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6th IEA Heat Pump Conference / Environmental Benefits

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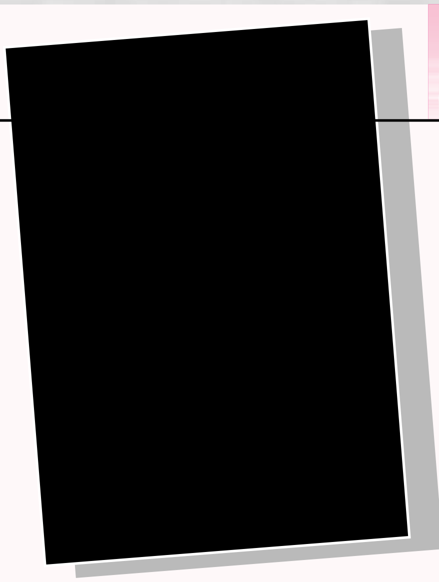
In this issue



6th IEA Heat Pump Conference / Environmental Benefits

'Heat pumps – a benefit for the environment' was the theme of the triennial 6th IEA Heat Pump Conference that was held in Berlin, Germany from 31 May – 2 June 1999. This issue of the IEA Heat Pump Centre Newsletter reports on each session, including technological and market developments, systems and applications.

Front cover:
Brandenburg Gate, Berlin.

TOPICAL ARTICLES

HEAT PUMP NEWS

FEATURES

COLOPHON

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IEA Heat Pump Centre
PO Box 17, 6130 AA Sittard
The Netherlands
Tel: +31-46-4202236, Fax: +31-46-4510389
E-mail: hpc@heatpumpcentre.org
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NON-TOPICAL ARTICLES

Heat pumps – a benefit for the environment

Germany was invited to host the 6th International Energy Agency (IEA) Heat Pump Conference by the IEA Heat Pump Programme. The German National Organising Committee chose the city of Berlin for this event, which was held from 31 May to 3 June 1999.

Heat pump technology contributes to reducing energy consumption, and hence to reducing greenhouse gas emissions. The theme of the Conference “Heat Pumps - a Benefit for the Environment” was chosen in order to emphasise the present and future role that heat pumps can play in saving energy and improving the environment.

Germany faces big ecological and economic challenges. These challenges have not only come about as a result of the Montreal and Kyoto Protocols, but also as a result of the problems following the reunification of East and West Germany. The focal point of the reunification, with all its problems of today and challenges of tomorrow, is the city of Berlin. In addition, the decision of the German Parliament to move the capital from Bonn to Berlin has had a large impact on the city. Berlin has been undergoing an enormous reconstruction, employing the latest technologies in energy systems. The International and National Organising Committees not only arranged an interesting conference programme with 32 invited oral presentations, around 70 poster papers and an exhibition, but several interesting technical excursions were also organised. These included visits to the new business centre and the political centre of Berlin, which are both located directly on the former borderline between the East and West, the Potsdamer Platz area and the Reichstag building, where the latest developed heating and cooling technologies (including heat pumps) are deployed.

As Chairman of the National Organising Committee, I would like to thank all persons and organisations that contributed to the success of this conference, including the 320 attendees. I hope that the Conference offered a better insight and that it laid the basis for increased ecological benefits through wider application of heat pump technology, as demonstrated in the presentations, the exhibition and the technical visits.

Dr Horst Kruse
Chairman of the National Organising Committee
Germany

New heat pump energy-efficiency guidelines in Japan

Japan - As of 1 April 1999, new energy-efficiency guidelines have been introduced by MITI (Ministry of Trade and Industry) as part of the revision of the energy conser–vation law. This revision was designed to accelerate energy conservation and to meet greenhouse gas emission reduction targets agreed at the 1997 Kyoto conference. Air conditioners (including heat pumps) are one of the eight regulated energy consuming products, which also include cars, television sets and fluorescent lamps.

A new procedure known as “Top Runner “ has been introduced for setting the energy-efficiency target. This efficiency level is currently the highest efficiency on the market. Air conditioners (including heat pumps) must meet the current Top Runner efficiency level by 2004 or 2007, depending on the product.

As a result of this measure, it is estimated that an average energy-efficiency improvement of 63% can be achieved for reversible heat pumps, or 14% for cooling-only equipment.

Source: K. Yamazaki, T. Yoshii
Japanese National Team

Joint distribution of European News and IEA Heat Pump Centre Newsletter

The IEA Heat Pump Centre and the European Heat Pump Network have agreed to intensify their cooperation by jointly distributing their quarterly newsletters. Readers of this IEA HPC Newsletter will find enclosed a copy of the second issue of the European Heat Pump News, *the Newsletter of the European Heat Pump Concerted Action.*

For more information please contact the IEA Heat Pump Centre or Mr A. Lehmann (Fax: +49-72-47808134 or e-mail: ale@fiz-karlsruhe.de).

Dutch sign declaration of intent on heat pumps

The Netherlands – On 26 May 1999, 25 market parties signed a declaration of intent as a first step towards an Agreement on Heat Pumps, which must be signed before the end of the year. The main issue is the government’s goal of having a million installed residential heat pump systems in the year 2020.

According to chairman Mr De Leeuw of SBR (*Foundation for Building Research*), this goal is still a long way off. He feels that during the first agreement, which has a four-year term, few heat pump systems can be installed. However, important long-term conditions can be created, e.g. product development, system optimisation, demonstration projects and market promotion.

The declaration of intent has been signed by the Ministry of Economic Affairs, 11 suppliers, four installers, one housing project developer, research institutes, The Heat Pump Foundation (suppliers), VNI (installers), EnergieNed (utility association), the well-chillers association,the Project Bureau for Renewable Energy and Novem (Netherlands agency for energy and the environment).

