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IEA Heat Pump Centre

# NEWSLETTER



**Residential Heat Pumps**



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OECD

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## Residential Heat Pumps

There are many ways to use heat pumps in the home. The choice of system must take account of the building design and the available heat source. The challenge is to market equipment that can conveniently meet the heating and cooling needs of the user, with good reliability and at an affordable price. In this issue, a number of residential heat pump options are presented and discussed.



**Front cover:** Direct-evaporation ground-source heat pumps such as this are used in increasing numbers in Austrian homes. The article on page 35 shows how advances in building design can further improve the heating efficiency.

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*Bert Stuij, IEA Heat Pump Centre*  
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*Hermann Halozan, Austria*  
The low energy requirements of new homes could be further reduced by using heat pumps. But the full benefits will only be realized with low-temperature heat distribution systems.

## Non-Topical Articles

### Heat Pump Development ..... 38 Trends in Japan

*Jos Bouma, IEA Heat Pump Centre*  
Development work in Japan is wide ranging. From the latest innovations in residential equipment, to ambitious programmes for large-scale heat recovery, the pace of progress is impressive.

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# Promoting Renewable Energy for the Home



The Swiss Energy 2000 programme calls for 3% space heating requirements to be met from renewable energy sources by the year 2000. In the case of heat pumps, this means that 100,000 units will have to be installed in Swiss homes by the end of this decade. At present, some 43,000 heat pumps are in use.

At the Swiss Association for the Promotion of Heat Pumps (FWA), we have set ourselves the task of winning many more satisfied heat pump installation users in Swiss homes. They should have the opportunity of spending a cold winter day in their warm house, not only in comfort, but also in the knowledge that they are

contributing towards benefiting the environment, for example by helping to improve local air quality.

Thanks to our efforts, some 30% more heat pumps were installed in 1994 than in the previous year, despite the current recession. Nowadays, one in four newly constructed private houses is heated with a heat pump system. We are also trying hard to gain a foothold in the retrofit market.

Since July of this year, government subsidies are no longer available for heat pump installations. Instead of subsidies, we are seeking to reduce the cost of heat pump systems by improving the preconditions at several levels. For example, manufacturers could optimize the way heat pump components are purchased.

Customers requirements must always be at the forefront. That is why we want comparable services for estimates and consultations, and electricity supply companies must take on the responsibility of guaranteeing to support their customers. In addition, the cantonal authorities must simplify application procedures for ground-source heat pump installations.

Our goal is to compete successfully with other heating systems on the open market within the next five years. The progress so far shows how private companies, electricity companies and the authorities can work together to achieve a positive development in the field of renewable energy.

Gabi Brugger-Mariani, President of the Swiss Association for the Promotion of Heat Pumps (FWS)

# News & Views

## Industries to work together on IHPs

**The Netherlands** - The newly formulated Dutch heat pump programme, which was announced at the beginning of this year (see *IEA Heat Pump Centre Newsletter* March 1995), got off to a flying start with a workshop held on 12 May in Leuvenum. At this workshop, a number of industrial companies agreed to work together to support the market for industrial heat pumps (IHPs).

*The logo of the Dutch heat pump programme.*



Some 65 industrial experts met to consider how the market penetration of IHPs could be increased in the Netherlands. During the morning, presentations were given on a number of studies including that of Annex 21 of the IEA Heat Pump Programme.

In the afternoon, the floor was open for a discussion on the major market barriers and on how to overcome them. It was interesting to hear the marked difference in the perception of IHPs between those who are using them and those who are not.

Those not familiar with IHPs were fearful of corrosion, poor reliability and the need for an expensive back-up system. However, several representatives of large companies, which have been using IHPs for over twelve years, were able to dispel these fears by reporting that their heat pumps have been completely satisfactory without any problems. Another large company, Shell, showed that investment in a new plant with a heat pump can make very good economic sense, offering a payback period of less than two years.

In general, the major barrier to installing an IHP was considered to be a lack of application experience rather than the availability of good technology. Industries have little experience in

applying techniques such as process integration which are essential if a successful IHP installation is to be realized. An electricity to gas price ratio of four to five was also highlighted as an IHP market barrier. CHP (combined heat and power) equipment was highlighted as a major competitor to IHPs.

The discussions established the need for a forum for exchanging knowledge on IHPs among industries. At the workshop the represented companies agreed to work together on IHPs by setting up small working groups for exchanging knowledge and experiences. Some working groups will bring experts together from the same industry sector – a working group for the chemical sector is already active. Other groups will focus on specific technical fields such as reducing ground water use, process integration and environmental factors. Novem (the Netherlands Agency for Energy and the Environment), who are managing the Dutch heat pump programme, have agreed to coordinate these activities. As well as IHPs, the programme is also supporting the use of heat pumps in buildings. Developments in this field are expected soon. Figure 1 illustrates the logo of the Dutch heat pump programme.

*(Source: Onno Kleefkens, Dutch National Team)*

## 'Energy Star' plan promotes heat pumps

**USA** - The Environmental Protection Agency (EPA), a government agency, has introduced a new programme to promote energy-efficient residential space conditioning equipment. Under the "Energy Star Heat Pump and Air Conditioner Program", manufacturers are allowed to use EPA's "Energy Star" logo on their products as a mark of energy efficiency.

The logo can only be used on air conditioning products with a minimum

US rating of 12.0 SEER (equivalent to a cooling seasonal performance factor of 3.5) and heat pumps rated at 7.0 HSPF (equivalent to a heating seasonal performance factor of 2.1).

Boilers with a 90% efficiency or better also qualify under a similar scheme. The scheme applies to both electrically driven and gas-fired heat pumps.

An EPA proposal that qualifying products have a certain warranty period was

rejected when manufacturer organizations said the government shouldn't be in the business of setting warranties. EPA's Energy Star program was first introduced in 1992 to support energy efficiency in personal computers.

*(Source: The Air Conditioning, Heating and Refrigeration News, May 29, 1995 and Koldfax from the Air-Conditioning and Refrigeration Institute, April 1995)*

## Founding member of Greenpeace joins WaterFurnace

USA - Patrick Moore, PhD, a founding member and former director of Greenpeace International, has joined the board of directors of ground-source heat pump manufacturer WaterFurnace. Such a move can be interpreted as a stamp of approval for the environmental benefits of ground-source heat pumps (often called geothermal heat pumps in the US).

"I really believe geothermal energy is the wave of the future," Moore told a local newspaper during a recent visit to the company's Fort Wayne manufacturing facility last April. "It has virtually no downsides. It's good for the environment, the economy and it meets

community concerns. It's good for everyone."

Moore has advocated increased utilization of geothermal technology as a safe, proven means of reducing the pollution caused by burning fossil fuels to generate electricity and to heat and cool buildings. An active director of Greenpeace International from 1971 to 1986, he now provides environmental counsel on forestry, energy, environmental and public policy issues to industry and government.

(Source: Waterfurnace International Inc. Tel: +1-219-478-5667; Fax: +1-219-478-3029)



Patrick Moore.

## Subsidies promote thermal energy storage

Japan - As mentioned in the previous issue of the Newsletter – in the article by Mr Toshiko Tanaka – a subsidy scheme has been introduced to encourage the installation of air conditioning systems with ice thermal storage. More details of this scheme have been made available by the Heat Pump Technology Center of Japan (HPTCJ), headquarters of the Japanese HPC National Team, who are administering this scheme.

The rapid and dense penetration of air conditioning throughout the country has brought about a significant national economic problem. The demand for air conditioning is concentrated in an extremely short period of the year and for just a few hours of the day. Consequently, the Japanese power

factor (the operating rate of electric power generating plant) has fallen to almost 60% – representing a great loss of capital investment. Power load levelling, by shifting or cutting peaks, has thus become an urgent national need. Latent thermal storage, such as ice thermal storage, is seen as an important technology to achieve load levelling with air cooling equipment.

The newly introduced promotion scheme applies to owners of medium or small-sized buildings who borrow money to install an air-conditioning system with a thermal storage tank. By applying to the HPTCJ they can obtain a government subsidy equivalent to a 3% reduction in the interest rate for the bank loan.

To qualify for the subsidy, the air-conditioning system must use either individually separated air conditioners or, for buildings with less than 30% floor area and an electric peak shift rate of more than 30%, a central air conditioning unit.

In addition to this government subsidy, electric utilities are adding their own promotion plan by which they offer subsidies to manufacturers of thermal storage air conditioning systems. The amount is 30,000 to 50,000 Yen (US\$ 300 to US\$ 500) per kW of peak shift. Moreover, users of thermal storage air conditioning systems will be offered a specially discounted tariff.

(Source: Japanese National Team)

## Italian promotion campaign

Italy - ENEL (the National Agency for Production and Supply of Electricity) has begun a campaign to encourage the use of reversible electric heat pumps. Handbooks have been produced and distributed to help users and installers choose appropriate heat pump equipment.

So far, the campaign is targeting two specific application areas: hotels and greenhouses. A campaign for the residential sector is under consideration. Further information is available from Giacomo Korn, Via G.B. Martini 3, 00198 Rome, Italy. Fax: +39-6-85092-291.

(Source: EU Heat Pump Newsletter, July 1995, from the Concerted Action Activity of the European Commission)

## Technology and Applications

### New York utilities test a monovalent GSHP

**USA** - A new ground-source heat pump (GSHP) that uses little or no supplemental heat (monovalent mode) in cold climates is being field tested at two utilities in New York State.

WaterFurnace International, Inc. is working with the New York State Energy Research and Development Authority (NYSERDA), New York State Electric & Gas (NYSEG), and Central Hudson Gas & Electric to develop and demonstrate a

new GSHP called the 'Northern Leader'. Four preproduction models have been installed, two at the homes of Central Hudson customers and two in NYSEG's service area.

According to WaterFurnace, the new technology should require little or no back-up resistance heat and offers adequate dehumidification during cooling. Key features that make this possible are two-speed operation and an

oversized compressor. A desuperheater for hot water heating is also included. Full production of this model is planned to begin in 1995.

*(Source: EPRI News Exchange, Spring 1995 from the Electric Power Research Institute)*

### House with heat pumps uses 80% less energy

**The Czech Republic** - A low-energy house featuring a range of renewable energy technologies, including heat pumps, is expected to consume 80% less energy than a traditional building.

The recently completed two-storey building is fitted out with a 48 m<sup>2</sup> array of solar collectors, a large volume thermal storage tank and two electric heat pumps.

In addition, a photovoltaic collector and a small wind power station provide electric power. With the use of advanced insulation techniques, the energy requirements for both space heating and

hot water have been kept as low as 100 to 140 GJ per annum.

The house, which has a 15 - 20 m ground plan, features a low-temperature underfloor heating system. At the beginning of the heating system this is heated directly by heat from the solar collectors, which is supplied from the thermal storage tank. As the weather gets colder, this heat is used as the heat source for a Stiebel Eltron WPWE 18 K liquid-to-water heat pump. Water heating is provided by a Stiebel Eltron WWK300HC air-source, heat pump water heater, which takes heat either from returned ventilation air in winter, or

outside air in summer. Back-up heating is provided by an electric boiler.

Known as EKODUM, the low-energy house was constructed at Born in 1994, and the equipment is now being tested. The project was financed by the Ministry of Economy of the Czech Republic and a joint stock company known as VUES Brno made up of the Czech power utility CEZ Prague and Stiebel Eltron.

*(Source: News at Seven, March 1995 from SEVE and Dr Milan Siegl, VUES Brno Co.; Fax: +42-5-4521-1144)*

### Future buildings should use heat pumps

**Switzerland** - At the 2nd "think-tank" workshop of the IEA Future Buildings Forum, held in Wolfsberg, Lake Constance on 15 to 17 May 1995, Austrian HPC National Team representative, Mr Hermann Halozan, was given the opportunity to discuss the use of heat pumps in future buildings. He highlighted the fact that low heating energy buildings would not only result in a low heat demand but would also allow the use of heat distribution systems using

extremely low distribution temperatures. This, in turn, would allow heat pumps to deliver heat at SPF's of between four and six, further reducing the energy consumption of these future buildings.

The IEA Future Buildings Forum has been established by the IEA programme "Energy Conservation in Buildings and Community Systems". A number of workshops are planned for the coming

years. Proposed topics include low-cost high-efficiency heating systems, renewal of residential and commercial buildings, and systems integration in community systems. Mr Halozan is helping to forge close cooperation between the Future Buildings Forum and the IEA Heat Pump Programme.

*(Source: Hermann Halozan, Austrian National Team)*

# Test facility simulates real conditions

**The Netherlands** - A new test facility developed by TNO – the Netherlands Organisation for Applied Scientific Research, should help raise the standard of heat pump equipment for the Dutch market. The newly developed *dynamic test rig* (shown right) allows a heat pump to be operated as if it were connected to a real heating system in a real building. The behaviour of the heat pump can then be analyzed to determine its performance under all relevant operating conditions.

Particularly in the Netherlands, domestic heating-only heat pumps face stiff competition from cheap and effective conventional heating systems (high efficiency boilers). To penetrate this market, optimum system design is a prerequisite. At present, the standards for heat pump testing and consequently most of the documentation that manufacturers supply with their products, are neither sufficiently detailed nor sufficiently accurate to determine heat pump performance in a real application.

In order to design better heating systems using heat pumps, well-defined information is needed on the performance of the heat pump component. In the view of TNO, minimum requirements for heat pump performance specifications should include the following:

- COP and thermal capacity over the full range of temperature conditions where the heat pump is allowed to be in operation. The external media should be defined both by temperatures and mass flow;
- COP and thermal capacity under part-load conditions, both for heat pumps with on/off and modular capacity control;
- Use of auxiliary energies (control system, fans, pumps), including information about the relation between running hours of these components and running hours of the heat pump;
- Effect of frosting and defrosting, if any.

The information should be reliable and be obtained by clearly defined procedures, so that it can be verified, if

desired. The dynamic test rig, which has been developed with the support of Novem (the Netherlands Agency for Energy and the Environment) is a tool for obtaining this information.

At the core of the dynamic test rig is the simulation program DIBSIM – Dynamic Installation and Building Simulation Model. With intervals of 30 seconds this computer model calculates all variables of the building and the heating installation such as climate and the occupants' behaviour. The program can simulate a wide range of space conditioning installations including air heating & cooling as well as floor heating and radiators. Temperatures and flow-rates may be varied to simulate or optimize advanced control systems.

A heat pump under test is connected to the source and sink units of the dynamic test rig, both of which are controlled by DIBSIM. The response of the heat pump and its effect on sink and source is measured and fed back to DIBSIM. For example, the effect of a ground-source heat pump on the ground temperature can be simulated.

By running a series of test procedures, the dynamic test rig can be used to characterize the heat pump as a component under various operating conditions. The output is two-fold: product specifications and a mathematical model.

The mathematical model can be connected to DIBSIM as an alternative to

the real heat pump: then the system-evaluation is a complete simulation, with all corresponding advantages, e.g. independency from real time. Systems may then be evaluated either for a standard reference year or for a so-called reduced reference year.

Such simulation exercises result in validated heat pump models and specifications which give information about the performance of the heat pump in the heating system such as:

- annual COP or PER (primary energy ratio);
- heat pump contribution in bivalent systems;
- comfort conditions.

By varying design parameters such as the area of the radiators and the capacity of the heat pump, systems may be optimized.

TNO's next goal is to develop improved test-procedures to reliably characterize the (dynamic) behaviour of specific heat pumps over the full range of their application conditions. This should preferably be realized through international cooperation, which, for Europe, is now under development.

(Source: Peter A. Oostendorp, Department of Refrigeration and Heat Pumps, TNO Environment, Energy and Process Innovation, Apeldoorn, The Netherlands. Tel: +31-55-493493; Fax: +31-55-419837)



*Dynamic testing at TNO, the Netherlands.*

## Working Fluids

### Elf Altochem compares alternatives

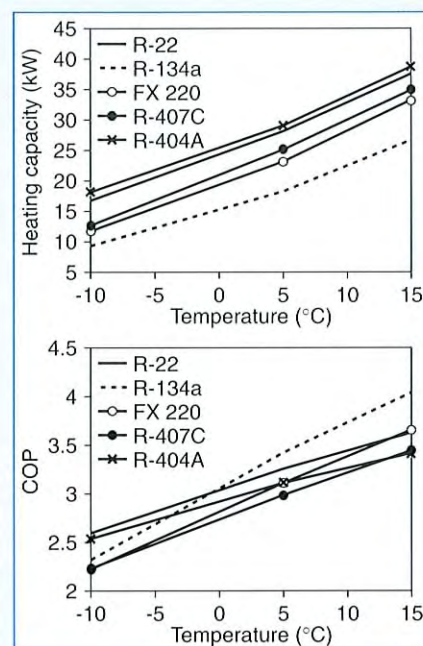
**France** - Refrigerant manufacturer Elf Altochem has completed a study on four alternative refrigerants to HCFC-22 for space conditioning. In the study, carried out in the Netherlands by TNO (the Netherlands Organisation for Applied Scientific Research), the performance of a water-to-water heat pump/air conditioner was compared using HCFC-22, HFC-134a, Forane FX 220, R-407C or R-404A. Figure 1 compares the heating capacity and COP of the test equipment using these refrigerants.

The study concluded that FX 220 (HFC-32/134a/23) or R-407C (HFC-32/125/134a) are the preferred refrigerants for air-to-air equipment or for applications where the condensation temperature often rises above the critical point. HFC-134a is recommended for large water-to-water systems where efficiency is of greater importance than capacity. In contrast, R-404A (HFC-125/134a/143a)

is well adapted for small capacity water-to-water equipment. It combines the advantages of high capacity and low temperature and has an acceptable COP for such applications.

(Source: *Revue Général du Froid*, April 1995)

Figure 1: Heating capacity with tested refrigerants. Coefficient of performance with tested refrigerants.



