EUROPE: HEAT PUMPS—STATUS AND TRENDS

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ABSTRACT

Heat pumping technology finds wide application in industry, commercial buildings and residential property. The climate in Europe varies considerably from north to south, which means that growth in air conditioning has therefore tended to be greatest in southern Europe. Heat pumps designed for space heating are more common in central and northern Europe, although interior heating of buildings is needed in all European countries. This paper discusses the market and trends for heat pumps in Europe. Although statistics show that conditions vary widely from one country to another, the overall trend of market growth of heat pumps in Europe is favourable.

Key Words: ***heat pumps, market, trends***

1 INTRODUCTION

Energy prices and each country's energy mix affect the conditions for heat pumps to be competitive with other alternatives. Other important factors influencing how and if heat pumps are used are tradition, knowledge and the condition of existing and new buildings. Research and development, various types of political incentives, requirements for specific minimum levels of energy efficiency and the dissemination of knowledge are all important instruments for encouraging growth of the heat pump market. The fact that climate, the condition of building stock, experience of the use of heat pumps and energy mix all vary widely from one country to another means that Europe is not a homogenous market. This has meant that everything from mature markets, through developing markets to markets with little experience of heat pumping technology, can all be encountered within the boundaries of Europe. When used in the right applications, heat pump technology is an energy-efficient technology that reduces greenhouse gas emissions and so contributes to the long-term aim of achieving a sustainable society. The purpose of this paper is to describe the situation on the European heat pump market.

2 BACKGROUND

2.1 Energy Use and Energy Resources

Most of the heat pumps sold in Europe are electrically driven. Electricity use in Europe increased by over 20 % between 1990 and 2001, with the greatest increases being in Portugal, Iceland and Ireland (Energy Markets, 2004). Buildings are the largest energy user and electricity stands for more than 50 % of the total energy used in buildings (Fernandes 2004). Heat pumps reduce overall energy use at a national level, although the reduction in CO_2 emissions depends on how the electricity is produced and on what types of heat sources that are replaced. Half of all electricity production in the EU is based on fossil fuels, one third on nuclear power and about 15 % on hydro power. The energy mix for electricity production in Europe varies, as shown in Figure 1. Within the EU, Luxemburg and Austria have the highest proportion of hydro power: in the wider OECD, Norway and Iceland occupy top places with almost 100 % hydro power. It has the advantage of not causing any CO_2 emissions, but production capacity is climate-dependent, which can result in energy shortages in dry years. Both Norway and

Sweden, for example, suffered from dry years in 1996 and 2003, with rising prices of electricity as a result. Reducing the risk of electricity shortages is one reason for improving the efficiency of energy use. Nuclear power production dominates in some countries, such as France, although Austria, Sweden and Switzerland also have relatively high proportions of nuclear power. Refuse incineration provides a relatively high proportion of electricity production in (particularly) Belgium and Netherlands, although it is also commonly used in Denmark and Germany.

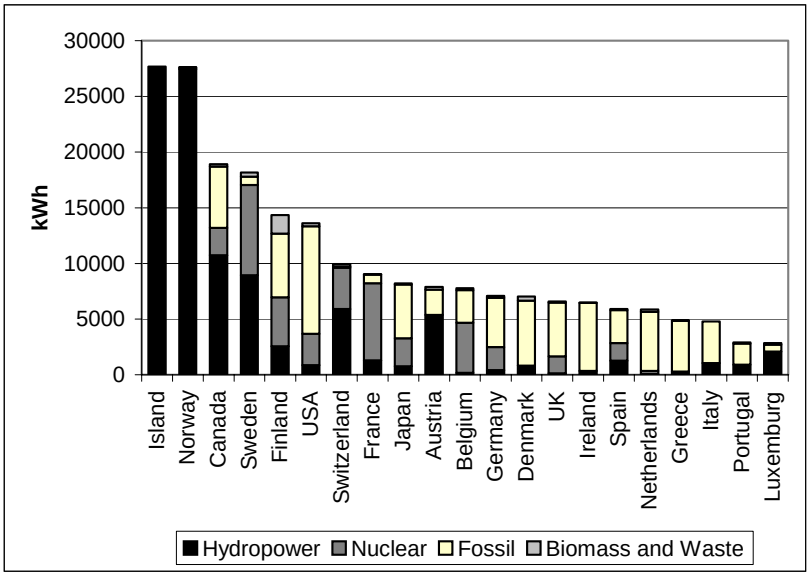


Fig. 1. Electricity production per inhabitant, year 2001, kWh (Source: Electricity Information 2003, IEA)

Natural gas supplied 24 % of total energy use in the EU states in 2002. Its proportions vary from about 1 % in Portugal and Ireland to almost 40 % in the UK, (Energy Market, 2004). District heating and district cooling are further alternatives for heating and cooling. Heat pumps may be used in both types of systems on the supply side: those supplying cooling often, in fact, use the district heating system as their heat sink. The following European countries have substantial district heating systems: Denmark, Sweden, Finland, Germany, Poland and France. Almost 40 % of total heating supplies in Sweden, for example, are met by district heating (Energy Market, 2004).