Source: Dutch National Team

European collaboration for market transformation

UK – A consortium headed by Scottish & Southern Energy pic aims to transform the European market for electrical heating of residences (EC Save project). Project partners come from the UK, Austria, Czech Republic, Germany, Finland, the Netherlands, Romania and Sweden.

A previous SAVE-funded study showed that 20% of European houses are electrically heated. Large energy savings can be realised by improving insulation levels of the older housing stock and heating with a high-efficiency heating system, i.e. a heat pump.

The current project aims to initiate key tasks necessary to transform the market and over–come the barriers that prevent a high penetration of heat pump technology. This includes developing suitable computer codes to optimise heat demand of a home (new or existing), correct sizing of a heating system, and creating and evaluating awareness. The partners will also develop information and training initiatives.

Together with the European Heat Pump Network, the project partners took the initiative to bring together heat pump manufacturers from all European countries in a European heat pump association, which will represent the interests of the members at European level, supply information, arrange education and training etc. A kick-off meeting has been scheduled for 22 October in Brussels.

Source: IEA Heat Pump Centre
More information: Mr Rayner Mayer, Sciotech, UK
Tel. +44 -1252-873564

Highlights ASHRAE summer meeting Seattle

USA - Alternative refrigerants/refrigerant mixtures, lubricant properties and geothermal heat pump systems were the main areas of interest at the Seattle ASHRAE meeting.

Refrigerants/lubricants
Ozone depletion and climate change trends continue to be major challenges to the industry, requiring them to develop efficient systems with new refrigerants. Equipment manufacturers have mainly concentrated on HFC refrigerants, but researchers have gone further and studied systems using working fluids with low global warming potential. During a seminar an overview was given of R-22 alternative refrigerants, both from the synthetic and natural family of refrigerants. Two papers discussed the performance issues of R-410A near the critical point, which may occur during normal operation. At higher ambient temperatures, the relative capacity and cooling COP for split and window air conditioners reduced compared to R-22.

Zeotropic HFC/HC mixtures were tested in a system consisting of an indoor coil and a ground-coupled outdoor unit using an extra loop to link the indoor and outdoor units. This is the only way an HC system may be used in the US. All flammables are isolated outdoors. Tested working refrigerants were R-22, R-290, R-32/R-290 (50/50), R-32/R-152a (50/50) and R-290/R-600a (70/30). In cooling mode, none of the refrigerants was able to match R-22 in a direct set-up, even if an intra-cycle heat exchanger was added (sub cooler/superheater). In heating mode, R-290 gave the best performance,for indirect systems but was slightly worse than R-22 in a direct system (without extra loop). With an extra heat exchanger, R-290 came out top and matched the R-22 direct system.

CO_2 as a refrigerant was studied for air-to-air heat pump and air conditioners using a hermetic reciprocating compressor. Little is known of this combination. The cooling COP at 32ºC indoors was calculated 7% higher than for R-22. At 27ºC the effect could be up to 7% higher or lower. Model validation would allow better predictions.

Some of the latest research progress relevant to heat pump technologies was discussed in a session dealing with heat transfer and pressure drop characteristics of alternative refrigerants/refrigerant mixtures. Topics included:

- two-phase flow condensation characteristics of R-502 alternatives inside air/refrigerant enhanced tubing;
- the performance of capillary tubes for R-407c;
- a comparison (R-22, R-134a, R-407c, R-410a) of condensation performance in smooth and enhanced tubes.

Various other papers covered specific aspects including a model correlation for R-134a flow through capillary tubes (adiabatic), multiphase flow of R-410a through short tube orifices and fractionation of refrigerant blends in contact with lubricants. Lubricant properties, methods of testing and data for lubricants used with chlorine-free HFC refrigerants were discussed by various speakers from the US, plus speakers from the chemical industry (UK and Japan).

In a special session the latest technology was presented in research and manufacturing refrigerant systems that operate with a transcritical CO_2 cycle in the transportation sector. Work in this area is ongoing in the US, Norway and Germany. The second year of operation with buses and trucks using CO_2 was described in a German paper.

Ground-source heat pump systems
Geothermal heat pump systems, as ground- or water-source heat pump systems are called in the USA, continue to penetrate steadily in the market. They are becoming a mainstream heating, cooling and ventilation solution for commercial/institutional buildings, including schools. Nine speakers presented empirical and analytical study results. One paper compared six commercially available geothermal heat exchanger design programs against field data. This study compared updated versions of five previously examined programs (with large disagreements in sizing) and a new program. The results indicate that the programs are now much more consistent, but undersizing was found in some cases. For a cooling-dominated site, design lengths vary by about 7%, and for the heating-dominated site these vary by 16%. Some of the software providers may need to examine the algorithms used to determine heat exchanger lengths for heating-dominated climates. Design methods are available that perform consistently well in both heating- and cooling-dominated climates.

The other empirical papers discussed the heat pump performance of four installations in schools, plus maintenance cost comparisons with those of conventional alternatives.

In the analytical session the focus was on recent developments in ground heat exchanger models along with system design strategies for ventilation, and analysis techniques for variable-speed loop pumping in water loop heat pump systems from Canada. In the latter paper, a non-dimensional graphical method, suitable for any project, was proposed to quantify minimum power requirements of variable-frequency drive pumps. The technique presented can predict the power requirements at any flow rate using just a single quantity i.e. the shaft power at nominal operating conditions.

Finally, the recycling feature of closed-loop water-source heat pump system applications was the subject of a special forum discussion. These different forms of activities demonstrate the growing interest in ground-coupled heat pump systems in the US commercial/institutional building sector, where there is a lot of experience in system sizing and monitoring. Ground-coupled heat pumps are accepted in the US and Canada as a key technology that contributes to CO_2 emission reduction.