## New phase out schedules proposed

**Kenya** - The European Union and Sweden have tabled separate proposals for bringing forward the phase-out dates for HCFCs. At the Eleventh Meeting of the Open-Ended Working Group of the Parties to the Montreal Protocol, held in Nairobi on May 5-12, the EU proposed that the current schedule should be brought in-line with current EU controls (see Table 1). The EU also stated that a proposal for more advanced phase-out dates may be proposed in future. The Swedish proposal, which was supported by Finland, Germany, Switzerland and Norway, would bring in still earlier phase-out dates, including a ban on using HCFCs as refrigerants in new equipment after 1 January 2000. A decision on these proposals will be sought at the next meeting to be held in Vienna on November 28.

(Source: *The Air Conditioning, Heating and Refrigeration News*, July 10, 1995)

Table 1: Current and proposed HCFC phase-out schedules.

| Date (January 1) | Current schedule       | EU Proposal            | Swedish Proposal       |
|------------------|------------------------|------------------------|------------------------|
| 1996             | 3.1% cap <sup>1)</sup> | 2.6% cap <sup>1)</sup> | 1.5% cap <sup>1)</sup> |
| 2000             | -                      | 50% <sup>2)</sup>      | 50% <sup>2)</sup>      |
| 2004             | 35% <sup>2)</sup>      | 75% <sup>2)</sup>      | 75% <sup>2)</sup>      |
| 2007             | -                      | 90% <sup>2)</sup>      | 90% <sup>2)</sup>      |
| 2010             | 65% <sup>2)</sup>      | -                      | 100% <sup>2)</sup>     |
| 2015             | 90% <sup>2)</sup>      | 100% <sup>2)</sup>     |                        |
| 2020             | 99.5% <sup>2)</sup>    |                        |                        |
| 2030             | 100% <sup>2)</sup>     |                        |                        |

<sup>1)</sup> Fraction of the ozone depletion potential of the CFCs plus the HCFCs consumed by a country in 1989.

<sup>2)</sup> Fraction by which the cap is to be reduced.

## Markets

### Hong Kong tops export market

Japan - New statistics on Japan's export market show that Hong Kong imports the largest numbers of Japanese heat

pumps. Table 2 indicates the countries and regions where Japanese heat pump exports exceed 10,000. Outside the

countries of the Far East, Australia and the Middle East offer healthy export markets for Japanese heat pump manufacturers. The European Union (EU) also imports large numbers of Japanese heat pumps, most notably in Greece and Spain. It must be added that the presence of locally-based Japanese manufacturing facilities offset these export figures in many countries, especially in the Far East.

(Source: Japan HVAC&R Directory 1995, published by JARN)

| Country/Region | Packaged heat pump | Other heat pump | Total  |
|----------------|--------------------|-----------------|--------|
| Hong Kong      | 8,418              | 68,793          | 77,211 |
| China          | 2,641              | 25,028          | 27,669 |
| Greece         | 106                | 26,133          | 26,239 |
| Australia      | 5                  | 13,802          | 13,807 |
| Singapore      | 6,779              | 6,467           | 13,246 |
| Spain          | 1,024              | 11,344          | 12,368 |
| EU             | 1467               | 55,338          | 56,805 |
| Middle East    | 1942               | 18,920          | 20,862 |

Table 2:  
Major export markets in 1994 for Japanese space conditioning heat pumps (Source: Customs Statistics, the Ministry of Finance, Japan)

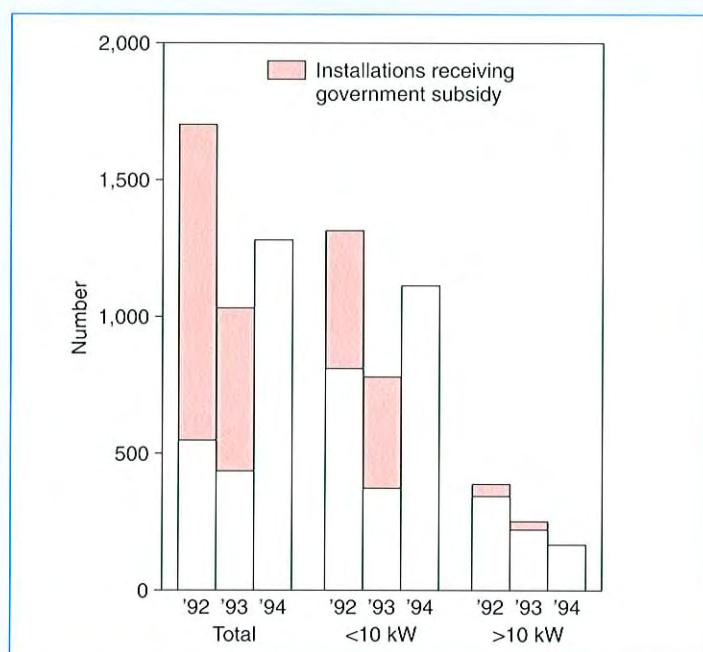
### Heat pumps save seven petajoules

Norway - With around 18,000 installations, heat pumps are estimated to supply around 10 PJ of heat per annum here, which can be equated to annual energy savings of some 7 PJ. Of these heat pumps, 72% are small-sized (< 10 kW<sub>th</sub>) and 85% are air-source (49% outdoor air and 36% ventilation air). In 1994, 67% of all heat pumps sold were outdoor air units of less than 10 kW<sub>th</sub>.

In 1991, the government introduced a subsidy of 40% for heat pump installations, which was reduced to 20% during 1992 and removed at the end of 1993. Figure 2 indicates that despite the removal of the subsidy, 1994 heat pump sales rose 8% on the previous year.

(Source: Ulf Rivenæs, Norwegian National Team)

Figure 2: Heat pump sales in Norway.



# IEA Heat Pump Programme

## Annex 21 completes its study IHPs can meet up to 5% of industrial heat demand

*Annex 21 "Global Environmental Benefits of Industrial Heat Pumps" has estimated that industrial heat pumps (IHPs) have the potential to realize net energy savings of some 1,330-3,100 PJ/year worldwide by the year 2010. Such savings would represent about 2-5% of the projected worldwide industrial process heating energy demand at that time.*

This global estimate is based on country-specific estimates for the eight Annex 21 participating countries (Canada, France, Japan, The Netherlands, Norway, Sweden, United Kingdom and the United States). Table 3 shows an estimate of the global net emissions reductions from using IHPs in 2010.

The projected environmental benefits of IHPs would be equivalent to eliminating the yearly emissions from 50-150 GW of fossil fuel-based electric generating capacity or would be comparable to saving 120-380 billion kWh/year of electricity, planting 30-85 million trees, removing 15-40 million cars from the road, or reducing petrol (gasoline) consumption by 40-95 billion litres/year.

### Report

The results are published in the recently issued report "Industrial Heat Pumps: Experiences, Potential and Global Environmental Benefits" (HPP-AN21-1), which can be ordered from the HPC (see back inside cover). This report also reveals that there are more than 4,600 IHPs in use in the eight Annex 21 countries (See Figure 3). The largest number is found in the lumber industry, but many are in use in the food, chemicals, petrochemicals/petroleum refining, pulp and paper, and textile industries. Heat pumps are also used by electric utilities (e.g., waste concentration) and water/sewage treatment plants.

Annex 21 found that IHPs can yield a wide range of benefits in addition to reduced energy consumption and lower emissions. The potential benefits will be site-specific, but some of the more common ones are:

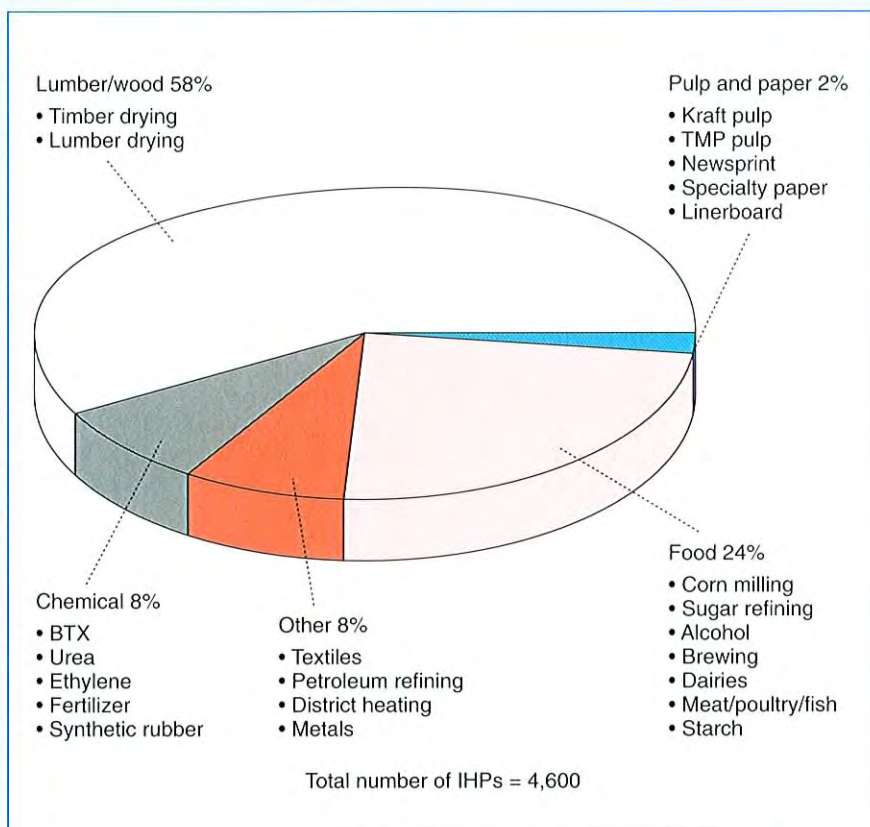


Figure 3: Application of industrial heat pumps in 1992 in member countries of Annex 21.

- Increased production capacity through plant debottlenecking;
- Increased steam, hot water, or refrigeration capacity;
- Increased energy available for on-site power generation;
- Delayed investments in boiler capacity;
- Improved product quality;
- Reduced make-up or cooling water requirements.

### Potential

While IHPs are now widely used in some industrial processes, their overall use to date has been far below their true technical and economic potential. This low rate of utilization partly results from the lack of information and industrial experience with heat pump technology in some industrial sectors, and also from

misperceptions of the technology based on poorly designed installations dating back more than 10 or 20 years. By providing information on IHP technology and the necessary tools to screen for potential IHP opportunities, Annex 21 is helping to address these issues.

### Program

In addition to the Annex 21 report, a personal computer-based IHP screening program is available (firstly only in participating countries) to assist in a preliminary screening of the technical and economic suitability of IHPs in industrial process applications. The program contains data on more than one hundred processes in five industries: food, chemicals, petroleum refining, pulp and paper, and textiles. These data

can be modified to assess site-specific IHP opportunities. More than 50 types of IHPs can be examined, divided into five main categories: closed-cycle compression, mechanical vapour compression, thermal vapour recompression, and absorption heat pump (types I and II). Those wishing to order this program should contact the HPC.

#### Message

One of the main messages of Annex 21 has been to show that IHPs are one of the most flexible (in terms of process design) and cost-effective technologies for industrial waste heat recovery. At the same time, the Annex has tried to stress that IHPs should be considered as a part of an overall plant heat integration study, to first identify heat exchanger improvement opportunities, which are

generally lower-cost than IHPs, and then to determine the potential for heat pumping. Such a process will lead to the minimum plant-wide energy consumption and the maximum environmental benefits at the lowest total investment cost.

With the completion of the report and the computer program, the work of Annex 21 is complete. Now the challenge is to disseminate the information as widely as possible. The brochure "Industrial Heat Pumps - a means to mitigate global industrial emissions", which highlights the results of Annex 21, is available from the HPC.

(Source: Steven Williams, Hagler Bailly Consulting, Inc. (Contractor to the US DOE) Arlington, VA USA; Tel. 703-351-0300, Fax. 703-351-0352)

|                 |                                             |
|-----------------|---------------------------------------------|
| CO <sub>2</sub> | 25-58 million tonnes carbon equivalent/year |
| SO <sub>x</sub> | 295-695 thousand tonnes/year                |
| NO <sub>x</sub> | 180-425 thousand tonnes/year                |
| CO              | 55-125 thousand tonnes/year                 |
| CH <sub>4</sub> | 3-6 thousand tonnes/year                    |
| Particulates    | 10-24 tonnes/year                           |

Table 3: Global emissions reduction IHPs.

## IEA Heat Pump Programme activities update

| No.                                                                                                                                                                                                                                                                                                                                                 | Annex                                                                | Operating Agent | Participants                                                 | Start Date           | Completion Date      |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|-----------------|--------------------------------------------------------------|----------------------|----------------------|
| 16                                                                                                                                                                                                                                                                                                                                                  | Heat Pump Centre                                                     | NL              | AT, CA, JP, NL, NO, CH, US                                   | Jan 1990             |                      |
| 18                                                                                                                                                                                                                                                                                                                                                  | Thermophysical Properties of Environmentally Acceptable Refrigerants | US              | AT <sup>1)</sup> , CA, DE, JP <sup>2)</sup> , NO, SE, UK, US | Dec 1989<br>Jan 1993 | Dec 1992<br>Dec 1996 |
| 21                                                                                                                                                                                                                                                                                                                                                  | Global Environmental Benefits of Industrial HPs                      | US              | CA, FR, JP, NL, NO, SE, UK, US                               | Jan 1992             | June 1995            |
| 22                                                                                                                                                                                                                                                                                                                                                  | Compression Systems with Natural Working Fluids                      | NO              | CA, DE, JP, NL, NO, CH, UK, US                               | Jan 1995             | Dec 1997             |
| Participating countries: Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), Spain (SP), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US).<br><sup>1</sup> Phase one only. <sup>2</sup> Japan is the Cooperating Agent of phase two. |                                                                      |                 |                                                              |                      |                      |

# Residential Heat Pump Applications

## An International Overview

Bert Stuij, IEA Heat Pump Centre

*Out of the vast array of possible residential heat pumping technologies and applications, a few typical examples are highlighted in this article. In the blue section, common installations in a number of countries are presented. In the white section some general remarks are made on the "art" of residential heat pumping around the world, on its value for comfort, environment and economy, and on the residential heat pump market. In conclusion the importance of application oriented information exchange is stressed. Only an informed international perspective can ensure that in a particular country the best technology is applied, one which will provide optimum comfort at minimum cost, energy use and environmental impact.*

\* \* \*

There is an almost overwhelming profusion and diversity of residential heat pumps. Every year about 8 million units are sold, in a multi-billion US\$ worldwide market. These heat pumps can provide cooling, heating, de-humidification or tap water heating - or any combination of these. They may be electrically driven or gas fired. The free heat source they use may be the ground, water, ambient air, ventilation air or even industrial waste heat flows. And they come in all sizes, shapes and prices.

But nearly always they show a well appreciated ability to meet basic and universal human needs for comfort. And in many cases they do this with minimum use of primary energy resources, and consequently with minimum environmental impact.

### The Art

The art of residential heat pumping knows many styles. Heat pumping is a flexible technology, that can comply with a great variety of comfort and life-style demands. Such demands are influenced by a complex mix of factors, which include climate, culture, affluence, energy prices, and others.

As a consequence of this mix, the centralized stand-alone unit is commonly applied in North America. This

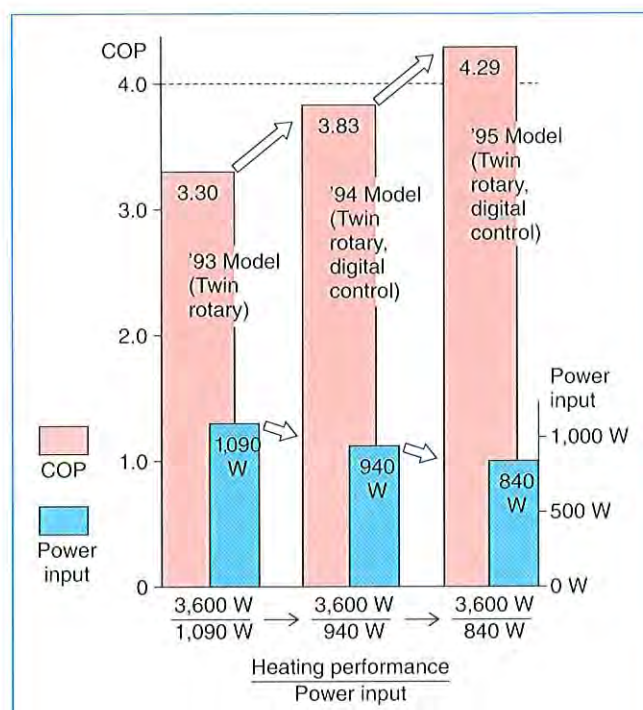


Figure 1: Performance improvement in Japanese room heat pumps (source: Toshiba).

heat pump conditions air that is distributed through a duct system. Outside air is used as a heat source. The heat pump will always cool in summer, and the North American experience is that heat pumps will only sell if there is a climate and life-style induced cooling demand. Heat pump developments in North America include steady performance improvements, growing attention for gas fired technology, and ground coupling. Especially in Canada, a growing percentage of heat pumps are ground coupled. The widely applied HCFC-22 will have to be phased out in due course, with HFC mixtures the most likely replacement candidates.

A somewhat different mix of factors in Japan led to the massive penetration of small room heat pumps. About 50% of all households now have such a heat pump installed. Major developments include sharp performance improvements (see Figure 1), and improved control for optimum comfort. Sophisticated room heat pump control systems now react on the location of people in a room, and even on the clothes they are wearing.

## Austria

The Austrian residential heat pump market was fairly strong in the early eighties. However, it declined sharply after the 1986 oil price collapse, at which time the government also withdrew nearly all market support. Since 1989 the market is slowly recovering.

Traditionally, the residential heat pump market was dominated by mono-valent groundwater-to-water heat pumps for new buildings, and bi-valent outside air/water heat pumps for retrofit applications. Heat pump systems normally fed medium to high temperature radiator distribution systems. In recent years a technology shift has taken place away from these systems. Mono-valent ground coupled systems are now most common, mainly for new buildings with a low temperature floor heating system. In general they use horizontal direct-evaporation collectors. The table shows two typical installations. Propane is beginning to be used as working fluid. There is also growing interest for air-source ground-coupled systems, where air is drawn through buried concrete pipes before entering the heat pump evaporator. Exhaust air-to-air heat pumps get an increasing market share, and new opportunities emerge for high efficiency outside air source heat pumps.