The EU, and most European countries outside the EU, has ratified the Kyoto Protocol which came into force on the 16th of February. This means that industrialised countries have committed themselves[1] to reducing their combined greenhouse gas emissions by 5 % of their 1990 emissions during the First Commitment Period, from 2008 to 2012. For the EU, there is an overall commitment of an 8 % reduction over this period. The Protocol covers six greenhouse gases, of which one is carbon dioxide. Work on changing the energy mix by increasing the proportion of renewable energy and reducing the overall use of energy, is in progress, with the aim of introducing measures intended to reduce environmental impact on climate. Energy use at European level continues to increase, which means that both energy efficiency improvement measures and a change in the energy mix will be needed in order to meet commitments concerning reduction of greenhouse gas emissions.

The competitiveness for electrical driven heat pumps is dependent on the electricity price in comparison with other energy sources such as natural gas, oil or biofuels. The price of electricity in comparison with other energy sources varies as does the electricity prices from one country to another and from one customer category to another. In general, large electricity users pay a lower price than those using less electricity. Figure 2 below shows prices in a number of countries, illustrating an important factor that affects the economic competitiveness of heat pumps. Historically, energy prices have been low, which has not encouraged improvements in the efficiency of energy use to the extent that would have been desirable. However, trends over the last five years show that prices have risen.

[1] Those that have ratified the Protocol, that is.

Directives 2003/54/EC and 2003/55/EC of the European Parliament and of the Council set out common rules for the internal markets in electricity and natural gas respectively, requiring the respective markets to be fully open to industrial customers by 1st June 2004 and to domestic customers by 1 July 2007. However, despite the ongoing harmonisation, there are substantial differences between European countries today in these respects. The UK, the Nordic countries and Germany can be regarded as fully deregulated markets (Energy Market, 2004) while other European countries is not.

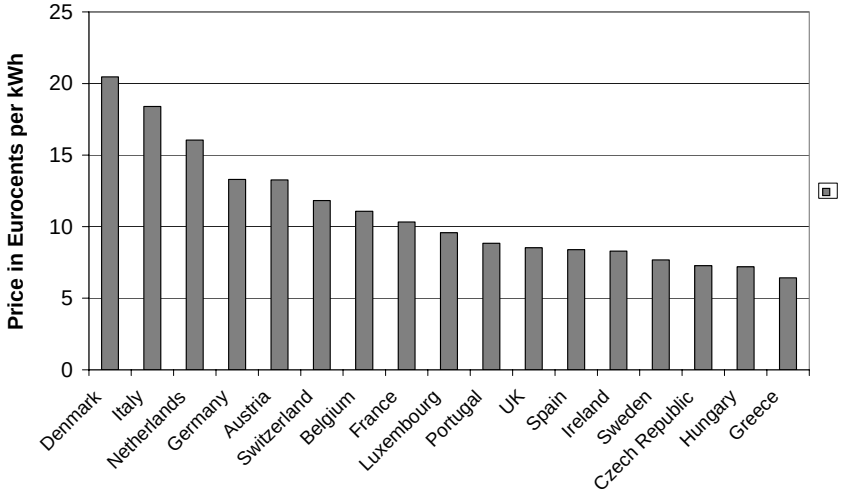


Fig. 2. Electricity by country including taxes for residential consumers > 7000 kWh/year, data from 2002, (source INRA)

2.2 Climate

Climate affects heat demand, cooling requirements and the conditions for using various types of heat sources. Southern Europe has a Mediterranean climate, while central Europe has a continental climate and northern Europe has a Nordic climate. However, it should be noted that the climate in the UK and on the Norwegian west coast can be described as a maritime climate, with mild damp winters and relatively cool summers in comparison with southern and central Europe.

2.3 The Status of Existing Buildings

About 40 % of energy use in Europe is accounted for by the built environment. A building commonly has a life of over 100 years. It is therefore the existing building stock that dominates demand, while the rate of growth of new buildings varies with time, depending on general economic conditions. According to EHPA, the European Heat Pump Association, Europe has approximately 145 million dwellings to house a total population of more than 370 million (EHPA Strategy Plan 2000).