Source: Jos Bouma
IEA Heat Pump Centre

UK heat pump network meets

UK - The UK network for information exchange and collaboration on heat pumps was launched on 7 July in London. The network is a partnership between government and industry, supported by the Department of the Environment, Transport and the Regions (DETR), the Department of Trade and Industry (DTI), the Heat Pump Association (HPA) and the wider industry. It is managed by the Building Services Research and Information Association (BSRIA). Further details in the enclosed European Heat Pump Network Newsletter.

Source: UK National Team

Geothermic properties of the Swiss Molasse Basin using the SwEWS program

Switzerland - Accurate knowledge of the physical properties of the ground is essential for an economic design of geothermic probe installations. Economic designs lead to reduced pump power requirements for both the circulation pump and the heat pump. In many cases, ethylene glycol/water can be replaced by pure water as the heat transfer medium.

A PC program now facilitates computations of the physical geothermic characteristics of heat conductivity, specific thermal capacity and ground density, to help determine the optimal location of geothermic probes. The software is primarily restricted to the typical rocks of the Swiss Molasse Basin, up to a depth of 500 m. The program interpolates and extrapolates the physical characteristics of the Swiss upper freshwater molasse, upper marine molasse and lower freshwater molasse, for 68 locations, using a databank of 604 records.

The program requires the following input for any location:

- coordinates;
- height above sea level;
- height of the water table;
- surface temperature (this can be estimated);
- density (thickness) of the individual molasse layers.

Users are assisted in their choice of input data, with the option of creating a table of measure–ments that form the basis of calculations (e.g. ranges of 10 km, 20 km and 40 km).

The program generates a graphical representation of the heat conductivity and the specific heat capacities of the loose rock and individual molasse layers, as well as the (undisturbed) temperature as a function of depth (depth profile). Furthermore, data for heat conductivity, specific heat capacity and density of each layer, plus weighted average values, are produced, together with standard deviations for all physical characteristics.

Source: Dr M. Zogg,
Tel.: +41-34-4226911
E-mail: martin.zogg@bluewin.ch

Miniature heat pumps

USA – Researchers at Pacific Northwest Laboratory are developing miniature heat pumps for a range of climate control applications, including portable cooling and distributed space conditioning (newsflash Newsletter 15/2). The heat pump is based on the well-known lithium bromide/water absorption cycle. The increased efficiency comes from enhanced heat and mass-transfer made possible by fluid flow in micro-channels. The heat pump can be 60 times smaller than a comparable con–ventional one. The laboratory expects to have a working prototype in about two years.

Source: The Air Conditioning, Heating and Refrigeration NEWS, 3 May 1999
More information: http://www.pnl.gov/microcats/fullmenu

Largest US water-source system under construction

USA – In February 1999, the pumps for the Great River Medical Center's water-source heat pump system started drawing water from the 60,000 m^2 artificial lake that serves as a heat and cold source. The medical centre is constructing a new hospital facility in West Burlington, Iowa. The pumps will distribute 0.32 m^3/s of water to over 800 heat pumps for space condition–ing in the hospital, two new medical buildings and two existing facilities (160,000 m distribution piping). In total, the heat pump system will heat and cool 66,000 m^2 of building space.

Source: The Air Conditioning, Heating and Refrigeration News, 24 May 1999

Increasing focus on ground- and water-source systems in Australia

Australia – In countries such as Australia, where temperatures are often extremes of hot and cold, constant temperatures not far below the surface of the earth (or water) can be used to advantage.

Australia currently has around 2,000 residences converted to geothermal heating. The efficiency of ground-coupled systems is demonstrated by the new ABC-CBN television building in Manila, which has an amazing demonstrated COP of 7. The US Department of Energy has declared it the most energy-efficient building in the world. A large heat pump, aided by absorption chillers and cogeneration, has contributed to this outstanding result.

A block of 34 new luxury apartments around Sydney harbour were recently equipped with water-source heat pumps, using 120 metres of coiled piping at the bottom of the harbour.

A showcase of ground-source heat pumps is in the display home Allunga, which the Armidale town council built to demonstrate the possibilities of renewable energy resources and energy-efficienct technologies. The largest ground-coupled heat pump in Australia is at the Australian Geological Survey Organisation, see Newsletter 16/2.

Source: Australian Energy News, March 1999

IIR on emission reduction and containment

France – The IIR issued its 14th informatory note on refrigerants entitled '*Reduction of emissions of refrigerants and containment in systems*' (3 pages) in May 1999. The Kyoto Protocol entails reducing emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and three other types of gas, including HFCs. This will affect the air-conditioning industry by imposing additional controls on refrigerant (direct effect) and CO_2 emissions during the production of energy used in refrigeration, air conditioning and heat pump applications (indirect effect). The IIR presents a series of measures to be taken, both general and specific containment measures.

The IIR recommends that priority be given to emission reduction, and the major impact of the indirect effect should be borne in mind. Coherent national plans for recovery, recycling and demolition should be implemented, together with financial and regulatory incentives to promote emission reduction and the use of replacement refrigerants. Staff and company certification to ensure good practise, and enforcing regulations regarding illegal imports and sale, complete the main measures to mitigate global warming.

More information: http://www.iifiir.org

UNEP: study on hydrocarbon refrigerator retrofit

France – UNEP is publishing a study on the use of hydrocarbons (HCs) to retrofit existing CFC-based domestic and small commercial refrigeration appliances. The study is designed to help policy makers make informed judgements about retrofitting this type of equipment by providing key information on developing and developed countries' experiences with hydrocarbons. The study provides conclusions from a crucial international forum on this subject, plus existing technical information collected from various sources, new data, and summarises the input in an overview report. The study will be available in hard copy and on the OzonAction website.

