GROUND-COUPLED HEAT PUMP MARKET AND PROSPECTS IN EUROPE

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1 ABSTRACT

Europe is the most developed part of the world for ground coupled heat pumps. This paper will give a background to the use of these heat pumps, the actual market situation and a forecast for the next few years. It will also summarise some technical data for the products in use.

2 HEAT PUMPS IN A GLOBAL PERSPECTIVE

If one takes into account *all* heat pumps sold in the world, the list of the five top countries would be

- Japan
- China
- USA
- Italy
- Spain

Most of these heat pumps are of the type air/air, and not considered as a subject for this presentation, that will concentrate on ground-coupled heat pumps (GCHP). With that restriction, Europe is the most developed part of the world.

Please note that from this point on, the term heat pump always refers to ground coupled heat pumps (GCHP) unless otherwise stated.

All temperatures in this paper will be in Centigrade (°C).

3 EUROPE

The second smallest continent (Australia is the smallest), Europe has an area of about 10.6 million km^2, about 7% of the earth. It has the second-largest population of all the continents, about 730 millions. Europe is divided into 36 different countries, see figure 1. There is a very big variation between these countries in languages, political systems, economy and climate. The climate varies between arctic conditions along Barents Sea to subtropical conditions along the Mediterranean.

Fifteen of the European countries have formed the European Union (Portugal, Spain, France, Ireland, Germany, Belgium, Netherlands, Luxembourg, United Kingdom, Sweden, Finland, Denmark, Austria, Italy, Greece). This union might in the end lead to something like the 'United States of Europe', but as of today the influence upon the individual countries is fairly weak.

Although the European Union do issue papers on energy savings etc, it is still very much up to the different countries to take what action they want.