Heating of buildings is needed in all European countries, and hydronic heating systems dominate even in countries that also require cooling. According to EHPA, 53 % of dwellings have a central heating system, 11 % are heated by electricity and 10 % are heated by gas (EHPA Strategy Plan 2000). Cooling is common in southern Europe in particular (southern France, Greece, Italy and Spain), and air is the commonest medium for distributing the cooling. In some countries (Norway, Finland and Sweden, for example) there is a substantial proportion of residential buildings with direct electric heating, and this presents an obstacle to the installation of heat pump, as it is not as easy to distribute the heat from them when the house has no heat distribution system to start with. Some countries, such as Holland, the UK and Germany, have an extensive natural gas distribution network. Germany, Sweden, Denmark and several other countries have district heating systems in urban areas that compete with small-scale heat pump technology, although they may use it themselves in the form of large units.

Hydronic heating systems are the main type of heating systems in commercial buildings, with both air and water being used for cooling.

The choice of type of heat pump and its efficiency are affected by the building heating system, i.e. its operating temperature and the distribution medium. Generally, the efficiency is improved by a lower condensing temperature, i.e. a lower operating temperature of the distribution medium. When air is used for both heating and cooling, its temperature is usually in the range 30-55 °C for heating and 16 °C or a little higher for cooling. In hydronic heating systems, heat is distributed via radiators, convectors or fan coils. In older, high-temperature, systems, the water temperature is 70-90 °C. In buildings constructed since 1980, it is common to find low-temperature systems operating at 40-55 °C. Europe has a large stock of older buildings with hydronic heating systems, with high-temperature systems predominating. This has been recognised by several countries, including Germany and Switzerland, as constituting a technical obstacle in the way of using heat pumps that needs to be overcome, (Laue 2004). The high temperature requirements of many existing buildings have meant that, in most European countries, heat pumps are installed mainly in new buildings.

It is common today, in new single-family houses, to install floor heating. The low temperatures at which it operates (supply temperatures in the range 30-40 °C) are very suitable for use with heat pumps. There is a general trend throughout Europe to build more energy-efficient buildings. In the case of new buildings, this means that heating requirements are reduced and cooling and ventilation requirements are increased. This is particularly clear in commercial and institutional buildings. This trend favours reversible heat pumps that can supply low temperature for heating and reject heat at high temperature for cooling. Lower heat demand for space heating also means that domestic hot water production will stand for a larger part of the total heat demand in the future in low-energy buildings.

2.4 Developments in Refrigerants

National regulations to phase out the use of ozone-destroying refrigerants have been implemented at different rates from one country to another in Europe. Table 1 shows the status of such bans in various European countries. The European Commission phase –out scheme for HCFCs is 35 % reduction in 2004, 60 % in 2007, 80 % in 2010 and 100 % in 2015. The phase-out of CFC and HCFC refrigerants led to the introduction of new refrigerants. The most common refrigerant used in heat pumps produced in Europe today is R407C, although R404A, R134a and R290 (propane) are also used. R410A is the most common refrigerant for air-to-air heat pumps, although R417A is also used.

Table 1. Phase-out of ozone-depleting refrigerants in new installations in some European countries.

Country	CFC	HCFC	HFC (F gases)
Austria	1996	1998	2006
France	1995	2015 all installations, according to EU	
Germany	1995 new, R12 all 1998	R22 2000	
Norway	1991		
Denmark	1995	31 Dec. 1999	2006
Sweden	R-12, R-500 and R-502 1995 Refilling banned since 1998	R-22, 1998 Refilling banned since 2002	

2.5 Types of Heat Pumps

Common heat sources are air, ground source (surface, rock, geothermal), water (lakes, rivers, and groundwater) and waste heat.

2.5.1 Air-source heat pumps

Generally, air as the heat source is particularly common in central and southern Europe, but has shown itself as an attractive alternative also in northern Europe. However, it is important that such

systems have effective control strategies for defrosting. Heat pumps of this type can be divided into two categories: air/air and air/water. The advantage of an air/air heat pump is that it is independent of the existing heating system in the house, and that it can be used for both heating and cooling. Its drawback, on the other hand, is that it cannot be used for domestic hot water production. Heat pumps of this type are widely installed in southern Europe because of their ability to supply air conditioning in the summer. Interest in them has increased dramatically in the Nordic countries over the last few years as a response to rising electricity prices. They offer an interesting alternative for houses with direct electric heating, as their investment cost is relatively low in comparison with other heating alternatives. Air/water heat pumps have been the most popular in central Europe.

2.5.2 Ground-source heat pumps

The use of the ground as a heat source has attracted growing interest. It has the advantage of less change of temperature with time of year or weather conditions. It is also possible to use the ground for cooling in the summer, although there are various types of national obstacles throughout the EU. Some countries (the UK and Germany, for example) have no tradition of drilling energy wells, and therefore suffer from a lack of trained well drillers. Other difficulties may be physical, such as unsuitability of the rock for drilling, or legal, such as ownership of the groundrock. In several European countries, the state owns the ground below a certain depth (e.g. Germany, below 100 m, or the Czech Republic, below 30 m), or there may be a fear of contamination of drinking water. Most countries in Europe require some form of application of licence before an individual property owner can install a ground source heat pump. Further difficulties that may be encountered include a recommendation for a certain minimum distance between boreholes in order to prevent energy wells from affecting each other thermally, and this can be a practical limitation in urban areas. In some areas, horizontal earth collectors can be an alternative to vertical boreholes. Work is in progress on the development of collectors for improving the efficiency of such systems in small plots, and to reduce the cost of installation.