Source: OzonAction, April 1999
More information: http://www.unepie.org/ozonaction.html

Conversion to non-CFC chillers slower than expected

USA – Building owners using ozone-depleting CFC (chlorofluorocarbon) refrigerants in chillers for comfort cooling in buildings only replaced or converted 4,231 units in 1998, according to a survey of chiller manufacturers released in April by the Air-Conditioning and Refrigeration Institute (ARI). Despite the slower than expected phase-out, production in 1998 of 7,558 non-CFC chillers, for use in the USA and abroad, is almost double the annual number of CFC chillers manufactured a decade earlier.

With so many CFC units still in service, manufacturers will see a steady demand for replacement chillers for many years to come. Non-CFC chillers in the USA use alternative refrigerants R-123 and R-22 (HCFCs), or R-134a and R-410 (HFCs). Replacement non-CFC chillers can be 40% more efficient than the CFC units installed 20 years ago, resulting in operating savings that can give a payback period of just a few years. Congress is being asked to consider accelerated depreciation for CFC chillers so that unused depreciation could be apportioned over a four-year period, giving building owners more incentive to replace their CFC units.

Source: ARI News releases
More information: http://www.ari.org

Manufacturers meet to discuss hydrocarbons

The Netherlands – Heat pump manufacturers from four European countries met on 21 June 1999 to discuss the hampering market introduction of equipment using hydrocarbons. They discussed the hurdles that need to be overcome and which actions will be required to achieve the responsible use of hydrocarbons as refrigerants in residential/ small commercial applications. Fourteen people attended the meeting, a joint initiative by the European Heat Pump Network (via TNO, the Netherlands) and the IEA Heat Pump Centre.

Participants felt the need to collaborate on aspects such as input to standardisation committees, discussions with component manufacturers, and influencing political opinion. A joint interest group will be established.

More information:
Ms Miep Verwoerd, TNO (+31-55-5493825) or the IEA Heat Pump Centre

High prices for HFCs

UK/USA – Expectations that increased demand for HFCs will lead to market shortages in Europe this summer, have led at least one UK company to increase their spot price for non-contracted orders of R-134a to around USD 5.35/kg. A US refrigerant vendor reports that prices have risen 70% during the spring of 1999. The domestic US spot price for bulk R-134a was reported to be above USD 4.27/kg in April 1999.

Use of HFCs worldwide has risen by an average 10-15% over the past two years. Since 1996 Europe has imported around 25% of its annual consumption from the USA. Factors contributing to the current shortage include increased demand from vehicle manufacturers, raw material supply problems in the USA, and the decision by three Japanese companies to stop R-134a production. The shortage is expected to continue into next year.

Source: OzonAction, April 1999; ASHRAE Journal, June 1999

Heat pump market success in the Netherlands

The Netherlands – The heat pump market is growing steadily in the Netherlands. The installed stock increased by 50% over the period 1994-98, and now stands at a total of 26,300. These heat pumps provide 760 MWh_{th} heating capacity and save around 3.4 PJ of primary energy per year (around 0.1% of total supply).

Heat pump sales have enjoyed a considerable growth from 1995-98, see **Figure 1**. In the residential sector, the typical newly installed heat pump is a heat pump water heater (in five out of six cases). The commercial sector is dominated by reversible heat pump systems, and accounts for the largest share (in numbers) of the heat pump stock.

In industry and agriculture, the number of installed systems is smaller, but the range of applications is wider and, particularly for industry, the energy saved by an individual installation is equal to many installations in buildings.

The primary energy saved per sector is illustrated in **Figure 2**. These calculations take into account the various types and applications of the heat pumps and the relevant baseline systems. One industrial evaporator, installed in 1995, saved 1.2 PJ. Similar to primary energy savings, CO_2 emission reductions can also be evaluated. Dutch heat pumps reduced the country's CO_2 emissions by 142,000 tons in 1998, a 13% increase since 1994.

Source: Netherlands National Team

Figure 1: Dutch heat pump sales 1995-98 per sector.

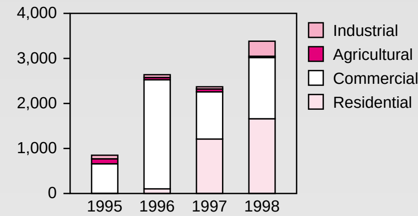
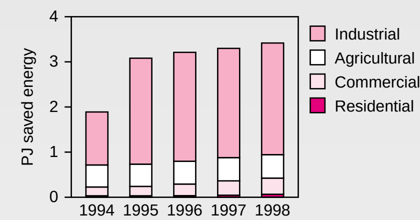


Figure 2: Total primary energy saved by heat pumps (cumulative) in the Netherlands.



Favourable market in Germany and Sweden

Germany/Sweden – Both German and Swedish heat pump markets have been increasing over the past three years. In 1998 over 18,500 small heat pumps were sold in Sweden (mainly residential), and nearly 4,500 in Germany (excluding heat pump water heaters). The German market has almost doubled since 1996 (see **Figure 3**), but is still relatively small, compared to Sweden (see **Figure 4**), Austria and Switzerland.

In Sweden, 64% of new installations are ground-source heat pumps. Installations in rock dominate the sector. Another 30% of the installations are exhaust-air source (primarily in new houses).

Source: CCI Zeitung 6/99; T. Berntsson, 6th IEA Heat Pump Conference

Figure 3: German heat pump market (excluding heat pump water heaters).