(Source: Mr Hermann Halozan, Austrian National Team)

|                               | Single family house,<br>Bad Ischl, Salzburg         | Single family house,<br>Reichraming,<br>Upper Austria |
|-------------------------------|-----------------------------------------------------|-------------------------------------------------------|
| Heat pump type                | Monovalent,<br>ground-source,<br>direct evaporation | Monovalent,<br>ground-source,<br>direct evaporation   |
| Heated Space                  | 206 m <sup>2</sup>                                  | 150 m <sup>2</sup>                                    |
| Annual heat demand            | 26,750 kWh                                          | 15,395 kWh                                            |
| Design conditions             | -14 °C outside,                                     | 20 °C inside                                          |
| Heating degree days           | 3,862                                               |                                                       |
| Heat distribution system      | Floor heating, 35 °C.                               | Floor heating, 35 °C                                  |
| Manufacturer                  | Neuratherm                                          | Neuratherm                                            |
| Capacity/Power rating         | Step 1: 8.6 kW / 1.8 kW<br>Step 2: 14.2 kW/3.5 kW   | Step 1: 8.6 kW/1.8 kW<br>Step 2: 14.2 kW / 3.5 kW     |
| Ground collector              | 7 coated copper coils,<br>each 75 m long            | 7 coated copper coils,<br>each 75 m long              |
| Installation depth            | 1.0 to 1.3 m                                        | 1.2 m                                                 |
| SPF (heating)                 | 3.6                                                 | heat pump: 4.7<br>total system: 4.5                   |
| Investment costs (US\$)       |                                                     |                                                       |
| heat pump unit                | 6,200                                               |                                                       |
| ground coil                   | 2,500                                               |                                                       |
| installation                  | 4,400                                               |                                                       |
| heat pump water heater        | 2,400                                               |                                                       |
| floor heating system          | 6,500                                               |                                                       |
| Complete installation (US\$)  | 22,000                                              | 21,000                                                |
| Annual operating costs (US\$) | 1,300                                               |                                                       |

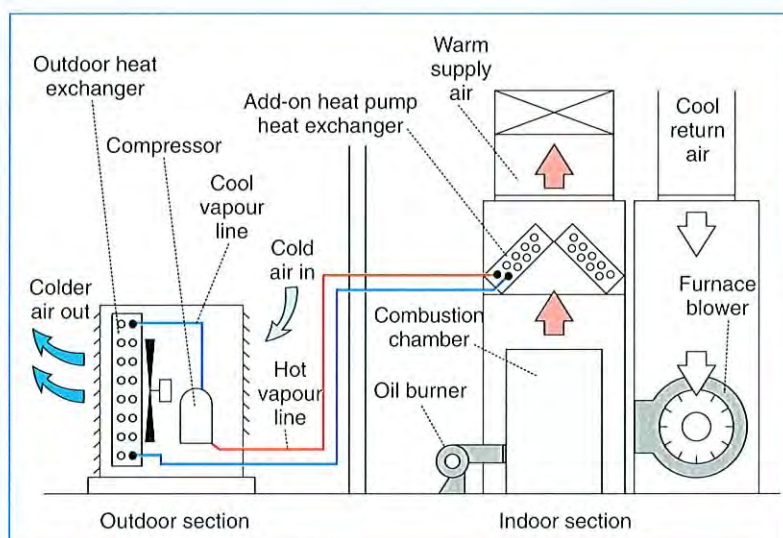
## Canada

The residential heat pump market in Canada has recently seen annual sales between 18,000 and 30,000 units. Air-source heat pumps remain the dominant technology, but ground-source applications are seeing significant growth over the past five years. Anywhere from 3,000 to 5,000 ground-source heat pumps are installed each year.

One of the most common applications, in particular in Southern Canada, is an add on heat pump to an existing fossil fuel, forced air furnace, as illustrated in the figure. Technical details are shown in the table.

(Source: Mr Keith Snelson, National Research Council Canada, and Canadian National Team)

|                                |                                                                                                      |
|--------------------------------|------------------------------------------------------------------------------------------------------|
| Heat distribution              | 35 °C to 50 °C during furnace operation (the heat pump turns off during furnace operation)           |
| Heat source temperature        | Employed in regions with winter temperatures down to -25 °C, summer temperatures up to 35 °C.        |
| Heating and cooling capacities | Heating: typically 5 - 12 kW at 8 °C; Cooling: typically 5 - 12 kW at 35 °C. Sized to cooling needs. |
| Heating SPF                    | SPFs above 2. Add on heat pumps typically displace 70% of oil or natural gas used.                   |
| Annual heat demand             | Typically 18,000 to 20,000 kWh in up-to-date dwellings                                               |
| Annual cooling demand          | Typically 5,000 to 5,500 kWh in southern Canada                                                      |
| Equipment costs                | About US\$2,250 to 2,750, including installation                                                     |
| Annual energy costs            | About US\$500 to 575 for heating, US\$85 to 100 for cooling.                                         |



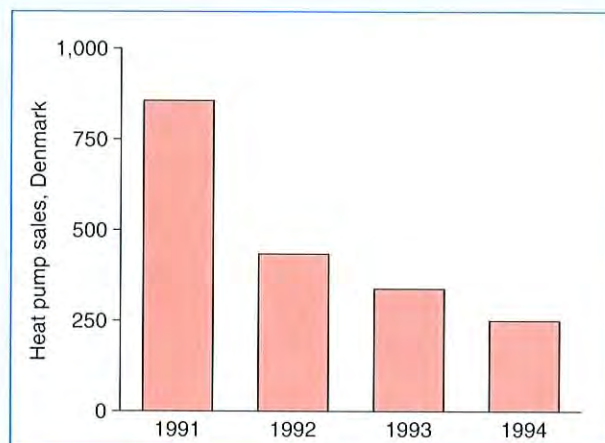
The European residential heat pump situation reflects the great diversity in climate, culture and affluence of this continent. Southern Europe is a cooling driven heat pump market, with a fair penetration of small,

reversible units. In Central and Northern Europe there is a negligible residential cooling demand, and heat pumps are typically "heating only". Notably in Sweden the space heating residential heat pump

## Denmark

The 1990 heat pump stock totalled 36,000 units, most of which were installed in the late 1970s and early 1980s. Later in the 1980s the market declined because of high interest rates, poor economy, low energy prices and a withdrawal of government support. Sales became very low in the 1990s, as shown in the figure. There are currently 8 producers of heat pumps, but, as stated by the chairman of the Association of Manufacturers of Heat Pumps in Denmark, unless something dramatic happens to the market, there will be no Danish heat pump producer in 1997.

Recent Danish energy policy has strongly hampered the heat pump market. The gas sector, dominated by the state owned National Danish Gas Company, was heavily supported to accelerate the penetration of gas into the Danish residential sector. So much so, that the Association of Heat Pump Manufacturers took the Danish government to the European court on the acquisition of partiality towards the gas sector. At the same time electricity companies are stimulated to build de-centralized CHP plants that feed district heating schemes.



Yet there are still many households that cannot take advantage of the gas distribution network, or district heating. The government has now decided to support solar power and heat pumps for these households. Grants will be available from 1996, and regional electricity companies are expected to provide support with financing, installation and service.

A revitalized market is expected to be dominated by three major groups of heat pump. First of all the air-to-water heat pump for space and tap water heating. Secondly air-to-air systems that can either be a ventilation system with heat recovery, or a system that combines fresh air intake with re-circulation, where the re-circulated air is heated with a heat pump. Finally hot water heat pumps, possibly with a space heating function via a heat exchanger will become important.

None of these heat pumps show major new technologies, but continuous improvements in control, efficiency and reliability will take place. To raise the image and quality of heat pumps, an installers training programme has taken place. Only approved installers will install and service Danish heat pumps.

(Source: Mr Palle Overgaard Sørensen, Genvex, Platanvej 4, Hadsten, Denmark)

market is mature. In Austria and Germany hot water heat pumps are commonly applied. Important developments are the onset of propane as working fluid in residential heat pumps, the phase out of groundwater source heat pumps in favour of ground-coupled units, performance improvements, and price reductions.

A complicating issue is the fact that high-temperature radiators are common as heat distribution systems in Europe. The introduction of heat pumps has to go hand-in-hand with a penetration of low temperature distribution systems, such as underfloor heating or forced air.

## The Value

The value of the residential heat pump lies in the human comfort it provides, its energy efficiency and environmental soundness, and its cost effectiveness.

Firstly the "comfort value" of heat pumps. Heat pumps will only sell if they convincingly meet the comfort demand of the customer. Experience shows that they do this very well if there is both a cooling and heating demand. The dual function of the reversible heat pump is a unique feature, and indeed the main reason for its massive worldwide sales.

## Japan

Room heat pump sales hit an all time high in 1994, with over 5.6 million units shipped. Sales were helped by a modest economic revival after the recession of 1992 and 1993, by a hot summer, and by an increase in building activity. A further strengthening of the residential heat pump market is expected. In 1993, air conditioners were installed in 76% of Japanese homes, and heat pumps in nearly 50%. The strong Japanese heat pump market is explained by the comfort desires of Japanese customers, in a climate which requires in most regions heating, cooling and dehumidification. Another factor is the improved level of insulation in new residences. The reduced heat demand in new dwellings is beneficial for heat pumps.

Important development trends include:

- *Performance*: lower noise, higher efficiency;
- *Functions*: models with an air purification function are bought increasingly;
- *Comfort and ease of operation*: advanced sensors and control systems;
- *Shape*: compact, low height models for installation above windows;
- *Maintenance*: easier installation, and easier servicing.

The table shows two room heat pump air conditioners in Japan, a state of the art "energy saving" type, and a common "low cost" type. Both are applied in the Tokyo area, and meet a total thermal demand of 5890 kWh<sub>th</sub> (1380 kWh<sub>th</sub> cooling, 4510 kWh<sub>th</sub> heating). The heat distribution temperature is about 40 °C, with a condenser temperature of 45 °C. Over the year the outside air heat source temperature ranges from -5 to 15 °C.

|                                                                                   | Energy saving type | Low cost type   |
|-----------------------------------------------------------------------------------|--------------------|-----------------|
| Annual power consumption [kWh <sub>el</sub> ]                                     | 1290               | 2250            |
| Annual performance factor<br>(= Total thermal load /<br>Annual power consumption) | 4.6                | 2.6             |
| Annual energy costs [US\$]                                                        | 387                | 676             |
| Annual consumption cooling [kWh <sub>el</sub> ]                                   | 270                | 550             |
| Cooling seasonal performance factor                                               | 5.1                | 2.5             |
| Annual consumption-heating [kWh <sub>el</sub> ]                                   | 1020               | 1700            |
| Heating seasonal performance factor                                               | 4.4                | 2.7             |
| Heating capacity [kW]                                                             | 3.6                | 3.4             |
| Power demand - heating [W]                                                        | 840                | 1250            |
| COP heating                                                                       | 4.3                | 2.7             |
| Noise indoor unit - heating [dB]                                                  | 39                 | 41              |
| Noise outdoor unit - heating [dB]                                                 | 41                 | 44              |
| Cooling capacity [kW]                                                             | 2.5                | 2.5             |
| Power demand - cooling [W]                                                        | 640                | 1120            |
| COP cooling                                                                       | 3.9                | 2.2             |
| Noise indoor unit - cooling [dB]                                                  | 35                 | 39              |
| Noise outdoor unit - cooling [dB]                                                 | 39                 | 44              |
| Size indoor unit [mm]                                                             | 265 x 790 x 174    | 245 x 740 x 160 |
| Size outdoor unit [mm]                                                            | 530 x 695 x 245    | 530 x 660 x 200 |
| Equipment cost [US\$]                                                             | about 1760         | about 1180      |
| Installation cost [US\$]                                                          | about 235          | about 235       |

(Source: Mr Yoshio Igarashi, Japanese National Team)

## Norway

Today, most units sold are residential, reversible air-to-air units which are nearly always employed in bivalent configurations with oil-fired or electric boilers, electric resistance heaters (baseboard heaters) or wood-burning stoves. For a 100 m<sup>2</sup> single-family house with an annual space heating demand of 12,000 kWh, a 3 kW (heating capacity) reversible air-to-air unit typically achieves an SPF of 2.5 and will save up to 50% of the annual heating demand. Such units are typically designed for warm climates and would exhibit a much better performance if they were better adapted to the Norwegian climate through changes to the evaporator design (such as widening the fin spacing) and improvements to the defrosting system.

The table below provides data on three heat pump systems which were monitored between 1982 and 1984. Data on more modern systems is not readily available but would be expected to show a much higher SPF for systems installed according to "good practice".

(Source: Mr Jørn Stene and Mr Geir Eggen, NTH SINTEF Refrigeration and Air Conditioning and Norwegian National)

| System description                 | Monovalent ground-to-water heat pump, feeding a hydronic (radiator) distribution system, and providing hot tap water. | Bivalent ambient air-to-air heat pump, space heating only, with electric back-up heating. | Bivalent exhaust air-to-water heat pump, tap water only, with electric back-up heating. |
|------------------------------------|-----------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| Heat distribution temperature [°C] | 55                                                                                                                    | 35                                                                                        | 50                                                                                      |
| Heat source temperature [°C]       | 0 - 14                                                                                                                | > -19                                                                                     | 20                                                                                      |
| Heating capacity [kW]              | 5                                                                                                                     | 3                                                                                         | 1                                                                                       |
| SPF - heat pump                    | 2.4                                                                                                                   | 2.4                                                                                       | 3.0                                                                                     |
| SPF - total system                 | 2.4                                                                                                                   | 2.0                                                                                       | 2.4                                                                                     |
| Annual heating demand [kWh]        | 17,000                                                                                                                | 17,500                                                                                    | 4,000                                                                                   |
| Energy costs [\$ / kWh]            | 0.11                                                                                                                  | 0.06                                                                                      | 0.07                                                                                    |

If there is only a heating demand, the heat pump has to meet a tougher challenge. To succeed, the heat pump requires an excellent control system, proper dimensioning, and a skilful installer. Common alternatives, such as fossil fuel or resistance heaters have a performance independent of outdoor conditions, and can in principle easily be controlled for optimum comfort. Heat pumps, notably air-to-air systems have

an extra variable in the outdoor conditions, which makes control fundamentally more complex. Additionally, fossil fuel or resistance systems can be over-dimensioned without too much of a penalty in investment costs or part-load performance. Hence they guarantee heating on the coldest days - a comfortable feeling in many respects. For heat pumps, over-dimensioning is costly and potentially detrimental for

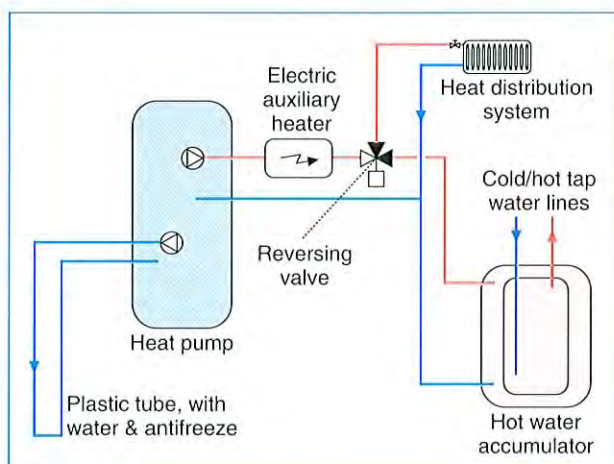
## Sweden

About 260,000 heat pumps are currently installed in Sweden, where they have been sold for thirty years in a strongly fluctuating market. After the boom in the early eighties, partly induced by government support, a sharp decline took place after 1986. In the early 1990s the market was fairly stable, with around 11,000 units sold per annum. A fair increase took place in 1994, and some predict a 15% annual sales rise for the rest of the decade.

Most heat pumps sold now are liquid-to-water heat pumps, which use the ground, rock, groundwater or lakes as heat source. These heat pumps give an excellent energy cover, also in Nordic climates. Reversible air-to-air heat pumps are also sold to customers who require cooling in summer. Ventilation air source heat pumps, or heat pumps using industrial process water as heat source are mainly applied in larger houses.

The figure shows a typical ground-source residential heat pump application. Typical data for such a unit are shown in the table.

|                                                       |                                                                       |
|-------------------------------------------------------|-----------------------------------------------------------------------|
| Heat source temperature                               | -4 to +1 °C                                                           |
| Output temperature<br>(without auxiliary heating)     | 35 to 55 °C                                                           |
| Heating capacity of the heat pump                     | 50 % of the peak heat demand (auxiliary with oil or electric heating) |
| Heat factor (COP)                                     | 2.8 - 3.5                                                             |
| Energy costs                                          | US\$ 0.085/kWh                                                        |
| Energy cover (portion<br>of total annual heat demand) | 90 %                                                                  |
| Installation costs<br>(all equipment shown in figure) | US\$6300                                                              |



For multi-family residences, ventilation-air source heat pumps are typical. Such units can be installed directly in the exhaust duct, but in some cases a liquid heat buffer is included. The units will often heat tap water to about 55 °C, at a COP of 3 to 3.5.

(Source: Håkan Persson, IVT Energy AB, Tranås, Sweden)

performance under normal conditions. Back-up heating may be installed, with the associated extra investment and control issues. A further complication is the installation of a heating-only heat pump, which requires special skills. These skills are often not available in heating only markets. Poorly sized and wrongly installed heat pumps have led to many complaints.

Alongside the "comfort value", the "environmental value" of heat pumps should be stressed. In temperate to cold climates, residential space heating may require up to 25% of the national energy consumption. Heat pumps are ideally suited to meet this heat demand, which lies at a temperature of no more than 25 °C. The box on page 21 highlights the energy efficiency

## Switzerland

The total heat pump stock amounted to 43,000 units at the end of 1994, with a combined heating capacity of 882 MW. Only 3% of this capacity is met by gas or oil driven heat pumps, the rest is electric. Over 3,600 units were installed in 1994, 28 % more than in 1993. 84% of the installations in 1994 were designed for monovalent operation, and 16% were combined with an additional heating system. Outside air was used as heat source in 63% of the installations, 31% used earth probes, and 6% used ground or surface water.