2.5.3 Using heat pumps for heat recovery

Waste heat from various types of industrial processes can provide a heat input to absorption heat pumps or compressor heat pumps. Another application is to recover heat from the exhaust air from mechanically-ventilated residential buildings. Exhaust air heat pumps are very common in newly built houses in Sweden, with over 90 % of all new builds having such a heat pump installed, generally supplying heat to a hydronic floor heating system. There has been considerable interest in such heat pumps for many years, originally as a result of a national legal requirement. The 1980 Swedish Building Regulations (SBN 1980) stated that buildings with a ventilation exhaust air energy content that exceeded the energy content of the outdoor air by 50 MWh/year during the heating season must install a heat recovery system. An example of an acceptable solution was an exhaust air heat pump for combined space heating and domestic hot water heating A requirement for heat recovery is also introduced in Finland, and has resulted in increased interest in exhaust air heat pumps on the Finnish market. Compact units for low energy houses using exhaust air as heat source, are increasingly introduced on the market in Germany and Switzerland.

2.6 Industrial Applications for Heat Pumps

In industry, heat pumps are used mainly in food processes, chemical processes, timber drying, pulp and paper processes and petrochemical and refining processes (Industrial Heat Pumps, 1995). Industrial heat pumps can provide a number of process-related benefits, including:

- Reduced energy consumption for process heating;
- Increased capacity of existing process heating systems;
- Improved plant-wide environmental performance;
- Expanded production capacity through de-bottlenecking;
- Improved product quality;

Despite these potential benefits, the number of industrial heat pumps installed to date is relatively low in comparison with the number of existing technically and economically viable opportunities. They

have been implemented on a wide scale in only a few industrial processes, such as timber drying and some food, chemical, and pulp and paper industry evaporation and distillation processes.

Several reasons have been identified as contributing to the poor level of industrial heat pump use so far:

- Lack of knowledge of the potential processing benefits of industrial heat pumps;
- Lack of experience or familiarity with industrial heat pump technology;
- Lack of combined process and heat pump technology experience and knowledge;

The participating countries report that more than 4600 industrial heat pumps are now in use. Note that the US and Canada account for more than 50 %. The primary applications for these systems are:

- Food processes, including dairies, corn milling, sugar refining, breweries, liquor production and fish processing;
- Chemical processes, such as ethanol, ethylene and fertiliser production.
- Timber drying
- Pulp and paper processes, focusing on evaporation operations;
- Petrochemical and refining processes, such as product separation and distillation.

In Sweden, large industrial heat pumps, recovering waste heat from industrial processes, are also widely used for district heating.

To date (note report published 1995), the majority of industrial heat pumps have been either mechanical vapour recompression or closed-cycle compression heat pumps. Thermal vapour recompression industrial heat pumps are most commonly found in food and pulp and paper applications. Comparatively few absorption heat pumps have been installed.

According to the report Industrial Heat Pumps from the IEA Heat Pump Centre, industrial heat pumps have the potential to:

- Reduce total industrial process heat energy consumption by an average of 2-4 %.
- Reduce thermal energy consumption for individual processes by up to 66 %, depending on the industry and process.

The use of industrial heat pumps looks to be quite promising in processes involving distillation and evaporation, with significant potential energy savings for beet/cane sugar, cheese, corn syrup/starch, milk, liquor, ethanol, chlorine/caustic, and pulp production processes. Industrial heat pumps could provide net CO_2 emission reductions (21-42 million tonnes per year) by 2010. For electrically driven industrial heat pumps, the most favourable are those where electricity is derived primarily from non-fossil energy sources.