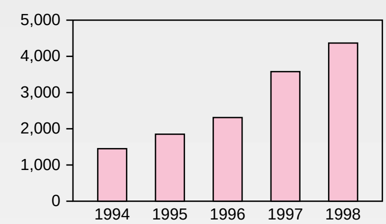
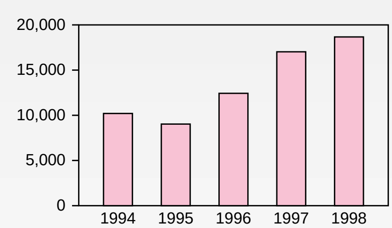


Figure 4: Swedish heat pump market.



Yanmar gas-fired heat pump presented in Europe

The Netherlands – Yanmar Diesel Engine Corporation is planning to introduce their E-series gas-fired heat pumps for small commercial use (14-56 kW) on the European market. Gastec, the Netherlands, therefore organised two information exchange days (30 June, 1 July 1999), which were attended by 50 people from gas utilities and other organisations across Europe (Belgium, France, Germany, Italy, the Netherlands, Spain and the UK).

Yanmar began selling gas-fired heat pumps in 1988 in Japan, and have sold 340,000 units since then. The company is now expanding its overseas business, and has selected the European market as its first target. Product requirements (adapting technical features), market characteristics and sales, plus the service network are currently being studied, and a collaboration with Daikin Europe is being set up. European utilities have been invited to carry out field tests of the latest 'E'-series.

Gastec is assisting the market introduction of this equipment and testing the Yanmar gas heat pump at its facilities. Reasons for using gas-fired heat pumps in Europe include low operating costs, CO_2 reduction compared to gas-fired boilers and the capacity of the electricity grid. Results of an exploratory feasibility study were presented, which show that larger systems are economically more attractive. Energy-saving potential depends on the efficiency of electricity generation in the particular country; if it is high, an electric heat pump will save more energy. However, Yanmar is further improving the heating efficiency of their equipment to better comply with the requirements of the European market.

The information days were concluded with a view of the Yanmar heat pump currently being tested at the Gastec facilities.

Source: IEA Heat Pump Centre

Thermophysical properties of alternative refrigerants: results of Annex 18

US/Japan - Since 1990, Annex 18 has brought together property experts in a cooperative, task-sharing arrangement and has provided a forum for information exchange and coordinating activities. The Annex has now been completed.

Annex 18 considers the thermodynamic and transport properties of CFC and HCFC alternatives, including HFCs and their mixtures, and natural working fluids. The activities have resulted in internationally accepted formulations for the thermodynamic properties of R-123, R-134a, R-32, R-125 and R-143a. A comparison of available models has facilitated the dissemination of a new approach to thermodynamic properties of HFC mixtures. Also included are surveys of the available thermodynamic and transport property data of numerous fluids. This work was aided by using a database, a version of which is now available on the Internet (http://www.itt.uni-stuttgart.de/~krauss/midas.htm).

Several publications on Annex 18 results are available from the IEA Heat Pump Centre. The latest two reports can be ordered using the response card stapled in this Newsletter. Visit the Heat Pump Centre Internet site http://www.heatpumpcentre.org for information on these and other publications.

Source: Marc McLinden, NIST

Dutch National Team on the Internet

The Netherlands - The Dutch National Team is now on the Internet (http://www.e3t.nl/heatpumps/Index.htm). The website contains general information on heat pumps, news items, subsidies, suppliers and interesting publications. This site also has links to other relevant websites, such as the Heat Pump Centre, the European Heat Pump Network, and a number of Dutch websites.

Source: Bram van Straalen, Dutch National Team

Workshops in Paris

France – Two heat pump related workshops will be organised at the Interclima trade fair in Paris-Nord Villepinte, close to Charles de Gaulle Airport. The workshop *Heat pump training programmes – the way to certification* takes place on 8 November 1999, and *Natural working fluids for heat pumps - a challenge for the future* on 9 November 1999. The working language will be English.

Heat pump training programmes – the way to certification will summarise the current training schemes available in various European countries with regard to heat pump improvement and implementation. The workshop is organised by the European Heat Pump Network under the auspices of the EC – Thermie B Programme.

This workshop is targeted at consultants, architects, designers, training companies, decision-makers and executives from industry, utilities and the public sector. It will contribute to a European activity regarding a certification procedure to guarantee product performance and the competence of installation specialists.

Natural working fluids for heat pumps - a challenge for the future aims to identify the activities required to promote safe use of natural refrigerants in heat pumps. The work–shop addresses hurdles and stimuli for the market introduction of residential and small commercial heat pumps using natural working fluids, with the emphasis on hydrocarbons and ammonia. The workshop is organised jointly by the European Heat Pump Network (under the auspices of the EC – Thermie B project) and the IEA Heat Pump Centre.

Heat pump manufacturers, policy- and decision-makers in governments and utilities, and installers are the target audience. The programme covers:

- EU policy on implementing the Kyoto and Montreal Protocols;
- liability aspects of components and equip–ment, and the view of insurance companies;
- new standards under development;
- the views of hydrocarbon and ammonia heat pump equipment manufacturers;
- safety aspects, for hydrocarbons, ammonia and CO_2;

Information and registration
8 November: Mr Michel Guittard, ADPM
Fax: +33-1-49850627
9 November: IEA Heat Pump Centre
(see back cover)

Ongoing Annexes

Red text indicates Operating Agent.

