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Energy Efficiency And CO2 Reduction In The Building Stock -The Role Of The Heat Pumps-

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ABSTRACT

Europe is facing unprecedented energy challenges resulting from increased import dependency and concerns over supplies of fossil fuels worldwide. EU set therefore binding targets for 2020 to reduce greenhouse gas emissions by 20%, ensuring 20% of renewable energy sources in the energy mix and planning to reduce EU global primary energy use by 20% by 2020.

Heat pumps (HPs) are among the most environmentally friendly and efficient heating technologies available. In various countries the markets have been mainly concerned with HPs for new buildings. There is a very larger potential for replacement with HPs 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.

This paper summarizes objectives and results of the IEA HPP Annex 30 Retrofit HPs for Buildings.

1. Introduction

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 utilization 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 accomplish the ambitious goals for the reduction of fossil primary energy consumption and the related CO_2 - emissions the use of renewable energy in the existing building stock has to be addressed. This is possible and realistic with the existing basic technology and knowledge for new and renovated buildings.
Heat pumps are among the most environmentally friendly and efficient heating technologies available (*IEA 2005, IEA 2006, HPTCJ 2007, IEA 2008*). The directive for Energy performance for buildings is therefore an additional

driver for HPs, which are still concentrated to new one- and two-family houses. There is, however, a much larger potential for replacement with HPs 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.

From the beginning of the International Energy Agency's (IEA) Heat Pump Program (HPP), as most national programs too, in the various IEA-countries the markets have been mainly concerned with the development and application of HPs for new buildings. Recognizing the potential (see *IZW 2002, Laue 2005, Kruse 2005)* of the retrofit market, the IEA-HPP initiated Annex 30 an international collaboration on "Retrofit Heat Pumps for Buildings". Active participants from France, Germany, Netherlands and Sweden with the operating agent IZW e.V. (Germany) gave their experience as input and collected data and information to get an overview of Europe.

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

The programme has been subdivided into four tasks:

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

As result of this work, it is clear today that in many cases HPs already can or will soon allow to be used as a preferable retrofit choice. The use of HPs is leading to drastically improved efficiency in heat generation, reduction in use of fossil energy and, at the same time, to enable people to use geothermal, hydrothermal and aerothermal renewable energy sources. It means that heat pumps are contributing to all three targets of above mentioned European Commission's 20-20-20 policy and this even in existing building stock (*IEA 2208*).

To achieve as quickly as possible more of this promising potential, barriers need to be removed or overcome. E.g. it is difficult to distinguish between different types, in which case a type of heat pump can be used and which assumptions a building should fulfil. Therefore a selection chart, which only distinguishes four categories (Standard, Bivalent, High temperature, Direct system) was created to simplify selection of heat pumps, see figure 1.