2.7 Market Development for Heat Pumps

In southern Europe, it is primarily the need for air conditioning that is driving the growth of the heat pump market, and so the commonest types of heat pumps are reversible air/air or air/water units. The report International heat pump status and policy review 1993-1996 from IEA Heat Pump Centre finds a link between increases and/or decreases in sales and average summer temperatures. Investigation of energy requirements during the year show that, even in these countries, it is a heating requirement that dominates, but it is nevertheless the air conditioning requirement that is the driving force behind sales. Air conditioning becomes more and more common also in central and north Europe. Today air conditioning in commercial buildings accounts for only 4 % of the load in the commercial building sector (Harrington 2004). (EECAC 2003) reports that a four-fold growth for air-conditioning is likely from 1990 to 2020 in Europe. In its Strategy Plan 2000, EHPA reports that over 4 million heat pumps had been sold in Western Europe (EU, Switzerland and Norway) by the end of 1999. By 2010, it is estimated that the residential heat pump stock will be 10 million units. Figure 3 shows the number of residential heat pump units sold during 2003. Sales on some markets have increased dramatically. An example is the French market that has grown strongly since 1997, when 1700 heat pumps were sold, to sales of 22 000

units in 2002 (Feldman 2004). Most heat pumps are installed in new buildings, and are of reversible air/water type that can be used for both heating and cooling. Cooling is usually distributed by fan coils, operating at a temperature above the dewpoint. On the heating side, it is common to have direct-expansion floor heating systems. Domestic hot water is often heated by a separate electric heater. Indirect systems are a new product, and are installed only in new buildings.

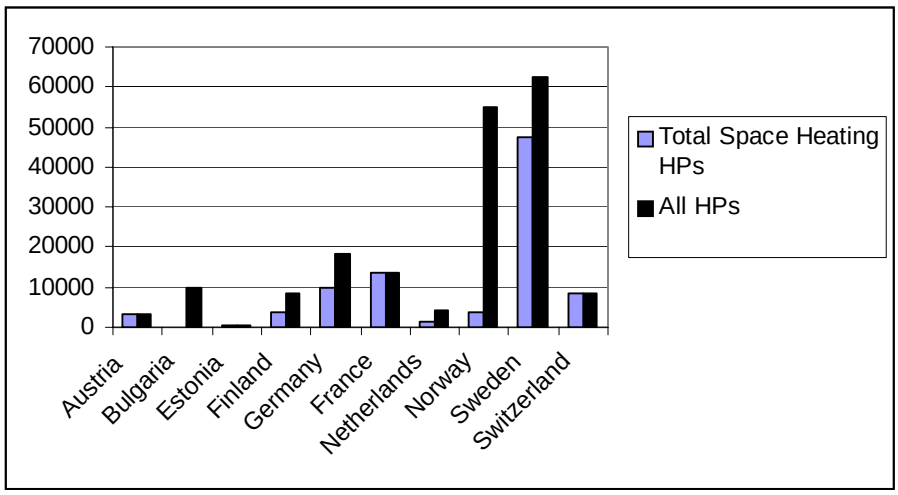
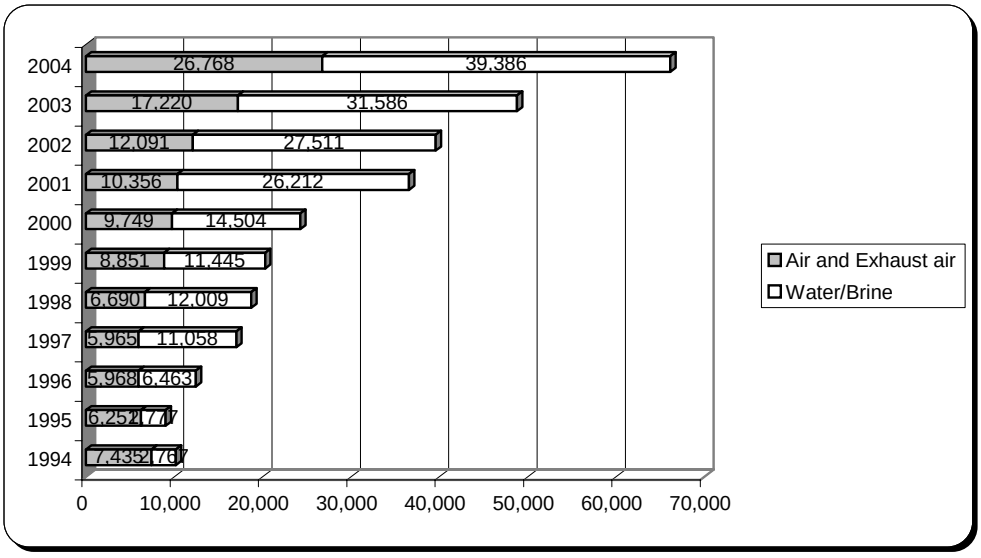


Fig. 3. Number of units sold 2003, (source EHPA)

The heat pump market is also growing rapidly in Norway, Finland and Sweden. The Nordic countries have in common a rapidly growing market for air/air heat pumps. The Norwegian market is another example of one where sales of heat pumps increased dramatically: from 2625 units in 2000, 21307 units 2002 to about 55 000 units in 2003. The main reason for this was that ENOVA[2] provided grants to encourage installation of air/air heat pumps during 2003. About 18 000 units were sold with the help of these grants, and a further 30 000 without grants as a result of increased awareness of air/air heat pumps, lower heat pump prices and higher electricity prices due to a dry summer. It should also be noted in this context that only 14 % of Norwegian properties have hydronic heating systems (Rose 2004). However, 45 % of new houses are now being fitted with hydronic heating systems, and properties with floor areas over 1000 m² are required to have them (Stene, 2004).