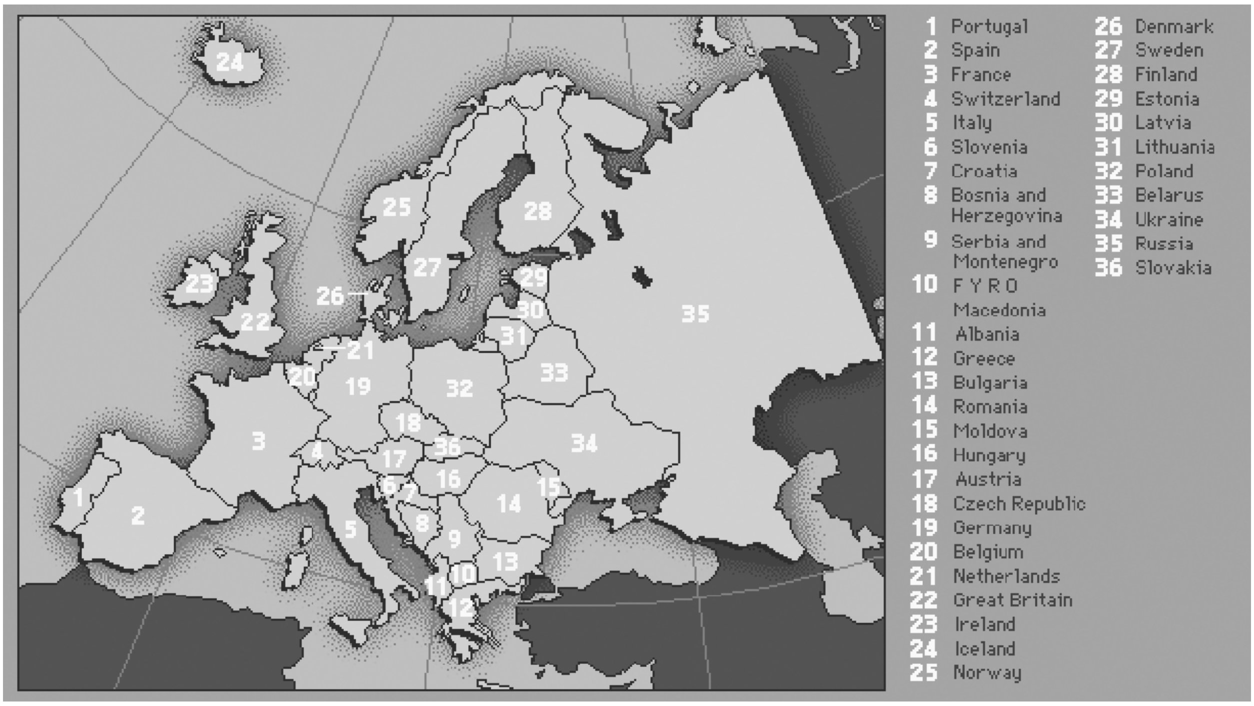

Figure 1. The European countries

The top nine countries ranked after number of inhabitants are listed below, with number of inhabitants in millions. It must be noted that of these countries only Germany and France have any sale of heat pumps worth mentioning.

Table 1. The top nine European countries ranked after inhabitants

Country	*Inh*	*Country*	*Inh*	*Country*	*Inh*
Russia	147	Italy	57	Spain	39
Germany	79	France	56	Poland	38
Great Britain	57	Ukraine	51	Romania	23

4 BACKGROUND TO THE USE OF HEAT PUMPS IN EUROPE

The introduction of heat pumps in USA and Asia was the relative simple process of developing air-to-air cooling units into air-to-air heating units. By use of a four-way valve these two features could easily be combined into a unit, simple to operate and install.

In Europe, air-to-air units were very seldom used. Heating was via fossil-fuelled boilers with hydronic heat distribution. This lead to the design of heat pumps for integration in a hydronic system. The heat pump is then a part of complex system.

In the mid 80's, due to government subsidies, a number of European countries started heat pump manufacturing and installation. However, very few companies had an 'overall knowledge'. Actors on this scene were mostly

- Refrigeration experts without knowledge of hydronic heat distribution
- Installers with good knowledge of hydronic heat distribution, but very little knowledge of heat pump dimensioning and installing.

After a few years of very rapid increase in sales, the market was flooded with unreliable products, incorrectly installed, without the promised cost reduction. This lead to a market break down in the end of the 80's. During this time the heat pump had got a bad reputation.

Only a few companies survived this break down. Even today, most manufacturers of heat pumps are just departments of companies making other heat sources, like oil burners or gas burners.

IVT Industrier in Sweden is the biggest manufacturer of GCHP's in Europe. They work only with heat pumps, and have a turn around of some 50 million USD. On an international scale this is of course a small company.

5 ENERGY CONSUMPTION

One of the driving forces for governments to enhance the use of heat pumps is energy saving and lowering emissions of for example CO_2 and CH_4. However, the energy consumption growth in Europe has been considerably lower than in Asia and North America [1]. This is illustrated in the diagram below.

Although this diagram could lead to the conclusion that European countries are less interested in energy saving, this is not the case. There are a number of reasons why energy saving is still a subject, like

- Many countries want to close down or restrict the use of nuclear power.
- Further development of hydropower is difficult since powerful groups oppose to using still untamed rivers and water falls.
- Many countries using gas have faced a fairly steep increase in gas prices.
- Very little oil is produced in Europe.