Annex	Participants
Annex 16 IEA Heat Pump Centre	AT, JP, NL, NO, CH, UK, US
Annex 24 Ab-Sorption Machines for Heating and Cooling in Future Energy Systems	CA, IT, JP, NL, SE, UK, US
Annex 25 Year-round Residential Space Conditioning and Comfort Control Using Heat Pumps	CA, FR, NL, SE, US
Annex 26 Advanced Supermarket Refrigeration/Heat Recovery Systems	CA, SE, US (NO, MX, UK to be confirmed)
Annex 27 Selected Issues on CO_2 as a Working Fluid in Compression Systems	JP, NO, UK, US

IEA Heat Pump Programme participating countries: Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), Mexico (MX), The Netherlands (NL), Norway (NO), Spain (ES), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US).

Heat pumps – a benefit for the environment

Report on the 6th IEA Heat Pump Conference

Gerdi Breembroek, IEA Heat Pump Centre

In Berlin, Germany, the 6th IEA Heat Pump Conference was held from 31 May – 2 June 1999. With a total of 320 participants, 32 speakers, a large number of poster presentations and an accompanying exhibition, the conference brought together the major players and developments in heat pumping technologies. The six sessions discussed the market status, technologies, systems, applications and market strategies. This article, and those on the following pages of this newsletter, summarise the ideas and views presented and discussed at the conference.

Opening session

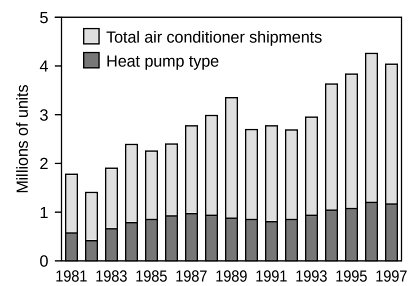
The opening session of the 6th IEA Heat Pump Conference included words of welcome a technical keynote and regional reports.

Participants were welcomed by the Chairman, **Mr Kruse**, on behalf of the National Organising Committee. He highlighted the importance of heat pumping technologies for heating and cooling and thanked the conference sponsors for their efforts. **Mr Strieder** (responsible for urban development, environment and technology in Berlin) showed the challenges of reducing CO_2 emissions in the city. As well as having to merge two energy systems into one, the city also has an ambitious goal of 20-25% CO_2 emission reduction. **Mr Schacht** of the Federal Ministry of Economy and Technology (BMWi) illustrated the relevance of heat pumps for the federal government by giving a brief review of past government heat pump policies. **Mr Ferriter** (deputy executive director of the IEA, Paris) focused on the Kyoto commitments. Immediate and sustained action is required in deploying current technologies, including heat pumps, to save energy and reduce CO_2 emissions. Governments need policies to promote these technologies, because their benefits are not always appreciated by the market. **Mr Steimle** (President of the General Conference of IIR) stressed the importance of refrigeration and heat pumping technologies worldwide, especially in tropical regions. The energy efficiency of systems and refrigerants is, in his opinion, the key to environmentally friendly development of heat pumping technologies. **Mr Meller** (representing VDEW, the association of German electric utilities) emphasised the importance of heat pumps for the German utilities. However, he expressed some concern regarding the framework for heat pump application in Germany. The planned extra energy levy on electricity would discourage heat pump applications, even though the technology helps reduce CO_2 emissions. VDEW would like to see the broader application of heat pumps, so that they become the rule rather than the exemption. This was the last speaker to address the conference during the welcoming session, which emphasised the environmental benefits of heat pumps.

Technical keynote

Mr Andersen (from EPA, USA) addressed the conference with a technical keynote speech. He reminded the participants of the major achievements of all concerned in combating ozone depletion (chlorine-free refrigerants). The new challenge is mitigating global warming. This requires searching new solutions for increased performance, reducing the impact of refrigerants, as well as creative thinking. Mr Andersen considered the containment of refrigerants to be a key issue. This will promote both the safety of flammables and NH_3 and the environmental acceptability of HFCs. The concept of life cycle climate performance (LCCP), which includes manufacturing, over the full service life up to disposal, should be elaborated to allow different solutions to be compared.

▼ *Figure 1: Unitary air conditioner and heat pump shipments (USA).*



North America

Mr Menzer (from ARI, USA) reviewed the North American heat pump market, identifying market forces and trends, and analysing the US situation. The market for unitary air conditioners and heat pumps shows a distinctly upward trend (**Figure 1**). Particularly in the residential sector, competition with natural gas is an important market factor. In the commercial sector, ground-source and water-source units (known as geothermal systems in the US) are becoming increasingly popular.

Factors that have an important impact on the market today include:

- shorter distribution chain;
- minimum efficiency standards and refrigerant phase-out demanded by

government regulations. New efficiency standards are planned for 2006;
- the shortage of good technicians;
- deregulation of the energy market. Almost all equipment rebate programmes have been cancelled. Seasonal rates and time-of-day rates will be available for an increasing number of customers. Distributed power production will also become more popular.

Mr Menzer concluded by observing that although utilities, contractors and manufacturers are all undergoing change, and although fuel prices will not encourage high-efficiency products, the North American heat pump market is expected to grow at a slow and steady pace. Geothermal systems are expected to show the fastest growth.

Asia

Mr Akiya (MITI, Japan) presented an overview of the Asia/Pacific region. The climate in large parts of Japan, China, South Korea and the Pacific region justifies installing heating and cooling systems. The energy demand is increasing rapidly in Asia, especially in China.

In Japan many technological developments are linked to the need to curb peak electricity demand on hot summer days. Ice thermal storage packaged air conditioners (mostly multisplit type) have been developed in recent years and are now available. Other innovations include medium-sized absorption chillers, with smaller units under development. District heating and cooling, combined with thermal storage, is also receiving more attention. Absorption systems and industrial heat pumps are becoming more popular in China. Industrial applications include drying and fish farming, along with large industrial and/or district heating and cooling absorption systems.