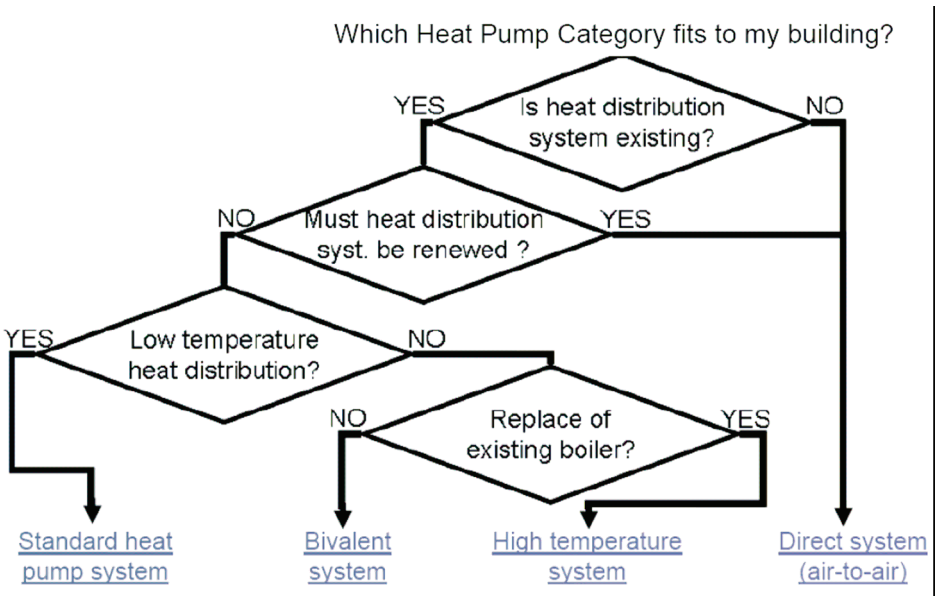

Figure 1: **Four categories of heat pumps for retrofitting purposes**

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.
- Finding solutions for existing heating systems (electrical overnight storage heaters) without a heating distribution system.

2. Overview Europe, State of the art – market analysis

The annex started (task 1) with a collection and analysis of statistical and other information on the present status of existing residential buildings and the present HPs market and potential technology economically applicable for retrofit of existing buildings in the different climatic regions in selected European countries.
The analysis has shown that the total market in Europe for space heating by HPs is growing. For Example in 2008 in **France** the HP figures rose from 69,600 the previous year by 119% to 152,510 units. In turn, the markedly disproportionate trend here was the increase in Air-Water HP by 161% to 133,080 appliances, which at 87% represented the market-leading technology. Over 70% of this technology is installed in existing buildings.
The **German** market for HPs has shown huge growth since 2005 and the boom year 2006 was followed by another new record in 2008. With almost 62,500 space heating HPs sold (+40% over 2007) and an additional 13,861 hot water HPs, almost twice as many as the previous year (7,354), the German market continued to grow strongly in 2008. The 62,500 space heating HPs sold in 2008 therefore exceed 10% of the total market for heating systems for the first time.
For example in **Switzerland** 2006 75 % of all new build one-family houses are equipped with HPs, however, as shown in figure 2, the retrofit market in residential buildings is between 2003 and 2006 only around 20 %, 2008 and 2009 it is around 30% of the total and in figure 3 the sale of HPs in Switzerland in 2008 shows a lead to oil and gas boilers. In Switzerland more than 140,000 HP were running and more than 80% of new residential houses (2008) are equipped with HPs.