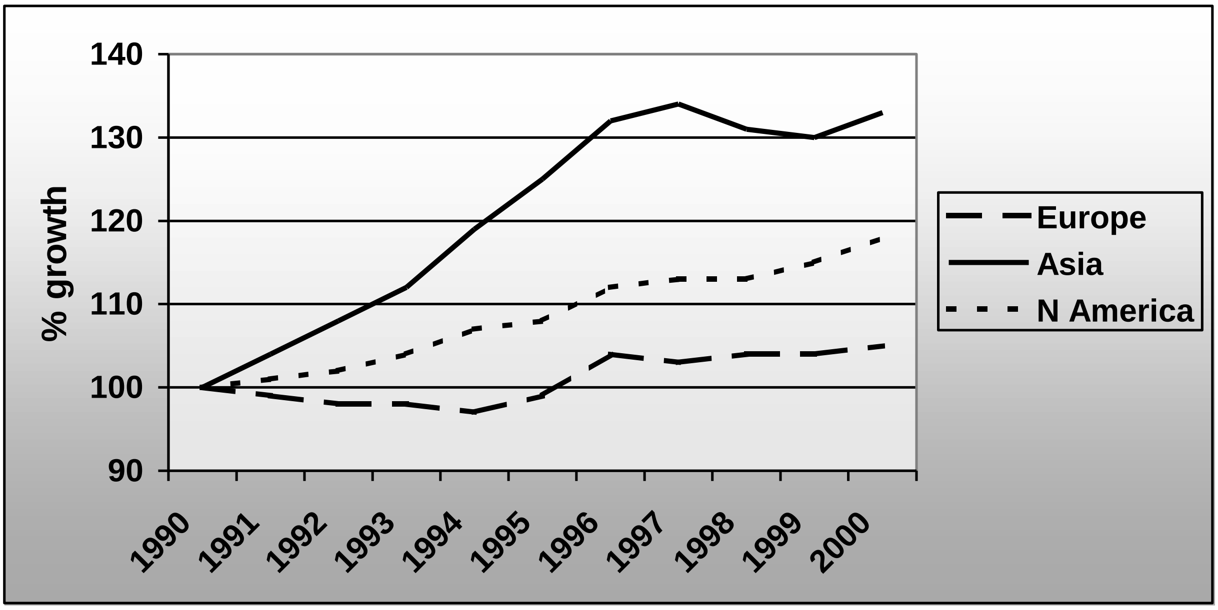

Figure 2. Energy growth since 1990

6 PRICE RELATION ELECTRICITY/OTHER FUELS

The driving force for customers to buy a heat pump is to a large degree economical reason. For some European countries the environmental aspect is important, for other countries subsidiaries play an important role. However, the basic factor is still the economy for the end customer.

The heat pump use electricity as energy. If we assume that the electricity in a given country costs 3 units and oil costs 1 unit, then a heat pump with a COP (Coefficient Of Performance, see page 371) of 3 would give the heat pump customer the same cost for heating as another house with oil heating.

However, since the heat pump customer must pay a larger investment, it would in fact be a fairly bad business to buy a heat pump in this case. The heat pump will need a higher COP in order to pay the higher investment.

In Europe, the price difference between electricity and other fuels are not quite as dramatic as in the example above, but for most countries electricity is more expensive that other energies, calculated as cost per kWh.

As some very general rule for Europe it can be stated that

- the cost of oil is about 50-70% of electricity
- the cost of gas is about 30-60% of electricity

It can be noted that for the Scandinavian countries, gas is not very much used, and oil is normally more expensive than electricity. This fact is of course an important part of the background to the widespread use of heat pumps in Scandinavia. There is also a tendency all over Europe to increase oil prices. One reason is of course to reduce the use of fossil energy, another to restrict the costly import of oil.

7 USAGE OF HEAT PUMPS IN GENERAL

For Europe in general, heat pumps are used almost only for new houses, often combined with a floor heating system. With a floor heating system the performance of a heat pump is of course very good. One reason for this limitation to new houses is that existing houses often are designed for a radiator temperature of 80-90 °C, which is too high for heat pumps.

For Scandinavia, and in particular for Sweden, the retrofit market is much bigger than that of new houses. Roughly 90% of the heat pumps installed in Sweden is a replacement for another heating system. It should be noted that in Sweden some 70% of all replacements of heating system is the installation of a heat pump.

For the European market in general, the heat pump is also used for heating of hot water. Many manufacturers deliver complete units with heat pump and boiler in one unit.

8 USAGE OF HEAT PUMP TECHNOLOGIES

Although a heat pump can be made using many different thermodynamic cycles, the use of vapour compression cycle is used for practically all heat pumps in Europe. The most common compressor type is the scroll or piston compressor. Due to global restrictions on refrigerants, most producers are now using environmental friendly refrigerants like R407C, R134a or similar.

In some countries heat pumps are connected to a 3-phase system, but in many countries only single-phase is available for installation in single family houses.

The vast majority of GCHP use a brine or water system on the cold side, although system with direct expansion on the cold side is available from some manufacturers. (Direct expansion is a geothermal heat pump system whereby the liquid refrigerant is sent directly out into copper coils buried in the ground where it is vaporised or condensed by contact with the earth).

In Austria systems with direct expansion is in fact more common than brine systems.