2 Enova SF is a public enterprise owned by the Norwegian Ministry of Petroleum and Energy. See http://enova.no/?itemid=425

Fig. 4. Number of sold units in Sweden, air/air is not included (source, Swedish Heat Pump Association).

Sweden tops the statistics in Europe for heat pumps intended primarily for heating. The Swedish Energy Agency ran a technology procurement project for heat pumps in 1995, since then sales have risen steadily, both for new buildings and for existing buildings, see figure 4. Over 90 % of new houses incorporate an exhaust air heat pump in combination with floor heating. In existing buildings, it is primarily vertical ground source heat pumps that are installed. There has also been a noticeable increase in the sales of air/air heat pumps in Sweden, which can be explained by the fact that there are many buildings without hydronic heating systems, and which are therefore considerably more difficult to convert from direct electric heating. Sales of these heat pumps are reported to be running at about 40 000 units per year (IEA Heat Pump Centre Newsletter, No 1/2005). The heat pump sales has risen tenfold in Finland during the last five years from about 700 units 1998 to about 3500 units 2002 (Hirvonen 2003). The sales of ground source heat pumps and air/air heat pumps stand for the largest share of the market.

In central Europe, where heat pumps are usually connected to a hydronic heating system, growth has been of the order of 10 % per annum. Switzerland is another long-established European market, with electrically driven heat pumps having a 46 % share of heating systems in new single-family houses, and thus the market leader in heating systems in low-energy houses in the country. The commonest type of heat pump is the air/water heat pump (52 %), closely followed by brine/water systems at 43 %. (Wemhöner 2003) reports that sales have increased from 2260 units 1992, to 5225 units 1997 to 7554 units 2002. This is an annual increase of about 5 % the last years. At present, although heat pumps are most commonly installed in new builds, the market for retrofit installations is considerably greater, not only in Switzerland but also in the rest of Europe. The Swiss Federal Office has therefore started a research project to develop heat pumps intended for retrofit applications (Interim report IEA HPP Annex 28, 2004).

The heat pump market in Austria grew steadily until 1987, at which time the sales of heat pumps for domestic hot water production dominated (National report, IEA HPP, Annex 28, Austria, 2004). However, the market has declined since 1988 due to increased competition from solar heating. Nevertheless, the market for heat pumps for space heating has been growing for the last ten years, with ground source heat pumps accounting for about 80 % of sales (and about 40 % of the ground source systems are DX systems). Sales are increasing on the German market, too, mainly of air/water heat pumps (which increased by over 30 % from 2002 to 2003) and of ground-source heat pumps (+3 % from 2002 to 2003) (National report, IEA HPP, Annex 28, Germany, 2004). Sales in Germany have risen since 1996: see Figure 5.

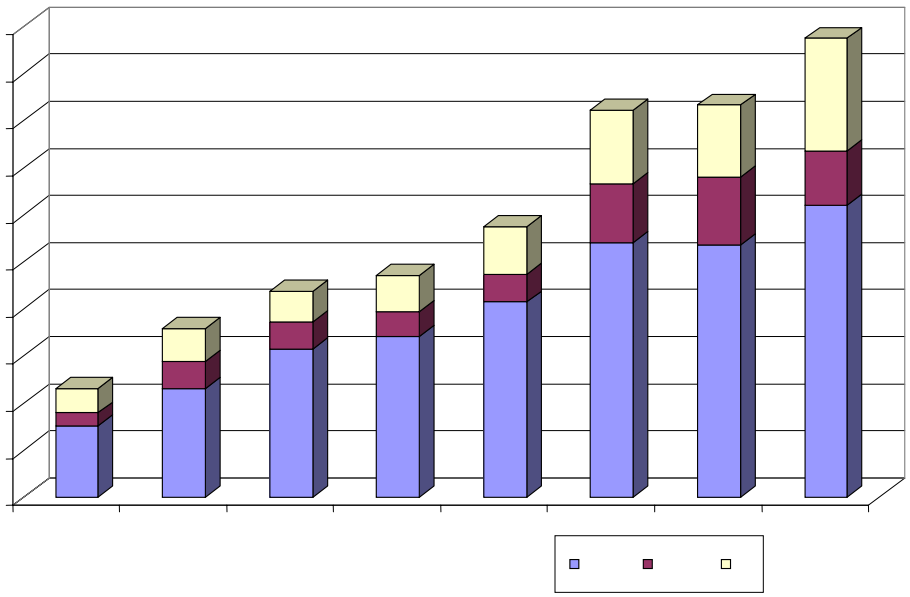


Fig. 5. Statistics for Germany, source BWP e.V.