Thermal storage and thermally activated systems are supported both by governments and utilities in Southeast Asia. In Japan, subsidies, tax deductions and low-interest loan schemes promote the use of thermal storage systems. In some cases a subsidy is available for installing gas-fired heat pumps. China offers considerable benefits to those installing ice thermal storage systems in their offices.

The market for heat pumps and air conditioners has continued to grow each year in most countries, though the mature Japanese market showed a decline in 1997 and 1998. The Chinese market became stronger, as can be seen from the boom in RAC production (**Figure 2**). The market in the Asia Pacific region is detailed further in the article on page 12 discribing Session 2.

Europe

Mr Heidelck (IZW e.V., Germany) addressed the situation in Europe. He observed that most European heat pumps are reversible heating and cooling types. However, he concentrated on heating-only heat pumps, as this northern and central European market is unique.

The European heating-only heat pump market is fairly immature, unlike the US and Japanese markets. After a boom around 1980 the market collapsed as a result of falling energy prices. However, the market is currently enjoying a new renaissance, due to the pressing need for increasing energy efficiency and reducing global warming.

The status of the technology and the heating demand in residences are crucial for saving energy and mitigating global warming. Modern heat pumps reduce CO_2 emissions compared to other heating systems, even in countries where the CO_2 emissions for electricity generation are relatively high (fossil-fuel-based generation, e.g. Germany, the Netherlands). Modern ground-coupled or water-source heat pumps with low-temperature hydronic heat distribution systems reach SPFs of 4.0 and higher. The percentage of heat pumps for space heating tends to be higher in countries where CO_2 emissions for electricity generation are lower (with the exception of France).

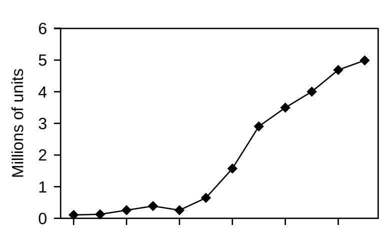
Europe demands a stringent HCFC phase-out schedule. HFCs are mainly used as alternative, but hydrocarbons are also possible. There are several manufacturers of hydrocarbon equipment in northern and central Europe. Ammonia is increasingly used for medium to large applications. In the longer term, CO_2 also presents a viable solution. A European research project and many national projects are currently developing CO_2 components and systems.

Market barriers in virtually all northern and central European countries include the investment costs of the systems, lack of awareness and lack of solutions for the retrofit market. Moreover, the European market is fragmentary, with too many small manufacturers with low production capacity.

The European Commission promotes Europe-wide actions to mobilise the European Union’s renewable energy potential and share successful implementation policies. Currently, the Commission supports projects aimed at establishing a European heat pump network, education and training, certification, promotion, plus research on working fluids.

The CO_2 reduction potential of heating-only heat pumps will promote their use in European countries. Heat pumps for low-energy houses, and the increasing demand for heating and cooling, are important future markets.

▼ *Figure 2: Room air conditioner (RAC) production in China.*



Session 2: Markets

Hanneke van de Ven, IEA Heat Pump Centre

The second session on markets was split in two parts. The first part reviewed the market in to the three most relevant regions for the heat pump market, namely North America, Asia Pacific and Europe. The second part included discussions on the specific market situation of gas-driven heat pumps in Europe and Japan, plus a presentation on exhaust air heat recovery in buildings.

North America

Mr Lewis (Lennox International) focused on the North American heat pump market. To illustrate the importance of this region he indicated that the US share amounted to 30% of the worldwide market for comfort systems (see **Figure 1**). As North America has a mature heat pump market, with resulting levels of market saturation, the best growth opportunities will occur in the replacement market. Sales of unitary heat pump systems for commercial and residential applications totalled around 1 million units in 1998. Most new homes have ducted heating and cooling comfort systems installed at the time of construction. A record 257,000 heat pumps (23%) were installed in new single-family homes in 1997.

The trend in consumer decisions confirms that they are better informed. As well as initial costs, energy efficiency, reliability or quality, brand name, noise level and the installer's recommendations are also decision points. Owners tend to place increasing emphasis on equipment that is simple to operate. Unlike (for example) cars, consumers do not consider preventive maintenance necessary.

An important trend on the supply side is the changing system of distribution channels, with both horizontal and vertical integration. Many distributors/ wholesalers have joined forces under one banner, while some manufacturers have started building a distribution chain ranging from manufacturing to installation and after-sales service.

From a policy point of view, two trends can be observed. Utility measures such as rebates, low-cost financing and lower tariffs were introduced in the 1980s. Governments have also imposed standards on energy efficiency. Mr Lewis argued that government-imposed standards need to be cost-effective to the consumer and not increased further, so that product differentiation and innovation can be encouraged to meet market requirements. Furthermore, Mr Lewis also expressed the opinion of US industry, that the agreements made under the Montreal Protocol need to remain stable concerning the phase-out and production caps for HCFCs.

Asia

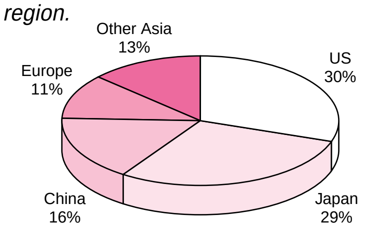
The presentation by **Mr Iwatubo**, from CRIEPI, Japan, included an overview of the market in the Asia Pacific Region. He illustrated the importance of this region for the world market in RAC/PAC (room air conditioners/packaged air conditioners) - of the 31.6 million units sold in 1997, over half (17.7 million units) were sold in this region. This is comparable to the data in **Figure 1**. The market was discussed in detail for three countries: China, South Korea and Japan.