9 USAGE OF DIFFERENT COLLECTORS

9.1 Rock

The use of vertical collectors is widely used in more matured markets like Scandinavia and Switzerland. The reason for this is that it takes time to build up drilling capacity for heat pumps, and investors are not willing to invest until they can see a market.

Typical drilling depths are 70-200 meters, with diameter around 125 mm. It is often sufficient with one hole for single family houses. For larger heat pumps a number of bore holes are used. These bore holes are separated by some 10-15 meters.

In Scandinavia these bore holes are not filled after drilling. They relay on water for thermal coupling. In the winter the water will freeze to ice. Since ice has a better thermal coupling than water, more energy can be taken out of the rock in winter.

Figure 3.Collectors in rock, earth, lake and open system

In other parts of Europe bore holes are often filled with Bentonite. One reason is that it will prevent leakage of ground water from higher levels (that can be polluted) to lower levels (with clean water). The method is also of value when drilling in 'unstable rock', i.e. rock with tendencies to break apart.

In most Scandinavian installation two hoses, diameter 40 mm, is used. Some parts of Europe use four hoses, usually with a smaller diameter (32 mm).

9.2 Ground

Horizontal collectors are used to some extent in Scandinavia and widely used in Europe. This is especially true for countries with a small heat pump market. The reason is of course that it is comparatively easier to find capacity for digging than for drilling.

The typical ground collector in Scandinavia is one single tube at a depth of 1 meter. Separation between tubes is 1 meter as indicated in the picture above. The tube has a diameter of 40 mm. Many companies have also designed digging machines especially for this, see picture 4. These machines will 'plough' a ditch and lay down the tube in one single operation. For a single family house a typical length is 350-400 meters.

Figure 4. Machine for ploughing and tube placing in one operation

In other parts of Europe other methods are used like a grid of thinner tubes, parallel connection, grids of tubes at different depths etc. Electricité de France, EdF [2], has published a good summary of techniques used in Central Europe [3].

9.3 Sea/Lake

For countries with many lakes, like Scandinavia, it is often possible to place the collector at the bottom of a lake. The collector must be held down with weights, evenly distributed over the collector. One example of such an installation is the Swedish King's Castle at Drottningholm. In this case the heat pumps have a heating capacity of 300 kW, and the length of the collector is 7200 meters. The collectors are placed just outside the Castle in Lake Mälaren.

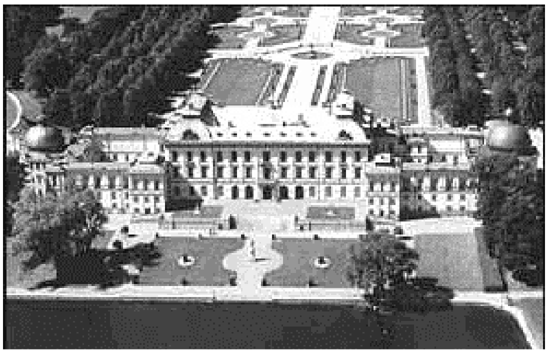

Figure 5.Drottningholm Castle

Although a simple way to place the collector, it must be protected from damages from anchors etc.

9.4 Open systems

In these systems water is taken from one well to a heat exchanger and then disposed of in another well. The water used can be ground water or industrial wastewater. Although not very common, the system is used in most European countries.

9.5 Combined systems

In Scandinavia, a new type of heat pump has recently been launched. It is an exhaust air heat pump, combined with a ground source heat pump. The background is that the amount of energy from exhaust air is limited to some 1.5 – 2 kW, which of course is insufficient for any house. Combined with a ground source this heat pump will give some 4 – 5 kW, which is much closer to the need of a modern, low energy house.

10 DIMENSIONING OF HEAT PUMPS

When dimensioning a heat pump a crucial figure is the peak power of the house. In verbal form the peak power can be expressed as 'how many kW is needed for the heat source on the coldest day of the year with sustained indoor temperature'. The real extremes are never used, but modified to something like 'accepting that some 3-5 days per year the power is not quite enough'.