Details of a typical heat pump heating system with a vertical earth probe and a brine/water heat pump are given in the table. The picture shows the installed Saurer heat pump.

(Source: Mr Thomas Afjei, Swiss National Team)



|                                                                  |                                                                                                                            |
|------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------|
| Heat pump type                                                   | Saurer Thermotechnik, WS07.1, monovalent, ground coupled                                                                   |
| Application                                                      | One family house, 150 m <sup>2</sup> heated space                                                                          |
| Heat source system                                               | 3 Grundag earth probes, Duplex, 130 m, Ø 32 mm                                                                             |
| Heat distribution system                                         | Underfloor heating, supply 45 °C at -8 °C outside temperature. No buffer storage. Hot water with existing electric boiler. |
| Heating capacity                                                 | 9.6 kW at Brine 0 °C / Water 35 °C.                                                                                        |
| SPF                                                              | 2.9                                                                                                                        |
| Investment Costs (US\$)                                          |                                                                                                                            |
| Heat Pump                                                        | 9,400                                                                                                                      |
| Heat pump accessories (circulation pump, expansion vessel, etc.) | 3,200                                                                                                                      |
| Heat pump installation/transport costs                           | 1,300                                                                                                                      |
| Drilling costs                                                   | 9,600                                                                                                                      |
| Earth probe                                                      | 4,900                                                                                                                      |
| Electrical installation                                          | 3,700                                                                                                                      |
| Heating engineer                                                 | 1,100                                                                                                                      |
| Various                                                          | 1,500                                                                                                                      |
| <b>Total</b>                                                     | <b>34,700</b>                                                                                                              |
| Annual operating costs (US\$)                                    | 720                                                                                                                        |

benefits of residential heat pumps) In warmer climates heat pumps are real winners, providing year round comfort, and realizing significant energy savings and environmental benefits in the heating season. The example of the advanced heat pump in Tokyo (see page 36) shows that even in the cooling driven market of this city heat pumps

can save more energy in winter than they consume for cooling in summer.

Finally heat pumps must offer an "economic value" to the customer. Arguably, comfort is a basic human need, and technology will be used to meet it. The economic value of the heat pump can then be

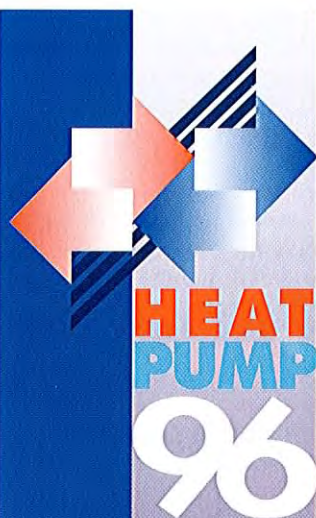
## United Kingdom

As in many other countries, residential heat pump sales boomed in the late 1970s and early 1980s, when nearly 70 national heat pump producers operated the market, and significant quantities were imported. By 1990 all national producers had withdrawn, leaving customers without spare parts or services, and the heat pump with a poor image.

In the late 1980s electricity companies launched the "Medaillon 2000" houses programme. Medaillon 2000 houses were well-insulated, and covered their heating needs with electric storage heaters that utilized night-tariff electricity. Balanced ventilation systems with heat recovery were also part of the programme. One step further was the inclusion of heat pumps in well-insulated, balanced ventilation residences. Cooperation between the Danish manufacturer Genvex, and the UK research institute EA Technology resulted in a heat pump with a COP of 3.7 in a test house.

Heat pump manufacturers view the UK residential market as promising. Heat pumps for heating with ventilation have good prospects, as such systems are a good solution for compact, well-insulated homes. The market for reversible units is also expected to expand, in response to a growing comfort cooling demand. In general, heat pumps are expected to benefit from better insulation, and from current building styles with large glass surfaces on the south and west.

(Source: Mr Palle Overgaard Sørensen, Genvex, Platanvej 4, Hadsten, Denmark)



## The 5th IEA Heat Pump Conference

To be held in Toronto, Canada, on September 22 to 26, 1996

This conference is the fifth in a series of triennial conferences on heat pumping technologies under the auspices of the Executive Committee to the International Energy Agency (IEA) Heat Pump Programme. With its triennial format the conference summarizes *technology status, progress and trends*. It is targeted at policy makers, research and development managers, product planners, equipment manufacturers, designers, engineers and consultants.

The conference programme consists of oral sessions with around 40 invited speakers on generic topics within heat pumping technologies, structured into *Markets, Applications and Technology*, covering all main regions in the world. There will also be open poster sessions focusing on specific projects and topics associated with the oral sessions.

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established by comparing heat pump investment and running costs with the costs of alternative technologies that provide the same comfort. In general, costs have hampered the market penetration of the heating only heat pump. Heat pump investment costs are still relatively high, and the current energy prices are so low, that energy savings translate in only modest operating cost savings. To improve the economic value of heat pumps, efforts must focus on reducing its costs. Important achievements were recently reported from Sweden, where a heat pump competition has led to significant cost price reductions.

By contrast, the heat pump competes well in many well-developed warm regions. In these areas there is often no cost-effective alternative for the air-conditioner (cooling only heat pump) to provide summer cooling. In many cases it will then make sense to buy a reversible unit, which can provide cost effective cooling in summer, and energy efficient heating in winter.

## The Market

Residential heat pumps dominate the world heat pump markets. Even in many heating-mainly countries the residential heat pump market is now developing positively. At the same time less than 5% of the annual residential heat demand is met by heat pumps (a fuller discussion of the heat pump markets can be found in the HPC Analysis "International Heat Pump Status and Policy Review", and in the International Overview article of the previous Newsletter, Vol. 12, No. 2).

To have a significant impact on national energy use and environmental protection, this share must rise, and it must rise a lot. Technologically, the heat pump is already well placed for such a rise. The technology is highly flexible, it can meet a variety of customer needs, utilize a wide range of heat sources, and be driven by both gas and electric power. Economically, the heat pump has yet to overcome some hurdles, in particular in the heating- mainly market. Manufacturer efforts must concentrate on cost reductions. Increased competitiveness can then be reinforced by the growing support for heat pumps amongst governments, utilities and the public at large.

## Quality Conscience

The variety of applications highlighted in this article are testimony to a diverse and lively heat pump market. At the same time the question must arise as to why certain applications are popular in some countries, and absent in others. Even more pertinent are questions on price and performance differences between apparently similar heat pumps applied in different countries. Clearly, differences can reflect the diversity in national conditions. But they may also highlight lessons from elsewhere that have yet to find a national incorporation. In this context this article underlines the necessity of exchanging application

## Six facts about heating a home

1. Direct combustion to generate heat is never the most efficient way to heat a residence.
2. Heat pumps are more efficient because they use renewable energy in the form of low-temperature heat.
3. If the fuel used by conventional boilers were redirected to supply power for electric heat pumps, around 35% less fuel would be needed, resulting in 35% less emissions.
4. Nearly 50% savings are made when electric heat pumps are driven by CHP (combined heat and power or cogeneration) systems.
5. Whether fossil fuels, nuclear energy, or renewable power is used to generate electricity, electric heat pumps make far better use of these resources than do resistance heaters.
6. The fuel consumption, and consequently the emissions rate, of an absorption or gas-engine heat pump is about 35% less than that of a conventional boiler.

experiences. Such an exchange allows HPC National Teams to be an *internationally* informed quality conscience in the *national* heat pump community of each country. And this conscience should not accept anything but the best for its country.

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# Vertical Borehole Heat Exchangers

## Bringing Heat From the Ground into the Home

Robert Hopkirk and Walter Eugster, Switzerland

*Vertical borehole heat exchangers are effective devices for extracting heat from the ground for use in heat pump space heating systems for the home. Compared with earlier installations, today's residential ground-source heat pumps achieve a better performance through closer integration of the BHE with the heating system and by taking better account of the BHE's thermal interaction with the ground. This article discusses the characteristic and trends of BHE installations.*

\* \* \*

During the past 15 years, the ground-source heat pump using a closed-loop vertical borehole heat exchanger (BHE) has become a popular device for space heating in Swiss homes. There are now well over 18,000 BHEs in Switzerland serving around 15,000 heat pumps. This is about one third of the total number of heat pumps installed in the country.

Figure 1 is a sketch of a typical installation for a single-family house. Modern heating systems in this part of Europe are mostly low-temperature hydronic systems using underfloor heating loops, sometimes combined with radiators to better follow daily heating demand profiles.

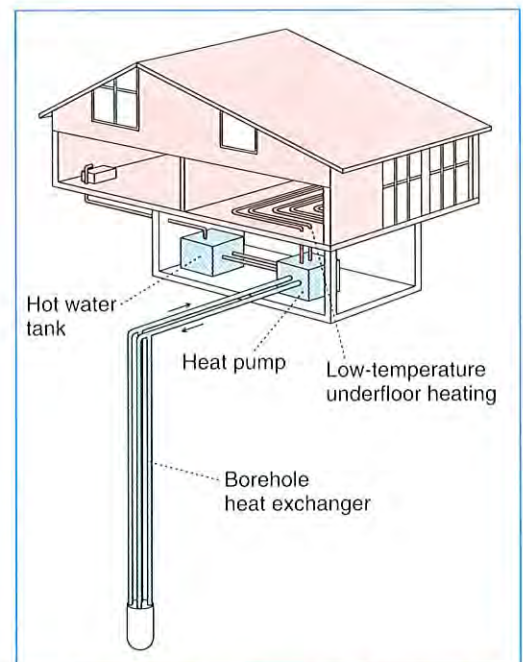


Figure 1: Typical application of a borehole heat exchanger (BHE) in a Swiss home.

### Choosing the Best Design

BHEs provide a reliable and flexible source of low-temperature heat for heat pumps. However, to achieve efficient operation at a reasonable initial investment cost, some care is required to ensure that

the BHE heat source is designed to suit the application. A primary requirement is that the three fluid circuits – the ground heat exchange loop, the heat pump working fluid circuit and the heat distribution circuit, be regarded as coupled components of one complete system.

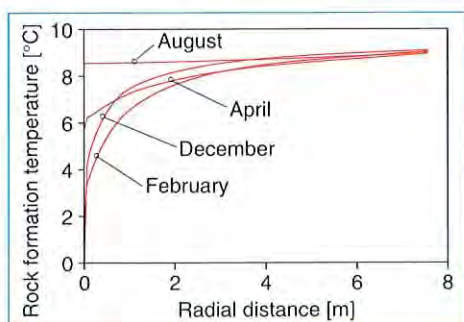


Figure 2: Cooling effect of a 105 m BHE on the surrounding ground at a depth of 50 m.

Borehole heat exchangers come in many types and sizes, some of which have been patented. The most common type is the double U-tube heat exchanger which is inserted into a 11.5 cm borehole of between 50 and 150 m deep. The borehole is subsequently backfilled with a mixture whose principal components are usually water, cement and bentonite clay. Initial experiences were with coaxial constructions and steel casings, but these have now largely given way to the double U-tube construction which is made of plastic. The handling advantages offered by the double U-tube, and the consequent cost reduction, override the thermodynamic advantages of the coaxial type at these small depths.

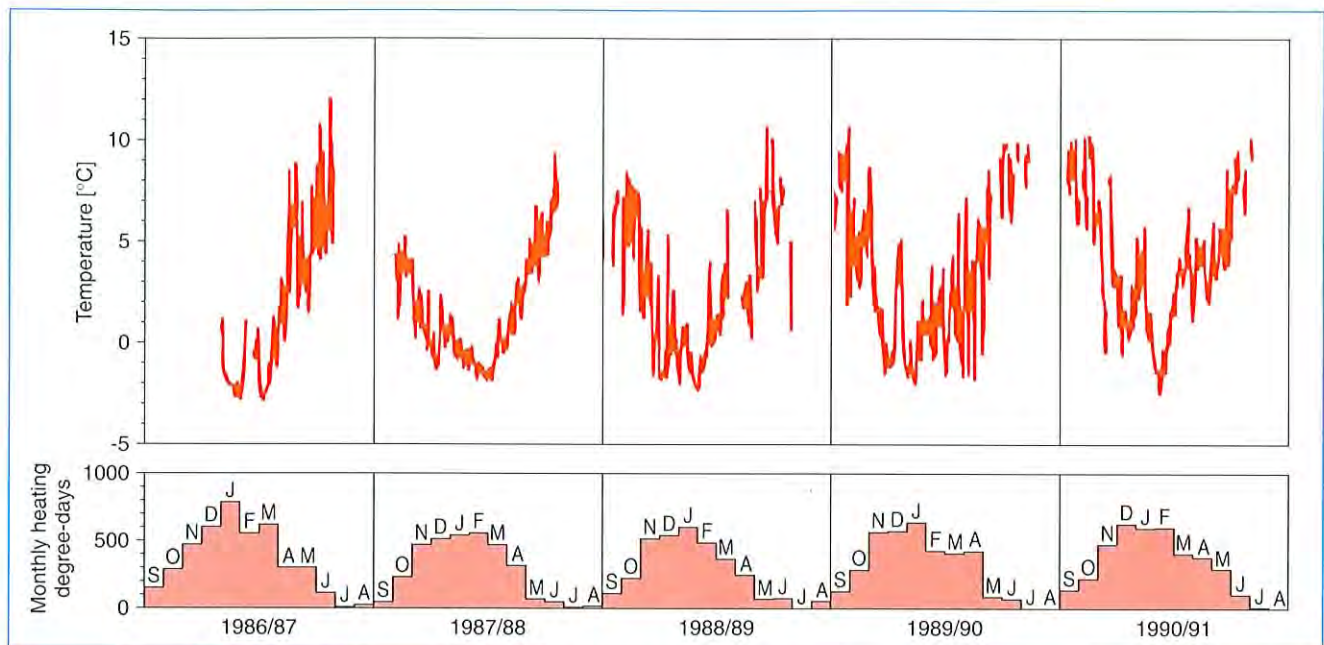


Figure 3: Annual variation in the temperature of brine fed to the heat pump.

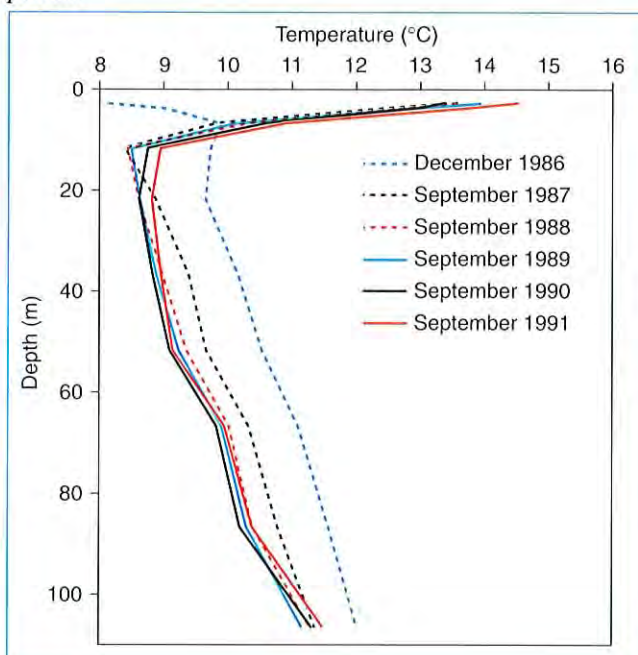
## Geological Limitations

In fact it is the low thermal conductivity of typical geological formations which essentially limits the heat flux into the heat exchanger. The limiting effect of the surrounding ground can be seen in Figure 2. In this diagram the ground temperatures around a 105 m deep BHE, at a depth of 50 m, are shown at different times during and after a winter heating season. It is

apparent that the temperature close to the BHE drops significantly during the heating period up until February. After that it quickly recovers as soon as the demand sinks below the supply potential from the ground.

As shown in Figure 3, a similar pattern is reflected in the annual profile of the source temperature (the inlet temperature on the brine side of the heat pump's evaporator). In this particular BHE, the source temperature regularly drops to between 0 and -3°C during the peak load period. This not only highlights the need for adding antifreeze to the BHE circuit but also shows that there is scope for improving the seasonal performance factor (SPF) by raising the average source temperature. Indeed this is desirable from the point of view of global resource conservation.

Figure 4: Temperature profile of a BHE over a five-year period.



## Improving the Performance

Since 1986, when the system illustrated in Figures 2 and 3 was installed, there has been a trend towards increasing the total installed BHE length per annual kWh demand, and towards deeper drilling. For a given application, fewer but deeper BHEs are more economical from the driller's point of view and also require less land area. Furthermore, the undisturbed ground temperature increases with depth. This means that the heat uptake potential is better if, for example, one 150 m hole is drilled instead of three of 50 m. However, in many situations, the drilling depth may be limited by other aspects, such as the need to limit the pumping energy in the ground loop, or to avoid a drinking-water aquifer.

A feature of BHE-system behaviour is a slight cooling of the ground during the first few years of operation. The

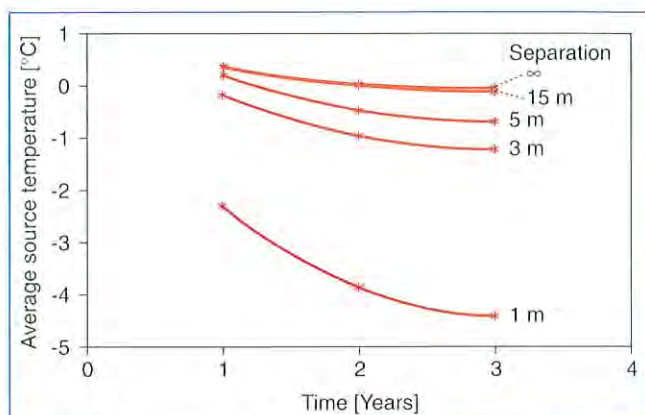


Figure 5: Impact of a BHE pair on the average brine temperature, for different lengths of separation.

incomplete recovery of the temperature field at 50 m depth by August 1989 is apparent in Figure 2. Figure 4 demonstrates the effect over the full length of the same BHE during five years of operation. After three years, fluctuations in the annual load begin to have a significant impact on the ground temperature, indicating that a new dynamic steady state is being rapidly approached in the ground. The BHE used in these measurements is by more recent standards rather heavily loaded at 110 kWh per meter length, at a site without the benefit of any groundwater flow and where the ground has only moderate thermal conductivity.