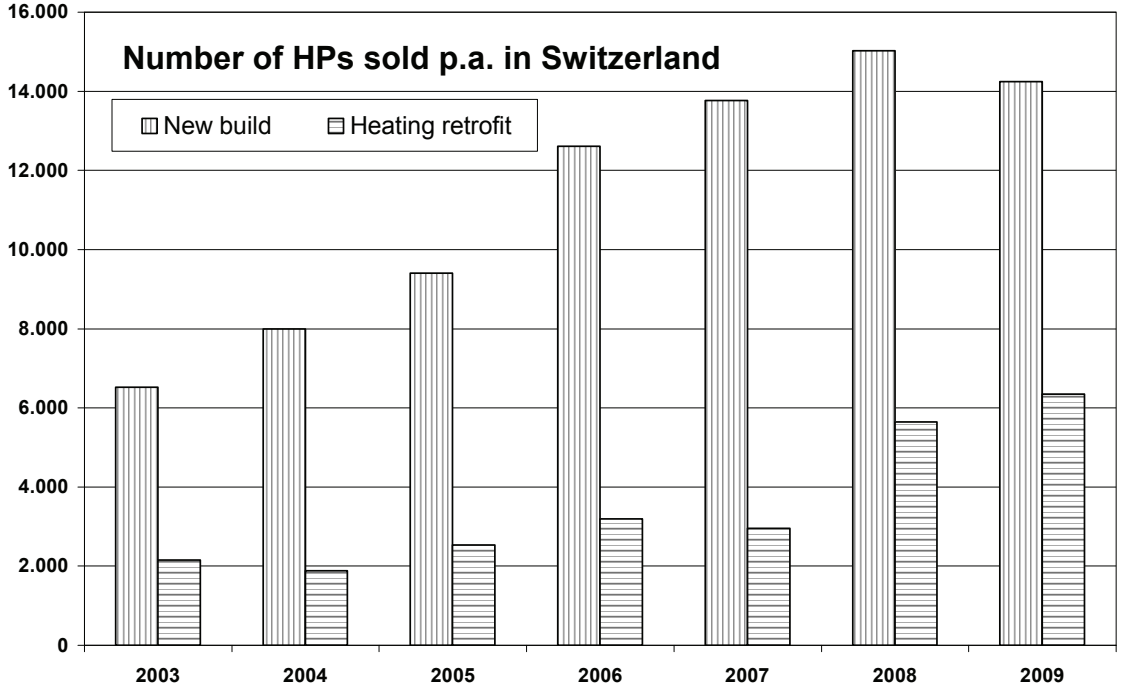

Figure 2: **HPs sold in Switzerland related to the application –new build or retrofit -** (Source FWS)

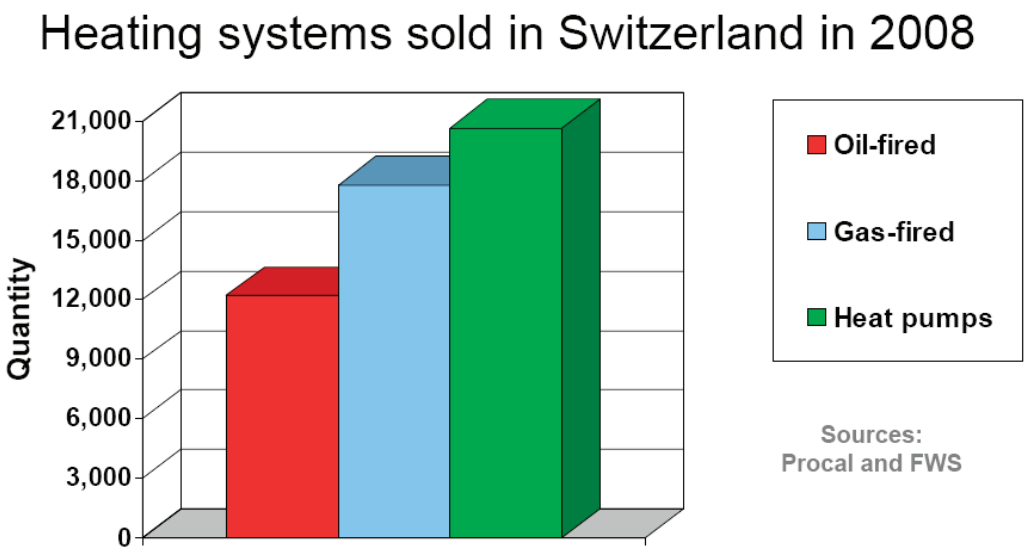

Figure 3: **Heating Systems -boilers (gas and oil) and HPs- sold in Switzerland in 2008** (Sources: Procal a. FWS)

3. Matrix of HPs (Case studies, R&D projects)

Task 2 presented 20 practical applications of HPs in existing buildings, analysing the present generation of HPs and possible improvement of components and systems for retrofit application, as well as Research& Development (R & D) projects directly related to the objectives of the annex, subdivided in systems, components and refrigerants from selected European countries, distinguished in four categories of HPs for retrofitting (see figure.1).

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.

BIVALENT 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 – 80°C require the development and market introduction of new high temperature HPs. An additional ideal application for high temperature HPs is domestic hot water production. (*Hafner 2005*)

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 HPs (air-to-air). (*Thiemann 2003*)

There is no general definition of an existing house which is the target group for retrofit with HPs. 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 HPs, the first step is to look into the renovation process and the frequency in which the several steps of the process occur.

4. Overcoming economic, environmental and legal barriers

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

The main barrier for the use of HPs 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 HPs in already improved standard buildings with reduced heat demand, the development and market introduction of new high temperature HPs is a mayor task for the replacement of conventional heating systems with HPs 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 GWP working fluids.