With this verbal definition of P_{peak}, there are some differences in dimensioning. In Scandinavia, it is common to use a heat pump with a heating capacity of around 0.5 * P_{peak}. The reason is of course that a smaller heat pump is cheaper to install and Scandinavia has very good supply of electrical energy. A heat pump with a heating capacity of 0.5 * P_{peak} will supply some 90-92% of all energy needed. For the remaining 8-10% Scandinavians are using electrical heaters built into the heat pump. This will of course imply that the electrical heater must also have a power of about 0.5*P_{peak}. For a heat pump with a heating capacity of say 12 kW, the electrical heater must also be in the range of 12 kW. For Scandinavia this is not a problem. The electrical distribution companies accept this, and the total cost for the customer is lower than with a bigger heat pump.

However, in other countries, like Switzerland, it is not at all accepted. The distribution companies do in fact not allow any electrical heater at all for normal function. They usually allow an electrical heater of around 3-5 kW for 'emergency use only'. So, for many countries heating capacities much closer to P_{peak} is chosen.

11 COP

COP, Coefficient of Performance, is defined as 'how many kW output for one kW input power'. A heat pump with a COP of 3 will give 3 kW output for 1 kW input of electrical power. The remaining two kW's are of course taken from the ground.

It is easy to see that a high COP is advantageous, since it will give more 'free energy'. The COP-value of a specific heat pump is often taken as some kind of quality label, and many heat pump manufacturers are using their COP-values as an important argument in advertising etc. Although it is quite clear that high COP is needed for best savings, it is important to be aware of some pitfalls:

- There are more than one definition of how to measure COP. It is not easy for an end customer or an installer to understand how COP is measured.
- The important figure is of course the performance of the hydronic system. A reduction of the temperature in the hydronic system with a few degrees will improve the performance significantly. As a general rule of thumb it can be said that for every ºC reduction of the temperature in the heating system you will gain a corresponding COP of 3%. So, a reduction of 10 ºC is 'worth' 30% in COP.

In Europe, and particularly in the less developed markets for heat pumps, there is usually a very high concentration on COP values, with different manufacturers comparing decimals in their respective COP's and debating different methods of measurement. As a result, there is a number of test institutes over Europe for heat pump testing. One of the best known is Wärmepumpen-Testzentrum, situated in Töss in Switzerland. They publish all tests they have done [4].

To give an indication of COP values for current products, the diagram below gives mean values of COP. The data is taken from all testing at Töss with heat pumps with an output power of 6-8 kW. Although testing is done in a laboratory, they reflect the data one will get in a real installation.

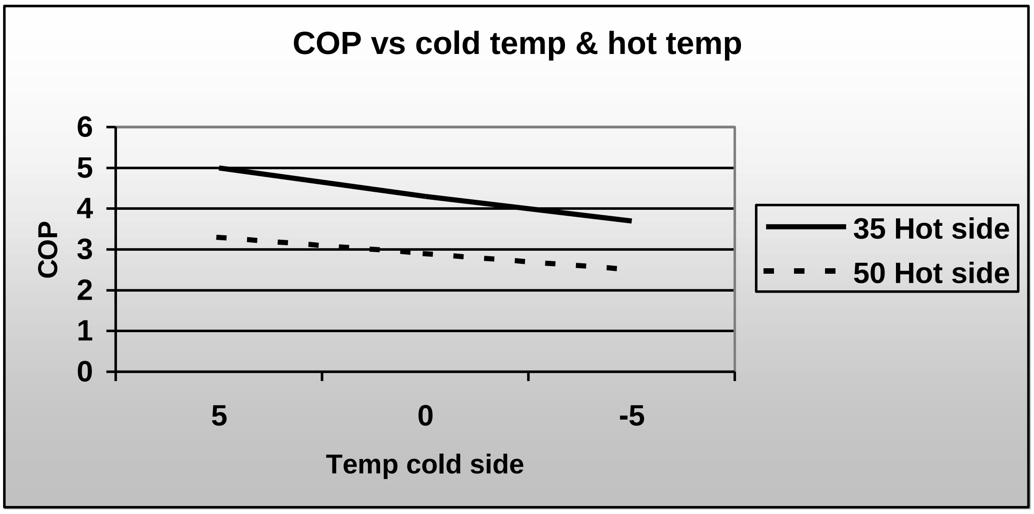

Figure 6. COP vs temp at cold and hot side

12 NATURAL COOLING

As a spin-off to the heat pump installation it is possible to implement comfort cooling to a very attractive price. Natural cooling can be described as a process whereby cold brine liquid is pumped directly, using a small pump, to an air coil so that cooling and dehumidification are provided without the operation of a compressor driven refrigeration system. The system should include a control unit capable of adjusting settings relative actual humidity and temperature.