### Choosing the Right Spacing

If it is decided that several BHEs are needed, the choice of the distance between them is crucial. Whereas a well-designed single BHE does not suffer at all from the cooling effect, multiple heat exchangers placed too closely together will interfere with each other. Figure 5 illustrates this point with a simple example. Two identical BHEs, similarly loaded, are situated at varying distances apart. The annual average source temperatures during each of the first three years of operation are plotted from numerical model simulations. Although the interference effect is also influenced by the load intensity and the thermal properties of the ground, it is clear that the performance of a heat pump system is sensitive to the spacing of the heat exchangers.

### Further Developments

Based on experience in the residential sector, it has become possible to serve larger buildings by installing BHEs to greater depths (several hundreds of metres) or to use them in larger groups. A well-spaced group of BHEs can serve a commercial building with both heating and cooling. By specifying air cooling rather than full air-conditioning, and by judicious sizing of the heat exchangers, it is possible to operate for at least part of the cooling period in free-cooling mode

without refrigeration. When the cooling load is too high for free-cooling, the heat pump is operated in reverse mode. The heat rejection to the ground in this case is essentially a thermal recharge and offers double use of the investment in the BHE installation.

More closely spaced heat exchangers, connected in series, can form a seasonal energy store. Here the interference between them has a positive effect in that the whole ground volume is warmed during the storage phase. Despite leakage at the edges of the volume, useful storage efficiency can be attained. Such systems offer considerable flexibility in the choice of a store to match the required operating temperature conditions. The overall geometry of the field, and the spacing and hydraulic connections between the heat exchangers, must be chosen on the basis of temperature levels, the pattern of energy supply and demand, permissible losses and the characteristics of the ground.

### Benefiting from Experience

Since the first installations in 1979, experience and know-how of BHE-coupled heat pump systems have grown, both on the practical and on the theoretical sides. This has led to product improvement, to a wide variety of options and to new applications of the technology. For new houses, an optimized heat pump system now typically costs just 25% more than an oil-fired heating system, with operating costs some 25% lower. A well-designed system for space heating alone, using a heating system with a maximum water temperature in the range of 30 to 35°C can now be expected to operate at a seasonal performance factor (SPF) of around four. BHEs are thus making an important contribution towards reducing energy consumption in Swiss homes.

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# Earth Energy Heat Pumps for Canadian Homes

Cam McNeil, Canada

*Canada has the potential to be an excellent market for ground and water-source heat pumps (known as earth energy heat pumps). The climatic conditions are ideal, with the winters being too cold for air-source heat pumps, but with a substantial cooling demand in the summer months. Furthermore, the drive to save energy costs has led to many advancements in housing design. This article looks at an example of the latest technology and reports on a demonstration project under the Advanced Houses Programme.*

\* \* \*

Canada and the northern US offer excellent conditions for earth energy heat pumps as the full economic benefit of the technology can be offered all year round. Here the need for heating and cooling closely matches the capabilities of the technology.

The Canadian Earth Energy Association reports over 30,000 earth energy units installed in the country today. In the US, the DOE (Department of Energy) and the EPA (Environmental Protection Agency) are predicting a ten fold growth in annual sales of ground-source heat pumps by the turn of the century. It is not unreasonable to expect 100,000 earth energy units in Canada by the same time.

*The Novtec advanced house.*



And the energy-saving benefits would be significant. Canada has proclaimed, through the Energy Efficiency Act, some of the most stringent performance requirements for earth energy heat pumps in the world. The minimum performance CSA C446 rating conditions allowed for well water systems is a COP of 3.1 at 10°C water inlet temperature and 2.8 at 0°C liquid inlet temperature.

## Advanced Designs

A number of Canadian manufacturers have developed lines of high performance earth energy heat pumps. A good example is the TES line now manufactured by Envirothermic Technologies Ltd. of Mississauga and marketed in Ontario by York International.

The results of calorimeter testing on the XHE liquid-to-air heat pump series is shown in Table 1. The design criteria for this series was to improve on the best units then on the market and to optimize for heating.

The Bristol Inertia, an improved gas flow reciprocating compressor was chosen over scroll or other configurations for efficiency at earth energy operating conditions, cost and availability (in that order). A tube-in-shell liquid/refrigerant heat exchanger provided lower pressure drops and near flooded evaporator performance, as well as being easier to assemble.

Also employed were a louvred fin, rifflled tube, air coil and a heating-optimized biflow thermal expansion valve. A direct current electronically commutated motor (ECM) with programmable controls was used for the fan motor.

## Advanced Houses

The applicability of these new heat pump designs have been demonstrated in Canada's Advanced Houses Program. Under this program, ten teams from across the country were selected, after a rigorous national competition, to build energy-efficient houses. Of these world class energy and environmentally efficient houses (requiring only a quarter of the energy of conventional houses), half used some form of earth energy.

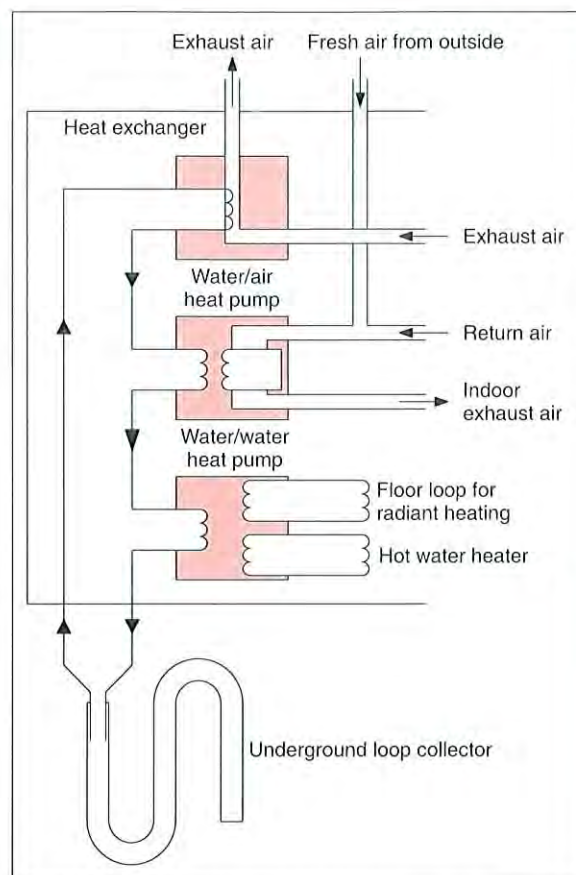
One example is the Maison Novtec in Montreal. Novtec has both a liquid-to-water and a liquid-to-air heat pump, each developed by Envirothermic Technologies Ltd. Both share a common horizontal

spiral ground loop with an exhaust-air heat recovery unit. This captures heat from house exhaust and excess solar gains from the sun-space to raise the heat pump inlet water temperature, thus raising the efficiency of the units.

The liquid-to-air unit provides all the cooling load and the upstairs heating load. The liquid-to-water unit meets the downstairs heat load with a radiant floor system. On a call for hot water, it diverts refrigerant to a second, double-walled condenser to heat the domestic hot water.

The Montreal Novtec house has an interior volume of 602 m<sup>3</sup>, with a design heat loss of 11.4 kW and total consumption of 11,864 kWh. Montreal has a design temperature of -23°C and 4,538 annual heating degree days.

Monitoring indicated that the power required for the loop pumping through the almost continuously-operating exhaust air heat recovery unit lowered the overall efficiency of the system to a COP of as low as 2.5. The heat from the exhaust air kept the short ground loop above 0°C through the record winter of 1993/94, but the efficiency gains to the heat pumps could not make up for the losses from pumping, from the extra heat exchanges to and from the earth, and earth storage losses. In the liquid-to-air heat pump, the parallel circuiting of the water to refrigerant heat exchanger has been changed to series in production models, which improves performance.



Heating/Cooling system for the Novtec house.

## More Than Capable

For success in tomorrow's residential and commercial/institutional HVAC marketplace, the next generation of earth energy heat pump technology must prove responsive to demands for:

- better indoor environment (comfort and indoor air quality);
- personal control and security;
- reduced utility peak load demands;
- performance throughout the building's life cycle;
- environmental responsibility (production, use and disposal);

- renovation and retrofit demands;
- capital and operating cost reductions.

The Advanced Houses programme will help prove that next generation Canadian earth energy heat pump technology is more than capable of meeting these challenges.

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|                                                                                                                              | Unit  | Air flow<br>(m <sup>3</sup> /s) | Liquid flow<br>(kg/min) | Pressure<br>drop<br>(kPa) | Heating<br>capacity<br>(kW) | Electric<br>power<br>(kW) | Heating COP<br>with pumping<br>(CSA C446) |
|------------------------------------------------------------------------------------------------------------------------------|-------|---------------------------------|-------------------------|---------------------------|-----------------------------|---------------------------|-------------------------------------------|
| Table 1:<br>Calorimeter<br>testing on<br>liquid-to-air<br>heat pumps by<br>the National<br>Research<br>Council of<br>Canada. | XHE-3 | 0.593                           | 18                      | 6.9                       | 9.78                        | 2.27                      | 3.7 @ 10°C                                |
|                                                                                                                              |       | 0.593                           | 30                      | 2.8                       | 7.82                        | 206                       | 3.5 @ 0°C                                 |
|                                                                                                                              | XHE-4 | 0.81                            | 26.4                    | 24                        | 14.3                        | 3.30                      | 3.8 @ 10°C                                |
|                                                                                                                              |       | 0.81                            | 37.5                    | 55                        | 11.3                        | 2.96                      | 3.6 @ 0°C                                 |
|                                                                                                                              | XHE-5 | 1.0                             | 30.0                    | 38                        | 17.5                        | 4.08                      | 3.6 @ 10°C                                |
|                                                                                                                              |       | 1.0                             | 45                      | 93                        | 13.5                        | 3.69                      | 3.3 @ 0°C                                 |

# The Nordic Heat Pump Competition

## Winners set New Standards in Performance and Price

Per Fahlén, Sweden

As was highlighted in the previous issue of the IEA Heat Pump Centre Newsletter (Vol. 13, No. 1), the Swedish National Board for Technical Development (NUTEK) announced two winners from its Nordic heat pump competition, in May this year. NUTEK has staged this competition in order to promote the development and sales of residential heat pumps in Denmark, Finland, Norway and Sweden. The aim is to substantially decrease the use of electricity for heating purposes in the building sector. While several contributions complied with the competition's requirements, two outright winners were selected. One winner was awarded for the best overall solution for the retrofit of houses with direct electric base-board heating (resistance heating) and one for the best universally applicable heat pump unit.

\* \* \*

Due to favourable electricity rates and well-insulated houses, electric heating has a substantial share of the Nordic market for heating systems in single-family houses. In Sweden alone, with a population of 8.5 million, around 1.2 million houses use electric heating. Approximately half a million of these houses have electric base-board heaters and thus lack traditional heat distribution systems.

Even though Nordic houses are energy efficient in an international perspective, the effect on the power grid is noteworthy. The annual electricity consumption in Sweden for residential heating purposes amounts to between 20 and 25 TWh, with peak loads around 5 to 10 GW. In this context, the heat pump generally comes up as the most viable energy conservation opportunity. Indeed, the 250,000 heat pumps already in use in Sweden provide annual savings of around 12 TWh, although it should be recognized that large district heating heat pumps provide two thirds of these savings.

NUTEK has set a target of reducing the annual national electricity consumption for heating purposes in the building sector by at least 5 TWh. A rough estimate is that this will require more than 500,000 residential heat pumps. On average, annual savings by

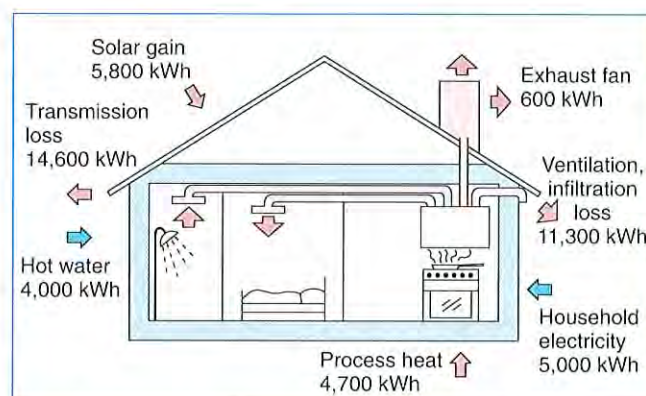


Figure 1: Annual energy flows for a typical Swedish home built in the 1960s-70s. With resistance heaters, 16,000 kWh electricity is required for heating and ventilation.

each unit must then be around 10,000 kWh. In the typical house (see Figure 1), this requires savings in both space heating and hot water supply.

It should be noted that in houses with electric base-board heating, retrofit installation of heat distribution systems will generally be expensive. Currently available equipment for these houses is either too expensive or provides insufficient energy savings.

### The Competition

The traditional means of promoting energy efficient equipment combine the stick and carrot in terms of legal requirements, grants and subsidized loans. These methods, however, have some drawbacks such as increasing public expenditure and maintaining high equipment costs at a high level. An alternative method, put to good use by NUTEK for other types of equipment in the past, is to stage a competition. Such a competition purports to focus public interest on energy efficiency in general and, in this case, on the heat pump in particular.

The objective of the Nordic heat pump competition has been to promote sales of heat pumps to electrically heated buildings by providing more effective, reasonably priced and sized heat pumps, specifically suited to these buildings. An important part of the competition was also to cooperate closely with companies having an influence on the market,

| Heat source       |                        |                        | Heat sink         |     |                |
|-------------------|------------------------|------------------------|-------------------|-----|----------------|
| Brine* inlet (°C) | Outside air inlet (°C) | Exhaust air inlet (°C) | Water outlet (°C) |     | Air inlet (°C) |
| +10               | +15(+12)               | +20(+15)               | +35               | +50 | +20            |
| +5                | +7(+6)                 | +20(+14)               | +35               | +50 | +20            |
| ±0                | +2(+1.5)               | +20(+13)               | +35               | +50 | +20            |
| -5                | -7(-8)                 | +20(+12)               | +35               | +50 | +20            |
|                   | -15                    | +20(+11)               | +35               | +50 | +20            |

\*For test with a DX-collector, the collector was placed in a tank with the prescribed temperature.

Table 1: Test conditions used for laboratory tests (temperatures within parentheses denote wet-bulb temperatures).

such as utilities and housing companies. Such companies were brought together in a task group which played an active role in laying down the specifications of the competition and which formed the jury that selected the winners. These companies will endeavour to install a minimum number of heat pumps and have provided contracts for the installation of heat pumps to the prize winners. Hence, the number of units will go up, prices will go down and energy will be saved at little extra cost for society.

To formulate a reasonable level of ambition, SP (the Swedish National Testing and Research Institute) used past experience from extensive testing, combined with calculations, to compile a set of technical specifications for the competition. These specifications consisted of two parts. Part one dealt with the heat pump per se and concerned installation, use, maintenance, repair-work, refrigerants, performance and noise. Part two dealt with the system aspects of the total installation such as the selection of heat source and heat sink, the power input to conveying devices, and the energy savings and economics.

## The Evaluation

After an initial screening of all entries, ten proposals were selected for the final evaluation process which consisted of:

- Laboratory tests at SP regarding performance and noise;
- Inspection of the heat pump units to check on ease of installation, use etc;
- Calculation of energy savings for a reference house;
- Perusal of the economic tenders and renewed price negotiations;
- Economic calculations based on estimated energy savings and the tenders.

Tests were carried out according to the European Standard prEN 255 whenever this was considered appropriate. Table 1 provides the test conditions.

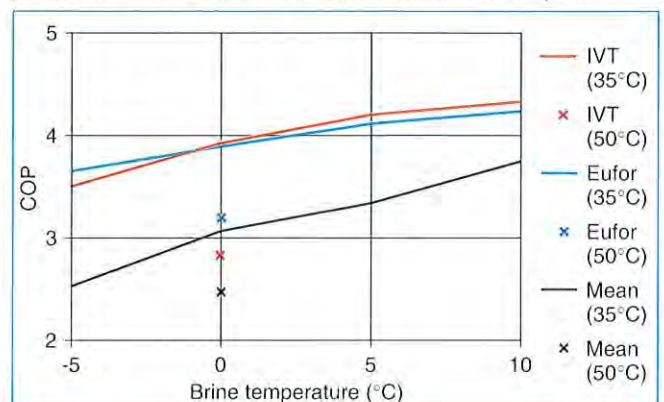
## The Winners

Of the ten finalists, six succeeded in complying with all the required specifications, of which three also managed to pass the desired high-level specifications. From the six successful designs, the task group of companies chose one outright winner in each of two classes. The winners, IVT and Eufor, were considered to offer the best balance in terms of efficiency, savings, noise, size, ease of installation, operation and maintenance, and general applicability. The winning designs both use shallow-grid earth collectors or dry-rock boreholes.

Negotiated investment costs for the winning heat pumps are below SEK 30,000 (US\$ 4000), making these systems economically attractive. This price includes the heat pump, borehole and installation costs, but excludes VAT (Value Added Tax), which is levied at 25% in Sweden. In the past, comparable installations would fetch a price exceeding SEK 40,000 (US\$ 5,400) excluding VAT.

The values measured for compressor coefficient of performance and heating capacity, under the test conditions of Table 1 are presented in Figures 2 and 3.

Figure 2: Coefficients of performance of the winning heat pumps. IVT has an indirect, pump-fed brine system and Eufor has a DX-coil. Results are therefore not directly comparable. Also included are mean values from tests made earlier on more conventional systems.



