

Needed focus for R&D:

- Development of high temperature heating concepts for space heating in buildings
- Optimisation of source systems with compact and air source heat exchangers and other innovative source systems to obtain heat from ground or air

- Integration of heat pumps in low energy, high exergy houses
- Development of concepts for renovation and retrofit in collective and individual domestic housing
- Compact storage systems
- High efficiency for water heating
- Alternatives for electric compression systems

NL 02 50 Heat pumps for privately owned houses

The renovation of privately owned one family houses is another type of renovation process than with corporate owned buildings. Experience has shown that most of this type of renovation doesn't go any further than the renovation of the heating system and/or the replacement of the heating boiler.

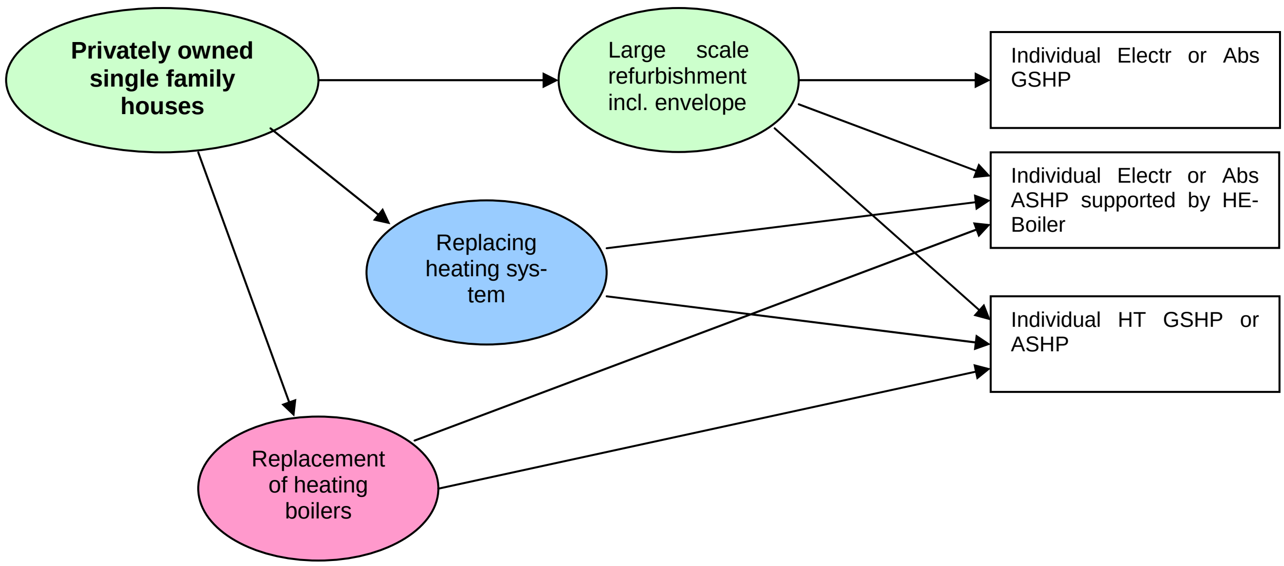


Figure 5: Renovation for private or corporate owned buildings

The major constraint is the lack of adequate insulation. Especially in privately owned houses a renovation project will not go further than replacement of heating systems and/or heating boilers (see Project monitoring input NL).

Several technical solutions are feasible, which will have to deal with project characteristics of existing buildings:

- High temperature heating systems can be replaced by low temperature systems if such systems are available and possible in an easy and cost effective way;
- A high capacity heating system dealing with the peak demand for space heating due to the lack of adequate insulation will have to be replaced by a system giving the same end use characteristics of such a system;

- A high capacity heating system dealing with the demand of a domestic hot water system will have to be replaced by a system giving the same end use characteristics of such a system.

There are several technical solutions possible for larger systems with storage tanks for the domestic hot water. However for the greater capacity needed for space heating a support with a gas-boiler or other boiler (oil or wood-pallets) should be used parallel to the heat pump and equipped with a well designed control system.

Especially in smaller single family houses there is no adequate space available for a larger heating system. In typical Dutch one family houses the central heating gas boiler is situated at the top of the house in the hydronic heating system. No extensive cellar space is available, which makes larger storage tanks and large heat pumps with ground sources although possible not the most viable solution in this configuration.

Two developments by heat pump manufacturers in the Netherlands are dealing with this problem.

Figure 6: Boiler at the roof of the house

As these heat pumps are basic air-to water heat pumps using the outside air as a source the heat pump can cover about 80% of the annual heating demand with a maximum outlet temperature of 55 - 65°C. The rest has to be covered by the backup-heating system based upon a gas-boiler.

The Dutch company of Techneco has developed such systems and is putting this into effect in a demonstration project covering 50 different houses and house-types. In most of the cases the heat pump will be installed as an add-on to the existing heating system with a gas boiler.

In a part of the project also new radiators will be installed with forced ventilation in order to be able to give cooling in summertime.

A further description of the project (capacities, costs and user experience) will be given later on as well as results from the first monitoring. A presentation of the final results will be given on the Heat Pump Conference in Zurich 2008.

3 Field tests

3.1 Examples of field tests in different European countries

In various countries are field tests performed to evaluate efficiency of retrofitted heat pumps.

For example:

- **UK:** **standard air-to-water heat pumps** (e.g. see case study 1.16ff)
- **France:** **standard air-to-water heat pumps** (e.g. see case study 1.13)
- **Germany:** **field experience of existing heat pumps** (e.g. see 2.3.3 Ger many and case studies 1.2; 1.4; 1.14; 1.20**)**

3.2 Altherma Monitoring

Altherma heat pump system

Split air /hydrobox / water heat pump

Scope of Service

Measurement at test points relevant for the assessment of the heat pump system with sensors approved and calibrated by arsenal research over a period of one year.