The brine liquid will of course have an increased temperature after the air coil, and will be cooled down in the well. For vertical collectors the temperature from the bore hole is usually low enough. The cooling capacity is usually in the order of 20-30 W/m. One advantage is of course that the bore hole is reloaded with (some of) the energy taken away in heating mode.

For horizontal collectors the ground temperature is normally sufficient low in Scandinavia, but usually too high in most parts of Europe to give sufficient cooling during hot days. In these parts it is possible to use a heat pump with a 4-way-valve for reverse operation. For cold days the heat pump works in heating mode. When there is a need for cooling the system will start with Natural Cooling. When there is a bigger need for cooling the heat pump will work in the reverse mode.

13 ACTUAL MARKETS FOR GCHP

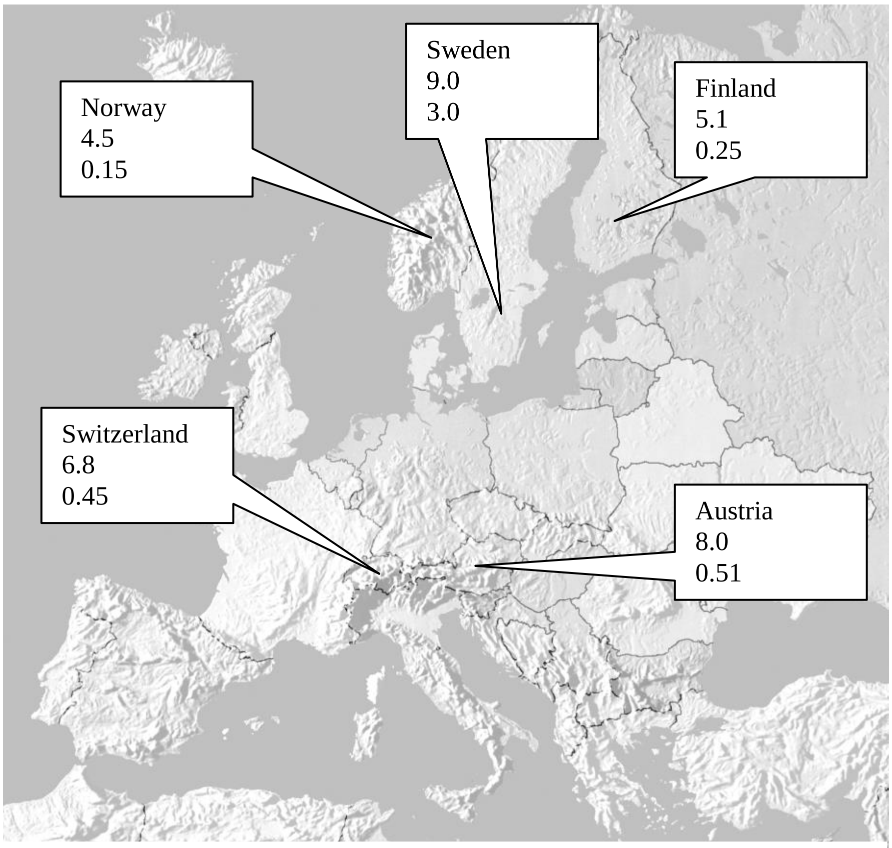

Figure 7. Countries in Europe with > 0.1 GCHP/1000 inh

Few countries in Europe have in fact any significant sale of heat pumps (GCHP). In the map the first figure is the number of inhabitants in million. The second figure is the number of ground-coupled heat pumps sold per 1000 inhabitants per year.

As an example Sweden has a yearly sale of 3 * 9000 = 27 000 ground coupled heat pumps per year.

For counties not specified in the map the sale is less than 0.1 heat pumps per 1000 inhabitants per year.