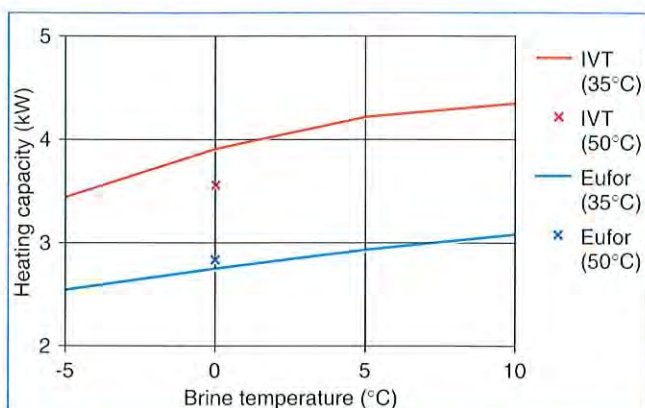


Figure 3: Heating capacities at an outlet water temperature of 35 °C for the two winning heat pumps. Capacities at the standard condition 0/50 °C are also included.

The measured indoor sound power emitted by the heat pump is depicted in Figure 4. As shown, all heat pumps tested were below the sound level classified as class 5.5. At this level the heat pump may be installed with only a door separating it from a sensitive space such as a bedroom or living room, where the level of sound experienced by the occupant should not exceed the stipulated maximum sound pressure level of 30 dB(A).

### The Best Unit

IVT of Tranås, Sweden were awarded first prize in the class for the best heat pump unit. Their contribution was an extremely compact and straightforward brine/water unit using R-407C as refrigerant. The unit, shown in Photo 1, measures 0.6 x 0.45 x 0.6 m and can be mounted on the wall and connected to a single-phase 230 V socket. It is quiet, with a noise level comparable to an ordinary refrigerator-freezer.

The compact size notwithstanding, the unit contains a rotary compressor, two stainless steel plate heat exchangers, circulation pumps for the brine and water systems, an expansion vessel, safety equipment and a control unit. Servicing has been made easier by providing the possibility to remove the entire cabinet, except for the bottom plate, without touching the pipe-work or electrical installation, thus facilitating easy access to all components. Calculated savings for the reference house exceed 8900 kWh/year for space-heating only, and rise by a further 2000 kWh if heating of tap water is included.

### The Best System

Top of the class for houses with electric base-board heating, i.e. no existing heat distribution system, was the heat pump system submitted by Eufor of Härnösand, Sweden (see Photo 2). With an interesting heat pump based on a direct-expansion (DX) ground-

source concept using two condensers in the indoor unit, the company succeeded in achieving high COPs and a heating capacity which is almost independent of the operating conditions (see Figures 2 and 3).

The heat pump is delivered as a hermetically sealed system with the DX-coil pre-charged (with R-407C refrigerant) and coiled-up on the heat pump. During installation the heat pump is positioned flat on its face and rotated while the collector is uncoiled and taken outside through a hole in a wall. The indoor unit contains a rotary compressor, an air-cooled condenser/sub-cooler, a water-cooled condenser, an expansion vessel, safety equipment and a sophisticated control/diagnostics unit. For regular service or repair-work, all the owner has to do is to plug in a smart-card and send it back to the manufacturer. This provides the service department with relevant information regarding the past and present status of the heat pump, hence minimizing unnecessary service-calls or arriving without the required parts.

The heat pump has a single-phase, 230 V connector and can be mounted, for instance, in an entrance-hall. It will then provide space-heating directly via the air-cooled condenser while the water-cooled condenser can be connected either to conventional radiators or to water-fed fan-coil units. Estimated annual savings for the reference house are approximately 8300 kWh for space heating, rising a further 1000-2000 kWh if tap water heating is included.

Photo 1: The winning heat pump unit from IVT.



## A Success to be Built on

As a result of the Nordic heat pump competition, a new category of heat pumps has been developed. It is specifically directed towards the market segment with an energy use too small to validate the use of traditional heat pumps but still large enough to be seriously considered by owners, utilities and society as a whole. The winning systems use the ground as heat source and show improved performance and a drastic price-cut for this type of system.

However, energy savings will only be accomplished by heat pumps in actual operation. No system, however promising, will contribute at the conceptual stage. Therefore, all parties involved in the competition are now eager to ensure that these installations are realized and that they perform according to expectations. Furthermore, NUTEK is actively working in the field to promote sales, not only of the winning systems, but of all systems that succeeded in complying with the specifications of the competition. With performance up and prices down, it may well be said that so far the Nordic heat pump competition has been a success.

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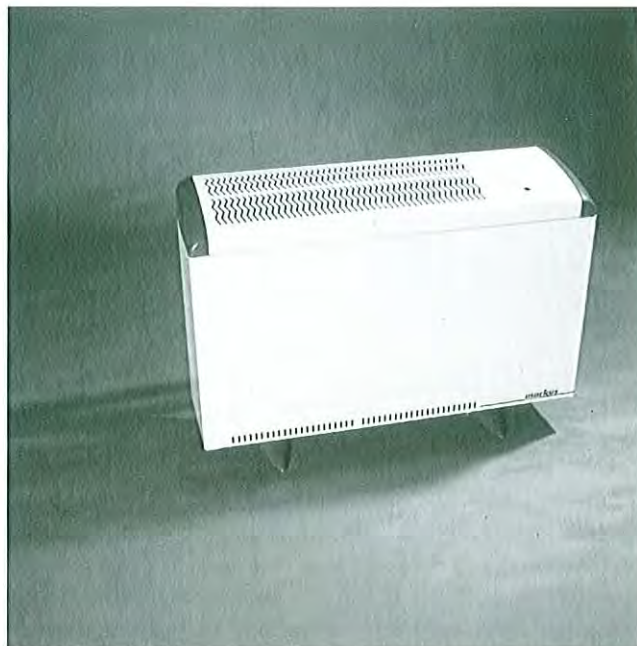
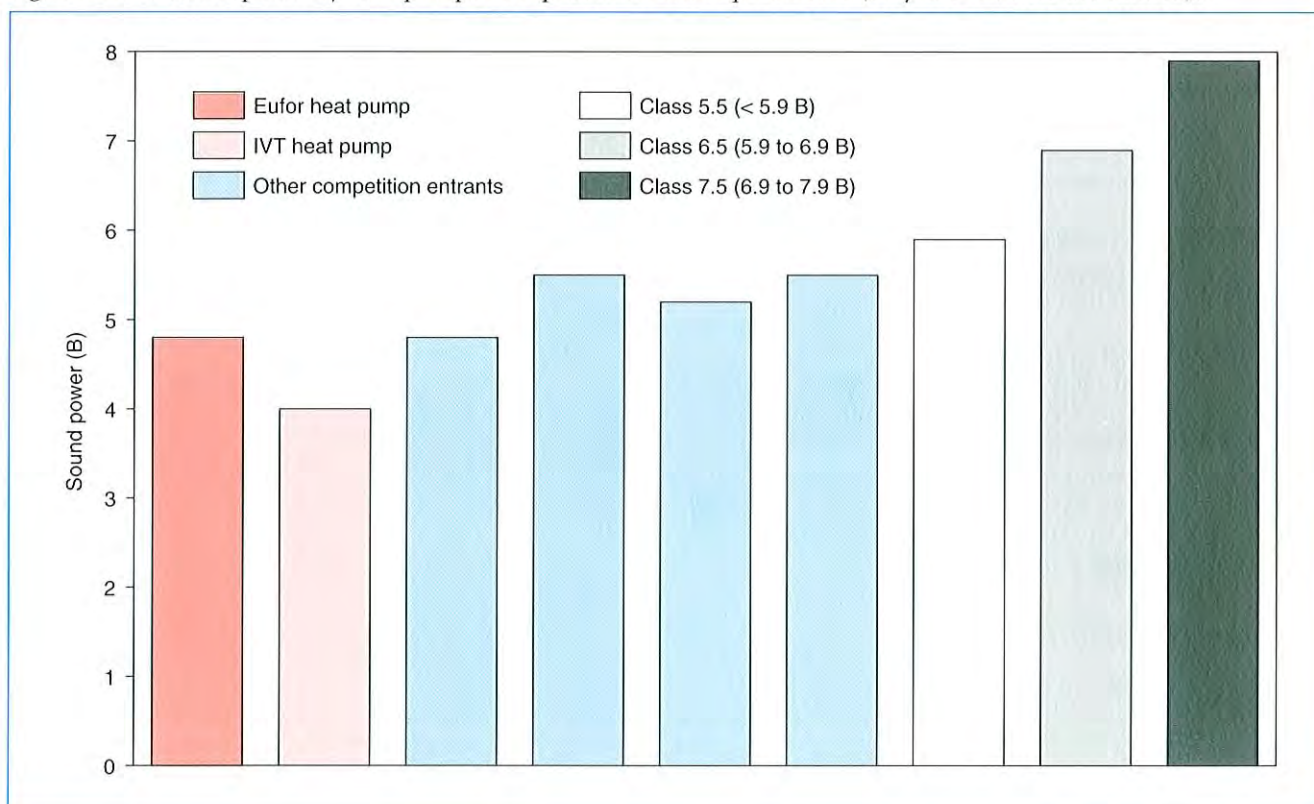


Photo 2: The winning heat pump system from Eufor.



Figure 4: The sound power of heat pumps that passed all the requirements (only the winners are named).



# The World's Best Selling Heat Pump

## What Makes the Japanese Room Heat Pump so Successful?

Hiroshi Itoh, Japan

*With 1994 sales of almost six million units in Japan alone, Japanese room heat pumps far exceed sales of any other heat pump type in the world. The remarkable popularity of these air-to-air reversible air conditioners is the result of a growing demand for increased comfort in the home, both in summer and in winter.*

*Since its introduction in the early 1970s, many refinements have been made to the room heat pump, bringing better comfort, less noise and improved energy efficiency. This article discusses the development of room heat pumps in Japan and describes the features of today's units that make them so successful in residential applications.*

\* \* \*

In 1994 about seven million room air conditioners (RACs) were sold in Japan of which about six million were heat pumps. Figure 1 shows the recent shipments of RACs. Though the shipments are influenced by business fluctuations and the weather,

the ratio of heat pumps has been getting consistently higher. This is because consumers have responded to improvements in basic performance factors such as heating capacity, power consumption and noise. Furthermore, there is increasing acceptance that heat pumps offer many benefits including safety, clean and easy operation, combined cooling and heating, and compactness. A brief history of RACs in Japan is given in the blue box.

Since 1987, most RACs sold have been inverter-aided (variable-speed) heat pump units. One reason for this is the habit of the Japanese user. Most people switch on their RAC when they enter the room, and switch it off when the room is not being used. Therefore, the inverter-aided RACs, which can be operated at high capacity at the initial stage and with lower capacity thereafter, are the most popular.

### Equipment Types

A typical 1994 room heat pump is shown in Photos 1 and 2. Table 1 compares the specifications of this model with those of the first inverter model of 1982. As depicted in Figure 2, the split-type room heat pump consists of two units: an indoor unit and an outdoor unit connected with piping and wiring. The outdoor unit has a compressor, a heat exchanger, a propeller fan and an inverter. The indoor unit has a

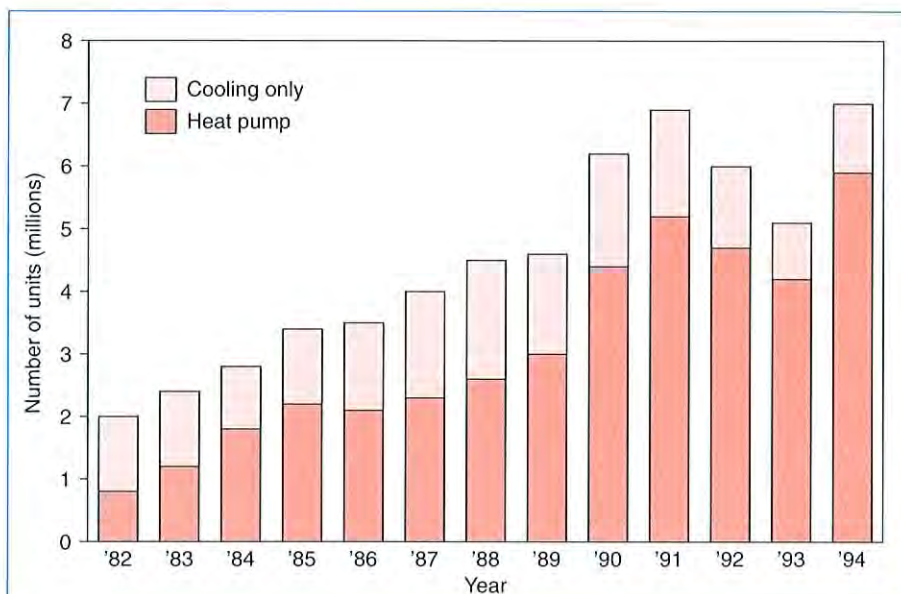


Figure 1: Sales of RACs (room air conditioners) in Japan.

heat exchanger, a cross-flow fan and a controller. The refrigerant is HCFC-22.

Most heat pumps are designed to operate using a 100 V power supply. Very few operate with 200 V even though many homes now have 200 V power.

The most common indoor unit is the wall-mounted type shown in Photo 1, which can be installed after the construction of the building is finished. Though the demand for built-in-type room heat pumps, which are installed during the process of building construction, is getting larger, they have not yet become significant.

The wall-mounted split-type room heat pump can be conveniently set in any type of house, and has the advantage of not taking up valuable floor space. However, fixing the indoor unit to the upper part of the wall can mean that only the upper part of the room is heated. To solve this problem, a louvre is put at the air-outlet that automatically directs the air downwards during heating, and horizontally when cooling.

Since the compressor is in the outdoor unit and the load on the indoor unit fan is low, split-type room heat pumps create very little noise or vibration. Furthermore, the speed of the indoor unit fan is reduced automatically when the desired room temperature has been reached. The noise level is below 30 dB(A) in the minimum air-flow operation.



Photo 1: The indoor unit.

The specified heating capacity is 1.5 times larger than the cooling one because of the heavier load in heating. With inverter-aided compressor speed control, the range of capacity can be varied between 20% and 160% of the specified values. The desired room temperature is generally achieved by setting the output frequency of the inverter according to the difference between the room temperature and the desired temperature.

Japan has a rainy season, and the humidity in summer is very high. Therefore the dehumidifying function of the room heat pump is important. Dehumidification works by cooling the air to below the dew point and draining away the water that condenses out. There are several methods for doing this:

- the heat exchanger in the indoor unit is divided into two parts: one is used for cooling the air to

### History of the Japanese Room Air Conditioner

|      |                                                                                                           |
|------|-----------------------------------------------------------------------------------------------------------|
| 1953 | First window-type room air conditioners (RACs).                                                           |
| 1961 | First split-type RACs.                                                                                    |
| 1964 | First Japan Industrial Standards (JIS) for cooling-only equipment.                                        |
| 1965 | One hundred thousand units shipped.                                                                       |
| 1967 | First RACs with rotary compressor.                                                                        |
| 1969 | First wall-mounted-split-type RAC. First dehumidifying RAC.                                               |
| 1970 | One million units shipped. Most RACs shipped were split-type. Complaints about noise were voiced.         |
| 1971 | First JIS for heating. First heat pumps, including back-up resistance heating. First multi-type RACs.     |
| 1973 | Two million units shipped.                                                                                |
| 1974 | Complaints about heating capacity were voiced.                                                            |
| 1975 | First wall-mounted-slim-type (17 cm in depth) RACs. First heaterless heat pumps (without back-up heater). |
| 1978 | First RACs with microprocessor.                                                                           |
| 1979 | Three million units shipped.                                                                              |
| 1980 | Most heat pumps shipped were heaterless.                                                                  |
| 1982 | First inverter-aided (variable-speed) RACs.                                                               |
| 1983 | First RACs with DC compressor motor.                                                                      |
| 1984 | Most RACs shipped were heat pumps. First heat pumps with electronic expansion valve.                      |
| 1985 | First built-in-type (cassette) RACs.                                                                      |
| 1987 | Most heat pumps shipped were inverter-aided. CFCs and peaks in electricity demand became issues.          |
| 1988 | First gas RACs (electric RACs with refrigerant heated by gas burner in outdoor unit).                     |
| 1989 | First RACs with two-cylinder rotary compressor.                                                           |
| 1990 | First RACs with scroll compressor. First RACs with fuzzy and neuro logic.                                 |
| 1992 | Outdoor units became compact and fashionable. The depression started.                                     |
| 1994 | First energy-saving-type RACs.                                                                            |

Table 1: Specifications of Japanese room heat pumps.

| Specification                           | '82 model       | '94 model       |
|-----------------------------------------|-----------------|-----------------|
| Cooling/heating capacity (kW)           | 2.6/3.6         | 2.5/3.6         |
| Cooling/heating power consumption (W)   | 1130/1150       | 640/840         |
| Cooling/heating COP                     | 2.2/3.1         | 4.1/4.3         |
| Indoor/outdoor unit noise level (dB(A)) | 39/47           | 35/39           |
| Indoor/outdoor unit weight (kg)         | 11/43           | 8/34            |
| Indoor unit size (mm) [H x W x D]       | 370 x 790 x 165 | 265 x 790 x 174 |
| Outdoor unit size (mm) [H x W x D]      | 525 x 720 x 300 | 530 x 695 x 245 |

below the due point and the other reheats it to the required temperature for air conditioning;

- a resistance heater is used to reheat the air after it has been cooled air to below the due point;
- the control program decreases the sensible heat factor of the evaporator and reheating is achieved by radiation from the human body and/or heat from outdoors.

## Compressors

The major types of RAC compressor are rotary and scroll. The rotary compressor has the advantage of being easier to manufacture, because of its simple construction. Also, the scroll compressor exhibits a lower efficiency due to its fixed compression ratio. The scroll compressor does, however, have the advantage of lower noise and vibration. This is because scroll compressors exhibit lower torque alternation despite many improvements in rotary compressor design such as the use of two-cylinder designs or motor torque control.

The compressor is generally mounted vertically, although the use of horizontal mounting has increased as it offers a more effective layout of heat exchanger and fan. Most room heat pumps are driven by an inverter-controlled DC brushless motor, operating between 600 and 6000 rpm. Under standard ASHRAE conditions, room heat pump compressors exhibit a cooling COP of at least three.