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

The high investment costs are more than compensated by the low operation costs, as shown with comparison of the operation costs of a water/water heat pump with the former natural gas boiler below:

08.07.05 –07.07.06	(natural gas 2005-2006)):	€	3.534	
20.07.06 -19.07.07	(HP electricity, 2006-2007)):	€	1.569	
Difference		€	1.965	(= - 55 %)

A widely shared opinion on the “appropriate” reduction of energy demand in older houses is the following renovation sequence”: -New windows and complete thermal insulation of the building, -Replacement of the boiler by a new high efficient one in combination with solar use for domestic hot water in combination with an improved heat distribution system or -Replacement of the boiler by a monovalent HP for space heating and domestic hot water in combination with an improved heat distribution system.
This renovation is costly and demanding on the house owner: individual effort, time and the willingness to incur trouble related to necessary renovation measures. Not every house owner has the money or is willing to spend it for this purpose and has the goal depending on his personal situation to improve the energy efficiency of his house.
Bivalent heating systems – the combination of the existing boiler with a HP are a cost efficient option to improve the energy demand and greenhouse gas emissions of the building at moderate cost. Experience from the early days of the mass market for heat pumps in Europe (the early 1980s) support this claim.
The bivalent system type combines two separate heat sources: energy from air, water or ground – to be used by the HP - and fossil fuel to be used by an existing boiler to cover 100% of the energy demand.
There are two types of bivalent systems: parallel or alternative operation. When parallel operating boiler is sized to cover capacity peaks only, in alternative configuration the boiler is sized to cover the full capacity on the coldest day of the year. The alternative bivalent configuration is here recommended where a heating system exist.

Poor perception has occasionally a detrimental effect on the retrofit heat pump market, which has tempted incompetent vendors and installers to enter. This has, in some instances and in combination with some brands not meeting a reasonable efficiency and quality standard, led to frustrated buyers and a setback in sales. This situation has arisen in several European countries, often in conjunction with energy saving initiatives and programmes
The limited awareness by decision makers, the public, authorities and politicians dealing with energy matters is due to a lack of professional information at all levels. It is worth mentioning that whereas such renewable energy sources as wind, solar, biomass and photovoltaic are well known alternatives, because of effective information campaigns and authority support, only modest emphasis has been placed on the energy saving and environmental potential of heat pump systems in particularly for the retrofit market.

5. Successful factors for the marketing of retrofit HPs

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

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

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

So far Europe has been concentrating on heating-only HPs with water distribution systems and heat recovery systems, but sales of air-to-air dual-mode units for both heating and cooling are now growing, not only in the southern part of Europe. The oil crises had changed this situation, and Kyoto is a further reason for the increasing market deployment of this technology.
It is well known that HPs significantly offer in the building sector the possibility of reducing fossil energy consumption and their related global emissions of greenhouse gases.

6. Conclusion

Europe is facing unprecedented energy challenges resulting from increased import dependency, concerns over supplies of fossil fuels worldwide and a clearly discernable climate change. EU set therefore 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.

The primary focus of IEA HPP Annex 30 is on all kind of domestic buildings. In order to reach the EU targets for such buildings it is recommendable to focus on following solutions and gain in experience concerning:

- Application of available HPs in standard buildings that have been improved, resulting in a reduced heat demand.

- Existing and further development and market introduction of new “high” temperature HPs (60-75°C) that use a compact source for application in existing buildings.

- Use of reversible (heating-cooling) HPs (air-to-air) in buildings without centralized heat distribution systems, to achieve easy use of aerothermal renewable energy sources.

- Using BIVALENT Heat Pump systems to upgrade existing heating systems by using installed boilers to cover peak demand

- A single radiator should not set the limit (bottleneck) for the whole building: The combination of different HPs and heat exchangers in one house:

Different Heat-Pumps for individual temperature requirement:

- One STANDARD Heat-Pump for space heating and one HP for domestic hot water

- Eliminating bottlenecks: Additional 'DIRECT' HP (air-to-air) for e.g. living space

- Reduction of heat distribution temperature: Combination of existing radiators and replacement of single radiators by convectors with fans, by fan coils and when possible by floor heating in single rooms (e.g. bathroom renovation)

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

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