Apart from these more ‘matured’ countries there is however some sale in other countries. The table below is listing twelve countries with some market for GCHP. In this table:

- Column ‘Inh’ is inhabitants in millions.
- Column ‘Sales 2001’ is estimated sale of GCHP in year 2001.
- Column ‘Est growth’ is the estimated yearly growth of the market in that country for the next 3-5 years.

Table 2. Countries with GCHP sales with actual sales and forecast

Country	*Inh*	*Sales 2001*	*Est growth %*	*Comments*
Sweden	9	27 000	6	Mature market, 90% existing houses
Austria	8	4800	8	Majority is direct expansion HP’s
Germany	80	3600	20	New laws for energy consumption can increase market
Switzerland	7	2800	6	Mature market, mainly new houses
Finland	5	1250	10	

Country	*Inh*	*Sales 2001*	*Est growth %*	*Comments*
France	58	850	10	
Norway	5	650	10	
Poland	39	500	5	Still weak economy
Netherlands	15	400	>25	Strong government interest, only open systems
Czech Republic	11	350	25	Still weak economy
UK	58	150	>100	Very low public awareness of heat pumps
Denmark	5	150	>100	Very rapid growth in the last years

14 THREATS AND OPPORTUNITIES

One of the great threats to the heat pumps is a repetition of the events in the 80's, i.e. a number of installers and manufacturers not aware of the need for thorough knowledge of hydronic heat distribution. However, in some respects the situation today is better than in the 80's.

First: In a number of countries organisations have been formed with the aim of helping users, installer and manufacturers. They also set guidelines for efficiency etc. Examples of such organisations are

- European Heat Pump Association (EHPA), formed in 2000 [5]
- DACH, an organisation formed with members from Germany, Austria and Switzerland
- IEA Heat Pump Programme, formed 1978 [6]

Second: The product heat pump of today is much more a complete unit from factory. Whilst the installer of the 80's often had to build some parts of the heat pump on site and often choose and install a control unit the heat pump now is a complete and fully tested unit with control unit integrated. This will certainly make installations safer and better.

Third: Many of the bigger manufacturers have developed software programs for dimensioning of heat pumps. This will certainly give better installations, since these software programs takes the hydronic heat system into account.

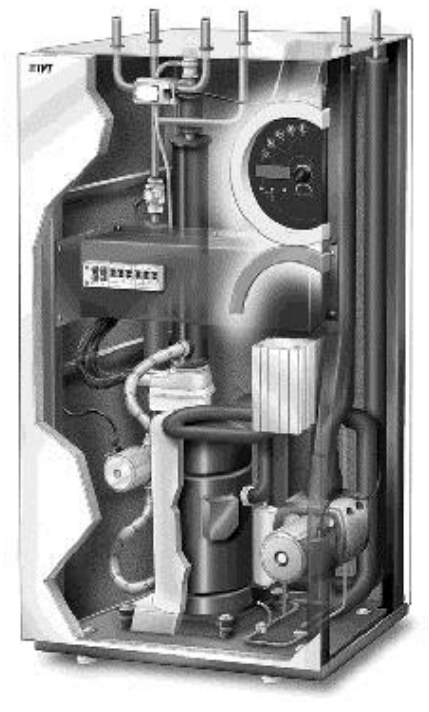

Figure 8. Modern, complete GCHP

15 CONCLUSIONS

- The European market for GCHP's is a very diversified market with a total sale in 2001 of about 41 000 units. Out of these 27 000 are sold in Sweden.
- Except for Sweden (and to some degree the rest of Scandinavia) the heat pump is today only taken into consideration for new houses.
- The low market penetration in Europe is a mainly a result of the bad systems and products delivered and installed in the 80's.
- A large number of different techniques are used for the system on the cold side, electrical connection, additional power etc.
- The future for the heat pump in Europe is to a large extent depending upon governmental actions, such as subsidiaries for heat pumps, price relation between electricity and other energy sources.
- A real break through would be if the heat pump were commonly accepted for replacement in existing houses, like it is in Sweden. This must include solutions for replacement in existing houses with a high-temperature hydronic heat system. To make this possible there must be radiators for (cheap) replacement to low temperature systems, systems with fan coils etc.

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