The UK is a relatively small market, with sales of only about 500 reversible air/air heat pumps in 2002 (National report, UK, IEA HPP, Annex 28, 2004). (Hitchins, 2004), notes that it is clear that the technical potential is predominantly in housing, although the existing market is overwhelmingly in commercial buildings. Only a very small proportion of this potential is being tapped. The principal market barriers are cost-efficiency and purchaser confidence – itself reflecting the absence of an established, well-regulated supply and installation structure. Many potential purchasers are wary of the technology, having memories of inadequate systems installed in the 1970s. The cost-efficiency gap is generally smaller than for some other high-profile low-carbon and renewable alternatives, but nevertheless real, especially in competition with fossil fuel heating. The ground source heat pump industry believes that the potential market is large. However, there are two key market barriers:

- Capital costs are high, but not impossibly so. The high-cost item is the ground loop, typically representing 35 %-40 % of the total cost. UK costs appear to be higher than those overseas, so increasing market size and the consequent more efficient use of resources and increasing skill levels could lead to cost reductions.
- Consumer barriers: unfamiliar technology, uncertainty about continuing maintenance and service availability. Successful (but relatively costly) ways of reducing these barriers have been demonstrated in other countries, but the relatively small companies currently trying to develop the UK market do not have the resources to set up support infrastructure on a comparable scale.

The market for commercial buildings, on the other hand, is established, with annual sales of about 70 000 units per year. Small reversible air/air heat pumps make up the greater proportion of these sales.

2.7 Legislation and Directives that Can Affect Future Heat Pump Development

Proposal for an European Parliament and Council regulation in certain fluorinated greenhouse gases (e.g. HFC refrigerants) (The Cabinet Office and the Ministries, PM on Fluorinated Greenhouse Gases, 2004/05:FPM) was announced in 2001 as part of the European Climate Change Programme, and is one of the proposals from this programme that has been presented by the Commission and is intended for common application throughout the EU. It has been under discussion by the Environmental Working Party throughout 2004 and if the member states reach an agreement at the second reading in 2005 the regulation will come into force during 2007. During the process, the member states have agreed to transfer requirements relating to the use of fluorinated greenhouse gases in vehicle air conditioning

systems to a special directive linked to type approval of vehicles. The ordinance (proposal?) covers the handling, supply and use of the fluorinated greenhouse gases specified in the Kyoto Protocol, as well as certain reporting requirements relating to these aspects. In addition to requirements and guidelines for the use of fluorinated greenhouse gases, the Ordinance (proposal) also includes requirements aimed at reducing the risk of leakage of these gases in use. This will involve regular inspection of plants, requirements relating to installation of leak-tracing equipment and the keeping of records.

The Directive EC/2002/91 of the European Parliament and the European Council on the Energy Performance of Buildings was published in December 2002. The objective is to promote improvement of the energy performance of buildings within the European Community, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost efficiency. Incorporation of the Directive into national law is required by January 2006, although member states have some flexibility concerning the exact manner in which it is to be implemented. Full application of the requirements for boiler inspection, air conditioning system inspection and building certification must not be delayed beyond January 2009. The Directive aims to reduce the use of energy in new and renovated buildings, excluding industrial buildings.

Discussions will take place in connection with implementation of the Directive concerning energy efficiency improvement measures in European countries. The intention is to arrive at minimum requirements for the energy performance of new buildings and that of renovated buildings. This will result in general design methods for determining the overall use of energy in residential buildings. The Directive will also include certification schemes for new and existing buildings, together with requirements relating to recurrent inspection of boilers and heating/cooling installations (EECAC 2003).

The European Commission has also developed a draft proposal for a new Directive 'Eco-design of End-Use Equipment' (to be adopted) which, amongst other measures, would give the Commission the right to establish mandatory minimum energy performance standards for end-use equipment. The annex of the directive stipulates that the level of energy efficiency used in the standard will aim to minimise life cycle cost for end users, on the basis of a real rate of interest of 5 % and with realistic assumptions of product lifetimes (EECAC 2003).

3 DISCUSSION

In general, statistics show that sales of, and interest in, heat pumps is increasing in Europe, which is satisfying. Some countries, such as Norway, Sweden and France, have experienced particularly substantial sales growth in recent years. However, if such surges are to be maintained, experience shows that it is important that the systems are successful so that customers are pleased, and that the technology is economically competitive. The European Heat Pump Association expresses this as follows (Bach 2004): "To ensure a sustainable market growth of heat pumping technologies, we will focus strongly on common quality aspects and standardisation on a European scale. Quality labels and their European standardisation are of interest to both producers and users."