## Heat Exchangers

The most common type is the two-row finned tube with a diameter of 6 to 9 mm. The slit fin with ripple tube (about 0.2 mm height) is usually used to achieve better heat transfer. Hydrophillic treatment is given to the surface of the fin to make water spread smoothly along its surface. To minimize pressure losses, the refrigerant flows are distributed in two, three or four circuits.

It is very important to have the right combination of heat exchanger and fan. For example, L-shaped or U-shaped heat exchangers should be used with a propeller fan. When a cross-flow fan is used, the heat exchanger should be designed to surround the fan.

## Inverters

The inverter controls the power input to produce variable frequency and voltage output. It consists of a converter section, which transforms AC into DC, and an inverter section, which transforms DC into AC at controlled frequency and voltage. A pulse-width-modulated (PWM) inverter has been chosen for heat pumps due to its simple configuration and low cost. The wave information is stored in read-only-memory (ROM), typically an 8 bit memory chip. Six power transistors are contained in one module and driven at about 2 kHz switching speed to produce power at the required frequency and voltage. The efficiency is over 90% at full load. An intelligent power module (IPM), in which the power circuitry is controlled by a microprocessor, is under development.

## Controls

The indoor unit contains a microprocessor-based controller — the RAC controller — which uses various control algorithms including PID (proportional, integral and difference), fuzzy, neuro, and genetic. Controlling consists of four aspects:

## Interface

A hand-held remote control unit (see Photo 3), equipped with a microprocessor and liquid crystal display, provides the interface between the user and the RAC controller. Its many functions include on/off control, operation mode setting (cooling/heating/



Photo 2: The outdoor unit.

dehumidifying) and automatic operation (setting the standard operation mode). It can, for example, be used to set the temperature, the air quantity and the timing, and can control the louvre. When a fault occurs, a code number is displayed which locates the point of the trouble and allows a quick service.

### Performance

The following functions are controlled:

- **the compressor speed** – for fast warm-up and minimum temperature fluctuation;
- **the fan motor speed** – for a good balance between low noise, comfortable temperature, air draft, and energy saving;
- **the defrost system** – for minimum defrost time and to prevent cold air blow and reversing noise;
- **the electronic expansion valve** – for efficient and reliable heat pumping.

### Protection

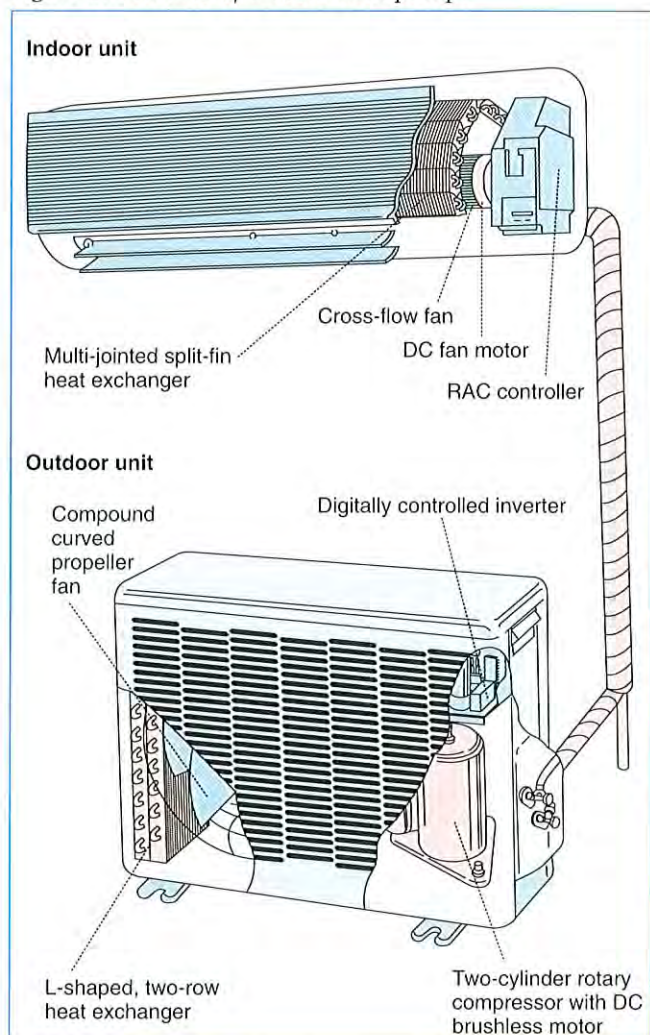
The RAC controller performs many tasks that help to protect the hardware:

Photo 3: The remote control unit.



- preventing operation when connection is made to the wrong supply voltage or if the wiring is incorrect;
- preventing overheating of the compressor, fan motor and power transistor;
- detecting refrigerant undercharge and evaporator freeze-up;
- maintaining the pressure balance by controlling the on/off switching cycle of the compressor.

Figure 2: Features of a room heat pump.



### Monitoring

To optimize comfort and to minimize noise and energy consumption, the RAC controller monitors a large number of parameters such as the air temperature, humidity, radiation temperature, compressor speed, fan speed and louvre direction. With this information, many control functions are carried out. For example, the system of best predicted mean vote (PMV) can be used to prevent direct draft, or to avoid over-cooling while the user is sleeping by increasing the temperature gradually.

### Remarkable Progress

The Japanese room heat pump has certainly made remarkable progress since its first introduction in 1971. The user has benefited from greater comfort and reduced noise. And, especially with the introduction of the latest energy-saving models, society as a whole is benefiting from a reduction in the use of energy resources for the provision of heating and cooling in the home. Further developments can be expected, with the introduction of a new refrigerant to replace HCFC-22 a top priority.

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# Getting the Best out of Residential Heat Pumps

Hermann Halozan, Austria

*Heat pumps offer the possibility of efficiently producing low-temperature heat for heating purposes in housing. But to fully utilize this feature, all other components such as the building itself, the heat distribution system and the heat source system, should be taken into consideration as well. Low heating-energy buildings equipped with low-temperature distribution systems offer ideal conditions for heat pumps, leading to seasonal performance factors (SPFs) of up to five.*

\* \* \*

Presently, 125,000 heat pump units are in operation in the residential sector in Austria, of which about 25,000 are used for space heating purposes and exhaust air heat recovery, and 100,000 are heat pump water heaters. The installed thermal capacity is about 550 MW, the annual heat delivery is about 1.4 GWh and the annual CO<sub>2</sub> emission reduction, based on oil, is about 800,000 tonnes. Additionally, an increasing number of reversible heat pump air conditioners are in operation.

In recent years, successful developments have increased the efficiency of heat pump units and components. However, looking at the performance characteristics of advanced units, one is astonished by the poor SPFs which are often realized in practical applications in the residential sector. Analyzing the systems, the reason for poor results can be easily found. It is either that the heat source systems result in extremely low evaporation temperatures during the heating season, or that the supply temperatures are too high. Either way, the temperature lift which has to be covered by the heat pump is too large to achieve a high SPF.

The heat source system is usually fixed by the site. The supply temperature depends on the building design and on the distribution system selected. The room temperature required in residential buildings, however, is always the same: 20 to 21°C.

## Thermodynamic Considerations

Heat in residential buildings is most commonly provided by burning fuels, mainly fossil fuels.

Considering the first law of thermodynamics, this process sounds favourable considering that energetic efficiencies based on the lower calorific heating value can reach 90%, or in the case of gas-fired condensing boilers up to 105 %. However, considering the second law of thermodynamics, things change.

Thermal energy can be divided into two parts:

- **exergy** which can be transformed into all other kinds of energy;
- **anergy** which is the amount of energy at the temperature level of the ambient, that cannot be utilized, except by heat pumps.

The value of heat - the amount of exergy - depends on the temperature of the heat and the ambient temperature: the higher the temperature, the higher the relative amount of exergy.

Energy at a temperature level of 21°C, at an ambient temperature of 0°C, consists of about 7% exergy and 93% anergy. These are average conditions for space heating. Fossil fuels can be considered as sources of pure exergy - the exergy content corresponds approximately to the higher heating value of the fuel. This means that when fossil fuels are used to provide this space heating, pure exergy is depreciated to energy of just 7% exergy. If an ideal heat pump were used, it would only require this 7% exergy - or in other words, the Carnot COP would be about 14.

In practice, the amount of exergy required by a heat pump will be higher due to the temperature differences necessary for heat transfer from the heat source to the evaporator and from the heat pump condenser to the heat sink medium. Additional losses will occur in the compressor.

## European Heating Systems

In Europe, the most common heat sink medium is water for use in hydronic (wet) heating systems. The supply temperature required is strongly dependent on the building and the distribution system selected: the higher the thermal insulation of the building, the lower the specific heat load (W/m<sup>2</sup> heated space). A low specific heat load offers the possibility of low-temperature distribution systems. The low supply temperatures required then present a distinct advantage for heat pump operation.

Buildings constructed in the Fifties and Sixties usually have a poor thermal quality. In those years, energy was cheap – the only important factor was to produce living space. The heat distribution systems installed were high-temperature radiator systems with design temperatures of 90°C supply temperature and 70°C return temperature. In Austria, an oil-fired boiler was commonly used for heat generation. Attitudes changed, however, after the first oil price shock in 1973, when governments and people realized the dependency of their countries on imported energy – mainly oil.

## New Priorities

In 1980, the IEA report "A Group Strategy for Energy Research, Development and Demonstration" was published. The result of this study, which used the MARKAL computer model, led to two important observations:

1. The sector in which energy conservation and oil substitution is most promising is the building sector. The reduction of energy consumption in industry will be slow. The energy consumption of traffic will further increase.
2. The major part of energy conservation in the building sector will be achieved by district heating with cogeneration plants, solar energy utilization, and heat pumps. Heat pumps should be responsible for 80 % of this energy conservation.

Investigations in Austria came to a similar result. The building sector is the most promising area for reducing the energy consumption by improved thermal insulation, ventilation combined with heat recovery, and highly efficient heating systems using heat from heat pumps or cogeneration systems.

The goal at this time was to reduce the consumption of imported oil. Nowadays, it is the reduction of CO<sub>2</sub> emissions from burning fossil fuels. Looking at Austria, the technical potential for energy conservation and reducing CO<sub>2</sub> emissions in this sector is in the range of at least 67%, considering the possible improvement of buildings. Introducing heat pumps means a further significant reduction potential.

## Advanced Houses

In recent years, the specific heat load of new residential buildings has dropped from 160 W/m<sup>2</sup> down to 60 W/m<sup>2</sup>, or even down to less than 50 W/m<sup>2</sup> with the use of the latest glass technology in windows. This reduction in the heat load has offered the possibility of designing radiator systems with supply temperatures of 55°C, and floor heating systems with temperatures of 45°C. And for houses with a 50 W/m<sup>2</sup> specific heat load, the ultimate low-temperature distribution system is floor heating at 35°C.

For a low heating-energy house, a properly sized direct-evaporation ground-coupled heat pump with a horizontally installed coil and a low-temperature floor heating system results in an SPF of four or even higher (see Photo 1). The explanation for this high SPF is simple. The maximum supply and condensing temperatures do not exceed 35°C on the coldest day and the evaporation temperature does not drop below -10°C. The maximum temperature lift is therefore 45°C and the average lift is significantly lower. It should be noted that the supply and condensing temperatures are at the same level when superheating is used.

To avoid mixing losses caused by too high a heat pump outlet temperature, the compressor can be operated at two speeds. On/off losses are reduced by using the cement floor as a thermal store which is charged by the heat pump. Temperature control is carried out by a room thermostat which automatically takes the building characteristics into account. With massive buildings, the heat load dependency on the outside temperature is damped and delayed such that, for example, heat load peaks in the morning, when the lowest outside temperatures occur, can be reduced.

For a specific heat load of 50 W/m<sup>2</sup>, more than half (29 W/m<sup>2</sup>) of this load is due to ventilation losses while only 21 W/m<sup>2</sup> is due to transmission losses. Ventilation losses, which are a result of the requirement for fresh air in the building, can be reduced in houses with controlled ventilation systems by using heat recovery systems based on various types of heat exchangers and/or heat pumps. While heat exchangers can only reduce the heating demand, heat pumps can additionally provide heat at a temperature level suitable for heating purposes or, if no heating demand exists, for hot water production. In Sweden, such systems cover up to 70% of the total annual heat demand for heating and hot water production. Presently, they are also being introduced in Austria.

A further step will be the reduction of the transmission losses down to 10 W/m<sup>2</sup>: In this case it should be possible to cover the total heating demand with the ventilation system equipped with a heat pump for heat recovery and heating purposes. An additional feature of such heat pumps is the possibility of cooling and dehumidification during summer time.

## Becoming Even More Significant

There are many possibilities for using heat pumps in residential buildings. The most important point to consider in the development of future homes is the interaction between the building, heat pump, distribution system, and last but not least the customer.

Primarily, a house must be designed in a way that matches the requirements of the consumer. It must be thermally insulated to reduce transmission losses

through the building envelope, and the air exchange rate must cover the needs of people and the building itself. This requires a controlled ventilation system which, when combined with heat recovery, minimizes the space heating demand of the house.

In this way, low heating-energy houses offer low energy consumption through the building structure itself. The remaining heat demand can be met at high efficiency by means of heat pumps. With a low specific heat load, such houses have the possibility of using low-temperature distribution systems. Systems with measured SPF's of four and higher are already in operation in Austria. In the most advanced houses, and with advanced heat pump units, perhaps using propane as a refrigerant, SPF's of five can be expected in the near future. Clearly, the heat pump's potential for energy conservation and emissions reduction, especially the reduction of greenhouse gas emissions, is becoming even more significant.

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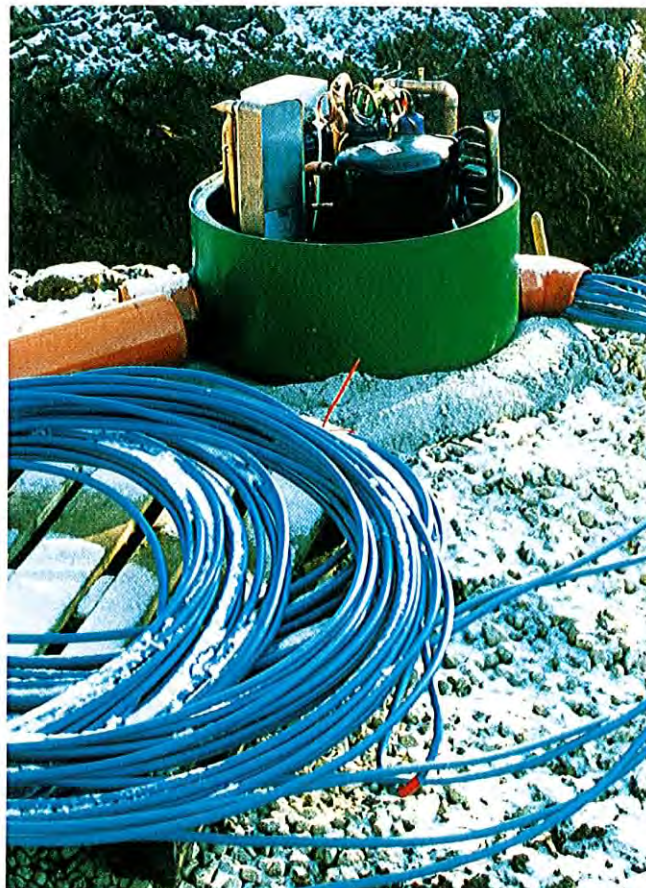


Photo 1: A popular heat source for space heating heat pumps in Austria, the propane-filled direct-evaporation coil can help to achieve a very high SPF in a low heating-energy home.

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# Heat Pump Development Trends in Japan

Jos Bouma, IEA Heat Pump Centre

*Japanese development work in the field of heat pumps has attracted worldwide interest in recent years. The results can already be seen in currently available products which feature many innovations for greater comfort and efficiency. Even more impressive are the targets set for the development of heat pumps for the next century. On a recent trip to Japan, the HPC's General Manager, Mr Jos Bouma, took the opportunity to keep in touch with the latest developments by meeting representatives of equipment manufacturers, government agencies and the Japan Gas Association. This article reports back from his visit.*

\* \* \*

The development of heat pump technology in Japan is strongly influenced by the need to reduce energy consumption. Residential electricity consumption in Japan is growing steadily. The share of space conditioning equipment has risen from 12.6% of total residential power demand in 1985 to 19.9% in 1993. Interestingly, the share of refrigerators has reduced in the same period from 26.4% to 19.8%.

New Japanese energy saving regulations will lead to further improvements in the efficiency of both space cooling and space heating equipment. Whereas energy saving regulations implemented in 1995 are

## Complaints About Comfort

Typical complaints concerning a lack of comfort when heat pumps operate in the heating mode (in order of severity):

1. Not warm at floor level;
2. Lack of humidity;
3. Not warm enough;
4. Unfavourable vertical air temperature distribution;
5. Long start-up time;
6. Too warm once floor has reached the right temperature;
7. Uneven temperature distribution in the room.

| Unit         | Present regulation | 1998 regulation                        |
|--------------|--------------------|----------------------------------------|
| Cooling-only | 2.92               | 3.09                                   |
| Heat pump    | -                  | 2.67 <sub>c</sub><br>3.20 <sub>h</sub> |

Table 1: Minimum rated COPs under Japanese energy saving regulations.

for cooling-only products, the new regulations to be implemented in 1998 apply to heat pumps as well. The 1995 and 1998 minimum average weighted COP at rating conditions for a split-type unit with a cooling capacity of less than 4 kW are compared in Table 1.

Minimum efficiency ratings are not, however, the only incentive for manufacturers to improve the efficiency of their equipment. Indeed, some of today's room heat pumps already exceed the minimum COPs that will be stipulated by the 1998 regulation. For manufacturers competing in the large room heat pump market, it is customer demand that drives efficiency improvements.

## Toshiba Corporation

At Toshiba, improvements in equipment performance have been steered by the results of a users' need survey. Many users complained of the relatively high running costs of space conditioners compared to other home appliances. They also expressed dissatisfaction over comfort (see Box).

Toshiba has tackled these complaints in many different ways. It's latest room heat pump features the following improvements:

- a new digitally controlled twin rotary compressor with improved rotor magnet;
- improved heat exchangers for greater evaporator/condenser efficiency and more uniform air flow from the indoor unit;
- a direct current driven fan motor (indoor unit);
- a screw cross-flow fan for low noise emission (indoor unit);

- a control system using predicted mean vote (PMV) and genetic algorithms (GA).