- Calculation of the performance factor in monthly and annual balance.
- Diagrams and trend description of relevant measured values.
- Comparison with conventional systems of heat generation by necessary primary energy use proportional to the resulting final useful energy: In the course of the evaluation, the systems are examined regarding their environmental impact. Furthermore, the TEWI of the heat pump can be calculated and compared to a conventional heat generation system.
- Total Equivalent Warming Impact (TEWI): The TEWI is used for the determination of the entire contribution to the greenhouse effect of a cooling process during its operation and is calculated for a period of 20 years. According to the energy consumption the emissions of the heat pump system occurring during electricity production compared to an oil or gas-fired boiler.

- *Selected measuring points:*

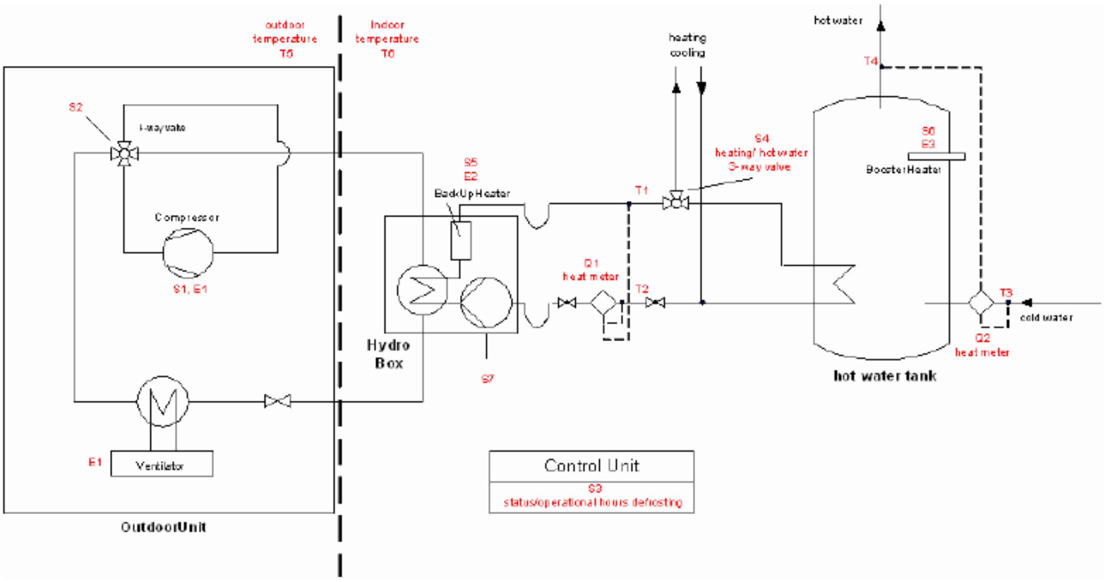


Figure 7: Measuring points

Aims of analyses and evaluation

- Energy-Output (Heat**)**
- Energy-Input (Electric power consumption: Compressor, Fan, Back up Heater, Booster Heater, Control-unit)
- System Performance Factor (analyzed per day, month and year)
- Operational hours of the heat pump (Compressor)
- Switching frequency / 24h (analyzed per month and year)
- Average Electric power consumption (analyzed per month and year)
- Average Heat Output (analyzed per month and year)
- Outdoor / Indoor temperature
- Supply and return temperatures of the heat distribution system
- Temperatures of the heat source system: air inlet and outlet temperature
- Operational hours of the heating mode depending on the outdoor temperature
- Operational hours of the defrosting mode depending on the outdoor temperature
- Operational hours in the hot water production mode
- Operational hours of the Backup Heater
- Operational hours of the Booster Heater
- Operational hours of the circulation pump
- TEWI (Total Equivalent Warming Impact)
- Environmental impact, CO_2 Emissions

Attachment V

Annex 30
Retrofit Heat Pumps for Buildings

Expert meetings and Workshops

Kick-off Meetings

1. 25.05.2004 Hannover, Germany
2. 14.10.2004 IKK 2004, Nürnberg Messegelände

Expert meetings

1. 12.05.2005 VDKF-Office Bonn / Germany
2. 02.12.2005 DAIkIN Regionalbüro Bochum - Wattenscheid / Germany
3. 04.04.2006 Copeland GmbH, Aachen - Oberforstbach / Germany
4. 01.06.2006 SenterNovem Utrecht / The Netherlands
5. 17.10.2006 IKK 2006 Nürnberg / Germany
6. 14.02.2007 Viessmann Werke Allendorf / Germany
7. 23.11.2007 DKV Jahrestagung Hotel Maritim Hannover Flughafen, Germany
8. 13.02.2008 Mammoni at Mariaplaats 14, Utrecht / The Netherlands

Workshops

Annex 30 Workshop "Retrofit Heat Pumps for Buildings"
07.11.2006, Hannover

Annex 30 Workshop "Wärmepumpentechnik" – AAIV,
Deutsche Kälte - Klima - Tagung 2007, 23.11.2007, Hannover

Annex 30 Workshop "Retrofit Heat Pumps for Buildings"
IEA Heat Pump Conference, 19. May 2008, Zürich Switzerland

Annex 30 Workshop "Retrofit Heat Pumps for Buildings"
DKV International Heat Pump Conference, 14. October 2008, Chillventa Nürnberg

Attachment VI

Annex 30
Retrofit Heat Pumps for Buildings

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