In the longer term, the proposal for an European Parliament and Council regulation in certain fluorinated greenhouse gases (e.g. HFC refrigerants) will mean that all countries in the EU will require installations to be regularly inspected. At European level, this can be expected to lead to improved knowledge of how present-day plants are working, which can result in development work to improve operation and maintenance of installed plant.

The phase out scheme for refrigerants in EU will also influence market and development for heat pumps in Europe. Natural refrigerants like propane have mostly been used in Germany and Sweden. Heat pumps with CO_2 as refrigerant was introduced on the Japanese market 2001. During 2005, heat pumps for combined heating and domestic hot water production with CO2 as refrigerant will be introduced on the European market.

In general, most of the market growth for heat pumps is for use in new buildings with hydronic low-temperature heating systems. However, the major potential market is in existing building stock with high-temperature hydronic heating systems: unfortunately, the high temperature of operation is a technical obstacle to large-scale use of individual heat pumps. An explanation for the substantial retrofit market in Sweden is that these heat pumps are intended and designed to cover about 60-70 % of the power demand, which in turn represents about 80-95 % of the annual energy demand. A further contributory factor is that older hydronic heating systems often have oversized radiators, so that they will still maintain comfortable indoor conditions even with a lower water supply temperature. Examples of other countries with good retrofit growth include Estonia and Latvia.

Austria, Sweden and Switzerland are defined by the EHPA as mature markets, a common feature of which is that various types of national incentives have been used to advance the technology. The Swiss government started a programme entitled 'Energy 2000' in 1993, with the aim of reducing the country's use of fossil fuels through greater use of heat pumps. New research projects were started, to increase the number of heat pumps in the country's existing building stock. Sweden conducted a technology procurement project for heat pumps to encourage development of efficient, economically competitive heat pumps. Sales of ground source heat pumps have increased steadily since 1995. In parallel with this, Sweden has been running a national research programme for heat pumping technology, which shows that effort put into R&D can have beneficial effects on the market.

The energy directive for buildings will most likely increase interest in energy efficiency improvement measures, which should favour heat pump technology. Switzerland, Germany, Sweden and Austria are already working on various types of heat pump systems intended for use in low-energy buildings. However, heat losses from computers, office equipment etc. and occupants in commercial buildings, from domestic electrical equipment and occupants in residential buildings, mean that cooling will be more common in the future. A study of the European air conditioning market reports that it is expected to double in size from 2000 to 2010, with about 25 % of the units being of reversible type. The results from the study show that there is considerable room for improvement in all types of systems. Reversible systems need to be further developed to make them competitive with separate systems for air conditioning and heating (EECAC 2003).

With improved insulation and heating systems, energy demand from new homes in Netherlands is steadily falling, although the demand for cooling in the domestic environment is increasing. The decreasing demand for heat makes it very expensive to provide the infrastructure for gas supply on new buildings sites, which means that there is a market for electrically driven heat pumps in new houses (National Position Papers HPC-AR7). (Kleefkens 2005) reports that great opportunities are seen in the retrofit market and the next two years at least 10.000 houses will be renovated in the Netherlands with gas driven heat pump-systems (mainly). In Norway, it is expected that the Energy Directive will increase the competitiveness of ground source heat pump systems for energy-efficient heating and cooling in non-residential buildings. There is also growing interest in small-scale and large-scale district heating (and cooling) systems. These factors facilitate the installation of ground source heat pump systems. (Stene, 2004). It is a large interest for ground source heat pumps in Europe. The ground can be used both as a heat sink and heat source (heating/cooling). In order to improve the technology and the competitiveness it is important to overcome technical and economical barriers like legislation, improve the design of the systems and develop improved technology for energy dwells. Ground source heat pumps have been identified as an important topic and work is in progress in an international research project (IEA Annex 29) within the IEA Heat Pump Programme to overcome technical and economical barriers.

As far as industrial applications are concerned, it is clear that there are many where the use of heat pumps would save energy, but there is a need for better awareness at system design level, both of the processes themselves and of possible ways of incorporating heat pump technology that suit each particular process (Industrial Heat Pumps, 1995).

Although the existing building stock is the market with the greatest potential for heat pump technology today, it is also the market with the greatest obstacles. The UK, Sweden and Norway have a

high proportion of properties without central heating systems, which makes it difficult to distribute heat from heat pumps. However, in many countries - such as Germany, Austria, Switzerland etc. - it is problems with hydronic heating systems designed for high temperatures that are cited as the main obstacle. One conclusion is that it will become increasingly important for heat pump manufacturers to develop economically and technically competitive systems that provide everything needed in a single package - everything from heat source, through the heat pump itself to the heat delivery system. Awareness and familiarisation, quality assurance of the entire chain of the heat pump, its ancillary systems and installation, coupled with continued research and development, are the bases for continued positive market development.

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