Innovations in control mechanisms are especially significant. PMV provides automatic room air temperature control based on human comfort needs. Parameters used for calculation of the desired temperature include humidity, radiation, air flow, metabolics and the type of clothing of people in the room. The energy saving effect is estimated at 20% relative to fixed room temperature control.

Genetic Algorithms (GA) control will be used for the first time in home appliances such as heat pumps. With this type of control, the computer applies a method that is said to imitate the process of the evolution of life. This leads to improved control dynamics with faster stabilization of conditions after start-up or disturbances such as the opening of a window.

Future developments at Toshiba will concentrate on efficiency improvement, especially in electric motors and heat exchangers, on the development of (H)CFC/HFC-free equipment, on cost reduction and on improved humidity control.

### Sanyo Electric Co.

The Sanyo Electric Co. is one of the world's leading manufacturers of medium and large-size absorption

equipment. It produces 60 to 80 systems every month, of which 30% are steam-fired and 70% are gas-fired. The company's latest model is designed to use water from sewage treatment plants and rivers to meet the air conditioning and heating needs of small urban areas. Sanyo Electric absorption heat pumps have also been successfully applied for heat recovery in refuse incineration plants in Sweden and Denmark.

Another significant product is the gas engine heat pump. On average, 25 units are manufactured daily by Sanyo Electric. Mazda engines drive the large heat pumps and the small ones are equipped with a Kubota engine. The system maintenance interval has been prolonged drastically.

Sanyo Electric is also working towards the next generation of environmentally friendly space conditioners using advanced cycles. A Stirling engine type direct drive heat pump (DDHP) using the Vuilleumier cycle has been successfully developed. The DDHP uses environmentally safe helium as the working gas and can simultaneously provide space and water heating as well as cooling. The company plans to have a 6 kW heating capacity unit ready for commercialization in 1997. The targeted PER (primary efficiency ratio) of these gas-fired units is 1.3 and 1.5 respectively.

### Japan Gas Association

With severe restrictions on building new power stations, coupled with the need to reduce summer peaks of electricity demand, the perspectives for gas driven HVAC equipment are likely to improve. With this in mind, the Japan Gas Association has been promoting an R&D programme for residential gas air conditioners since 1992.

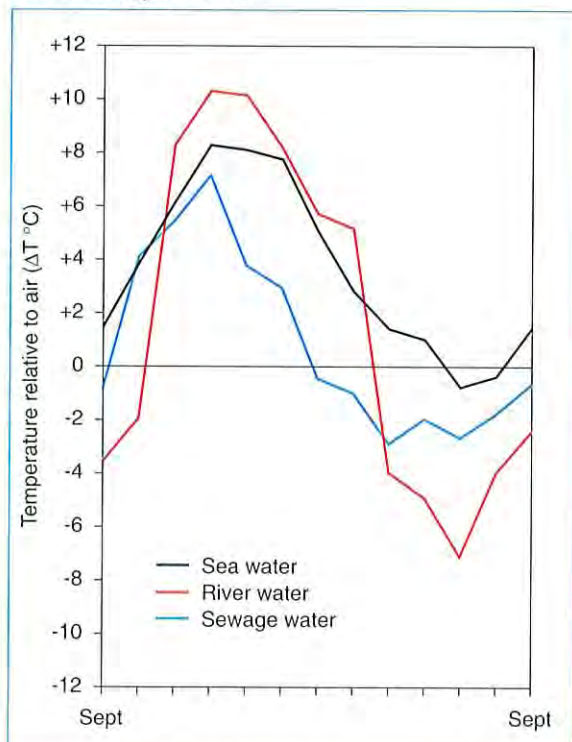
This US\$ 40 million R&D programme, which has equal backing from the government, through MITI (Ministry of International Trade and Industry) and the private sector, has resulted in three heat pumps that are now undergoing field tests, and which will be marketed within one to two years.

A 3.5 kW heating capacity, water/lithium bromide absorption heat pump has been developed by Takagi Industries. Its ventilation air heat recovery configuration eliminates the need for an indoor unit.

Gas engine heat pumps have been developed by Sanyo Electric and Honda (6 kW heating capacity), and by Yanmar Diesel Engine (8.7 kW heating capacity). Both operate at 3000 rpm instead of the conventional 2000 rpm and have vertically-aligned compressor and engine. These features have contributed to their small size. The engine lifetime is projected to be ten years with just one maintenance service after five years.

The Japan Gas Association is also supporting further development of a Vuilleumier heat pump by Sanyo Electric and an ammonia-water absorption system by Matsushita Electric.

Figure 1: An illustration of the potential effectiveness of low-temperature natural and waste energy sources.



## NEDO

In Japan, natural and man-made heat sources such as sea water, river water and sewage water are considered relevant energy sources that should be tapped for heating and cooling purposes. The potential of these sources is demonstrated in Figure 1.

Two loosely connected national programmes, coordinated by NEDO (New Energy and Industrial Technology Development Organization), are carried out in this area.

- Development of Technology for Load Levelling Air Conditioning Using Unused Energy;
- The Broad Area Energy Utilization Network System (Eco Energy City).

Under these programmes, activities are focusing on the development of large-scale technologies for energy-efficiency, heat transmission and thermal storage, and the planning and operation of integrated systems which combine these technologies.

## Unused Energy

The Heat Pump Technology Center of Japan (HPTCJ), home of the HPC's National Team, has a managerial role in the programme "Development of Technology for Load Levelling Air Conditioning Using Unused Energy". This programme is developing various technologies for using waste heat.

For low-temperature heat sources, a compression heat pump with improved load follow (adaption to daily and seasonal variations in source temperature) has been developed. For high-temperature heat sources, a system described as a "heat pump topping system" uses high-temperature steam to drive a turbine heat pump. The extracted lower temperature steam, goes on to drive an absorption heat pump.

Another system features a so-called "segmented heat recovery heat pump" that can heat and cool simultaneously. The programme is also developing software tools to help with the design of waste energy utilization systems.

The design and manufacturing of equipment was completed in 1994 and evaluation studies are now being undertaken. Medium-sized demonstrations are scheduled for the period 1995-97, in Tokyo, Fukuoka (Kyushu), Osaka and Kobe. Table 2 lists the demonstrations that are provisionally planned.

## Eco Energy City

The use of free waste heat also plays a key role in the Eco Energy City project. This project aims at building a broad area energy network that recovers industrial waste heat at 100 to 200°C and transfers the energy to

| Company                     | Type                                   | Cooling capacity |
|-----------------------------|----------------------------------------|------------------|
| Hitachi                     | turbo compressor heat pump             | 1.4 MW           |
| Mitsubishi Electric         | screw compressor heat pump             | 350 kW           |
| Tokyo Gas/Sanyo             | absorption heat pump                   | 350 kW           |
| Tokyo Gas/Yazaki            | waste heat driven absorption heat pump | 70 kW            |
| Mitsubishi Heavy Industries | turbo compressor heat pump             | 1.75 MW          |
| Osaka Gas/Hitachi Zosen     | 3-stage absorption heat pump           | 100 kW           |

Table 2: Demonstration projects planned under the "Unused Energy" programme.

an urban area with low losses. Heat pumps are then used to supply heat at different temperatures to end users.

Many innovative and new technologies are being developed to achieve this. Energy conversion and transfer over long distances will be achieved using either metal hydrides or chemical reactions with methanol. Heat pumps will play a role in the delivery of heating and cooling at different temperatures. The development of elementary technologies is due to be completed in 1996 after which pilot plants will be constructed. Many companies participate in this project, including the HPTCJ, plus companies and laboratories in the United Kingdom and the USA. The project is scheduled for completion in the year 2000.

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# Bibliography

## **Commercial/Institutional Ground-Source Heat Pump Engineering Manual**

Published by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE), 1791 Tullie Circle NE, Atlanta, GA 30329, USA; 1995; Price US\$ 87 (US\$ 58 for ASHRAE member)

Prepared by Caneta Research, Inc., Canada, and reviewed by an ASHRAE Technical Evaluation Committee, the manual is for use by engineers and architects designing large, multizone ground-source or geothermal heat pump systems for commercial or institutional buildings. The manual is the first attempt to bring together the necessary knowledge in one package.

A second edition is planned to be produced in about 18 months. This will be endorsed by ASHRAE and the International Ground-Source Heat Pump Association (IGSHPA). Individuals who have reviewed the manual and have comments or suggestions are asked to contact Patrick Hughes of Oak Ridge National Laboratory, USA (Fax: +1-615-574-9338; E-mail: pj1@ornl.gov.)

## **Ground Coupled Heat Pumps**

"2. Symposium Erdgekoppelte Wärmepumpen" is published by IZW (Information Centre for Heat Pumps and Refrigeration) in Germany (Fax: +49-7247-808-134); December 1994; 376 pp; Price DM 70 (German)

These proceedings include 33 papers presented at a symposium held in Schloss Rauischholzhausen on 17 to 19 October 1994. Application experiences in Austria, Germany and Switzerland are presented and a paper by the HPC discusses the international market situation. New developments are discussed including ground heat exchangers, direct expansion, ground water use, deep ground probes and thermal storage.

## **Heat Pumps: Energy Saving and Environmental Protection**

"Wärmepumpen Energiesparung und Umweltschutz" is published by VDI-Verlag, Postfach 101054, 40001, Düsseldorf, Germany; May 1995; 124 pp; ISBN 3-18-09177-8; (German)

Proceedings of the workshop held at Kassel on 16 May 1995. The ten papers provide an interesting commentary on the possibilities for using heat pumps in Europe and on the consequent benefits. The main focus is on residential heat pumps. Three papers

examine heat pump promotion initiatives in Austria, Germany and Switzerland.

## **Japan HVAC&R Directory 1995**

Published by the Japan Air Conditioning, Heating & Refrigeration News; Fax: +81-3-3584-4708; 196 pp (English)

Lists manufacturers of heating ventilation and air-conditioning equipment in Japan and, for the first time in this Directory, similar firms in Australia, China, Hong Kong, Korea, Singapore and Thailand. Industrial statistics cover the production and shipment of Japanese produced equipment as well as data on Japanese imports and exports.

## **CADDET publications**

The following publications are available from IEA CADDET Energy Efficiency, The Netherlands; Fax: +31-46-510389.

### **Small Electrical Heat Pumps for Hot Water in Offices and a Restaurant**

This four-page brochure reports on the application of heat pump water heaters which were installed in a building with offices and a restaurant in Switzerland in 1992. Using air from an underground garage, the heat pumps achieved seasonal performance factors in excess of three.

### **New Kind of Heat Recovery System for Boiler Plants**

This four-page brochure describes a building heating system in which flue gases from an oil boiler serve as the heat source for a space conditioning heat pump. Flue gases are first mixed with air from the boiler room and then used as a heat source for the heat pump. The system not only recovers heat but also results in cleaner flue gases.

### **Learning from Experiences with Advanced Houses of the World**

This analysis report reviews 25 advanced houses in 13 IEA countries. Eight of these houses incorporate heat pumps, mainly using the ground as heat source. COPs of up to four have been demonstrated. One house uses a gas-driven heat pump.



# Events

\* Call for papers

**Heat Transfer in Condensation - 47th Eurotherm Seminar**  
4-5 October 1995 / Paris, France.  
Contact Mrs M.J. Basset, CRETH-CENG, Fax: +33-7688-5161

**International Symposium on Two-Phase Flow Modelling and Experimentation**  
9-11 October 1995 / Rome, Italy.  
Contact: Dr Tommaso Setaro, ENEA Casaccia.  
Fax: +39-6-3048-3026

**Solarthermische Kraftwerke II (Solar-Thermal Power)**  
11/12 October 1995 / Stuttgart, Germany.  
Contact: VDI-GET. Fax: +49-211-6214-4363

**Solar Assisted Cooling with Sorption Systems**  
17-18 October 1995 / Munich, Germany.  
Contact: Dr Peter Lamp, ZAE Bayern eV.  
Fax: +49-89-3294-4212

**7th International Conference on Stirling Cycle Machines**  
5-8 November 1995 / Tokyo, Japan  
Contact: Mr Shigeji Tsukahara, Ship Research Institute.  
Fax: +81-422-41-3101

**1995 International Gas Research Conference**  
6-9 November 1995 / Cannes, France.  
Contact: Gas Research Institute. Fax: +1-312-399-8170

**Symposium on Heat Pump and Refrigeration Systems Design, Analysis and Applications**  
12-17 November 1995 / San Francisco, California, USA.  
Organized within the 1995 ASME International Congress.  
Contact: Dennis L. O'Neal, Texas A&M University.  
Fax: +1-409-862-2762

**Electric Heat Pumps: Meeting Customer and Utility Needs**  
6-8 December 1995 / St Louis, Missouri, USA.  
Contact: Linda Nelson, Conference Coordinator, Electric Power Research Institute. Fax: +1-415-855-2041

**Refrigeration, Climate Control and Energy Conservation**  
11-14 February 1996 / Melbourne, Australia.  
IIR Meeting of Commissions E2/E1 and B1/B2. Contact: Mrs Siew-Ling Teh, AIRAH. Fax: +61-3-328-4116

**Absorption/Sorption Heat pumps and Refrigeration Systems**  
14 February 1996, Atlanta, USA.  
Contact Srinivas Garimella, Western Michigan University.  
Fax: +1-616-387-3358.  
E-Mail: srinivas.garimella@wmich.edu

**1996 ASHRAE Winter Meeting**  
17-21 February 1996, Atlanta, USA.  
Contact: ASHRAE. Fax: +1 404-321-5478

**Frigair '96**  
6-8 March 1996 / Johannesburg, South Africa.  
Contact: FRIGAIR '96, Melanie Campbell.  
Fax: +27-11-442-5927

**RECLIEN '96 - 4th International Congress on Refrigeration, Air Conditioning and Non-Conventional Energy**  
18-22 March 1996 / Havana, Cuba.  
Contact: H. Remedios Carbalajes. Fax +53-537-33-8501

**1st UAE Conference on Air Conditioning in the Gulf**  
14-18 April 1996 / Al Ain City, United Arab Emirates.  
Contact: ACG96 Organizing Committee Chairman, UAE University. Fax: +971-33521

**2nd European Thermal Sciences Conference**  
29-31 May 1996 / Rome, Italy.  
Contact: Mr G.P. Celata, ENEA Casaccia, Energy Department, Via Anguillarese, 301-I-10060 Rome, Italy.

**Energy and Environment Towards the Year 2000**  
6-8 June 1996 / Capri, Italy.  
Contact: EURO MEETING IN. Fax: +39-81-7141414

**Purdue International Compressor Engineering Conference**  
21-26 July 1996 / West Lafayette, IN, USA.  
Contact: Prof. R. Cohen, Purdue University, Ray W. Herrick Laboratories, West Lafayette, IN 47907, USA.

**TIEES-96 First Trabzon International Energy and Environment Symposium**  
29-31 July 1996 / Trabzon, Turkey.  
Contact: Prof. Teoman Ayhan, Karadeniz Technical University. Fax: (462) 325-7405;  
E-Mail: energy96@risc01.bim.ktu.edu.tr

**Natural Working Fluids in Refrigeration and Air Conditioning**  
2-8 September 1996 / Aarhus, Denmark.  
Contact: Mr M. Arnvig, Danish Refrigeration Association.  
Tel: +45-42-88-4622

**Research, Design and Construction in Refrigeration and Air Conditioning in Eastern Countries**  
10-14 September 1996 / Bucharest, Romania.  
Contact: Prof. F. Chiriac, Asociatia generala a frigotehnistilor din Romania, Bucharest, Romania. Fax: +40-312-6880

**International Absorption Heat Pump Conference**  
17-20 September 1996 / Montreal, Canada.  
Contact: Darius Nikanpour, EDRL, Fax: 1-514-652-5177;  
E-Mail: Darius.Nikampour@cc2smtp.emr.ca

## IEA Heat Pump Programme

**Annex 22 Workshop on Natural Refrigerants**  
16-18 October / Trondheim, Norway

**5th IEA Conference on Heat Pumping Technologies**  
22-26 September 1996 / Toronto, Canada

Contact the HPC for registration information

# Available from the HPC

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| International Heat Pump Status & Policy Review                                    | Analysis Report (Vol. 1, 2A & 2B)<br>National Position Papers | HPC-AR3<br>HPC-NPP** | 250<br>40           |
| Consequences of (H)CFC Replacement in HVAC Applications                           | Workshop Proceedings                                          | HPC-WR-13            | 60                  |
| Utility Perspectives on Heat Pumps for Retrofit and New Applications in Buildings | Workshop Proceedings                                          | HPC-WR-14            | 80                  |
| Working Fluids and Transport Phenomena in Advanced Absorption Heat Pumps          | Annex 14 Report                                               | HPP-AN14-1           | 100                 |
| An Assessment of the Current Status of the Thermophysical Properties of Ammonia   | Annex 18 Report                                               | HPP-AN18-1           | 40                  |
| Comparison of Equations of State for HCFC -123                                    | Annex 18 Report                                               | HPP-AN18-2           | 40                  |
| Comparisons of Equations of State with Experimental Data for R134a and R123       | Annex 18 Report                                               | HPP-AN18-3           | 40                  |
| Industrial Heat Pumps: Experiences, Potential and Global Environmental Benefits   | Annex 21 Report                                               | HPP-AN21-1           | 100                 |

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Standards and Regulations - December 1995



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# National Team Contacts

## International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among its 24 participating countries, to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development.

## IEA Heat Pump Programme

Set up by the IEA in 1978, the IEA Heat Pump Programme carries out a strategy to accelerate the development and use of heat pumps, in all applications where they can reduce energy consumption for the benefit of the environment. Within the framework of the programme, participants from different countries collaborate in specific heat pump projects known as Annexes.

## IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC), itself an Annex. The HPC contributes to the general aim of the IEA Heat Pump Programme, through information exchange and promotion. For further information on HPC products and activities, or for general enquiries on heat pumps and the IEA Heat Pump Programme, contact your National Team or the address below.

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