China has seen rapid growth in sales of heat pumps over the past few years. **Figure 2** shows their share of the different types of HVAC systems in 1996. China has actively promoted absorption chillers because of its shortage of electricity. The number of units per type is shown between brackets. Thermal storage systems are also seen as promising applications for peak load shifting, estimated to shift 10-12 million kW by the year 2000. The abundance of available waste heat offers potential new applications, mainly in industry. The production capacity has grown from almost zero in 1990 to an export of 700,000-800,000 heat pump units in 1997, mainly through establishing joint ventures between Japanese and US manufacturers.

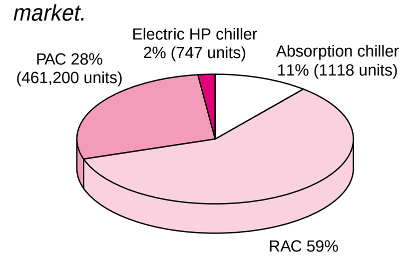
In South Korea the diffusion of RAC/ PAC is very high, but these are only cooling types – only 1% are heat pumps. The summer electricity supply shortage in Korea leads to an increasing demand for absorption and thermal storage systems, just as in other Asian countries.

Japan has a mature heat pump market. The climate in most regions is very suitable for heat pump applications. Ninety-four percent of the RACs are reversible. Multisplit-type PACs are mainly used in small and medium-sized buildings, while gas absorption is increasingly used in large buildings. The market for engine-driven heat pumps is increasing steadily and now covers 13% of the total cooling capacity.

▼ *Figure 1: Share in world market, per region.*



▼ *Figure 2: Share per type in Chinese market.*



In 1997, 4,300 thermal storage systems were installed, most of which use ice.

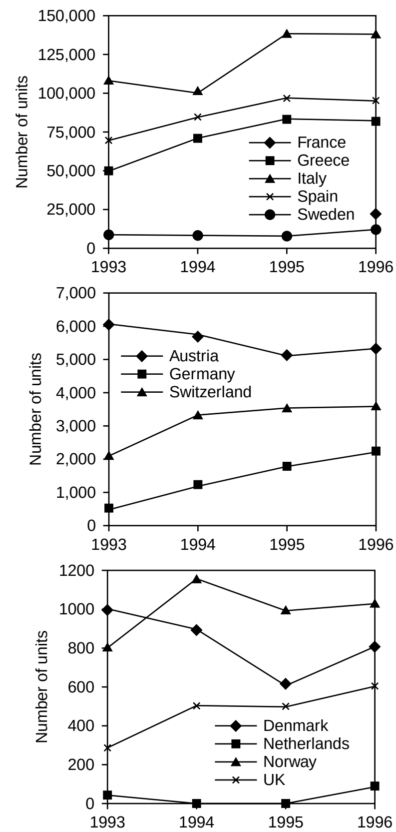
Summarising, the region can be characterised by a high demand, with some new and growing markets. The region is an established production area, supplying many other parts of the world. It often serves as a testing site for new technology, although developments have been limited due to the recent economic crisis.

Europe

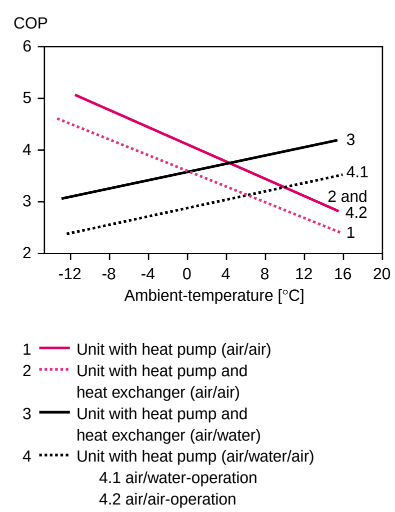
Mr Bouma, of the IEA Heat Pump Centre, discussed the heat pump market in Europe. As there are a wide variety of factors that influence the market (e.g. climate, national energy resource situation, energy prices, heat pump investment costs and buildings standards), the European heat pump market is extremely diverse. The space conditioning heat pump market is mature in sectors with a cooling demand, but requires policy support in most mainly-heating situations. Mr Bouma mentioned that heat pumps are becoming increasingly accepted as a renewable energy source, both by governments and the energy sector, and that this can have a positive impact on the short-term markets. The most efficient promotion policies seem to consist of a mix of economic stimulation measures and information dissemination.

The growing demand for space cooling in residences and the need for heat recovery from ventilation air in commercial buildings offers new possibilities for heat pumps in the central and northern European market. **Figure 3** (a, b and c) shows the European residential heat pump market for 12 countries.

▼ *Figure 3: European residential market.*



▼ *Figure 4: COP as a function of type and temperature.*



Heat pump markets in the three European regions are developing steadily. From 1992-96 the overall market grew from approximately 2.8 million to 4.28 million installed heat pumps, an increase of 50% over four years. This trend continued in 1997 and 1998. Strongest space heating market growth occurred in Greece and the Netherlands (100%), with moderate growth in Austria, Norway and Switzerland (20-40%). The total space heat demand met by heat pumps is typically between 0 and 2%, the average being 1.7%. However in individual countries, e.g. Sweden, this is 8%.

Mr Bouma emphasised that there is little statistical data to monitor the heat pump market in Europe, and suggested that a consistent monitoring methodology was required.

Gas-driven heat pumps

The presentation by **Mr Schramm** (Germany) focused on gas-driven heat pumps in Europe and covered the past, present and future. Since the mid-1970s gas-driven heat pumps have been used on a relatively large scale in Europe. Combined heating and cooling processes were the most economical applications. However, sales declined in the 1980s, mainly due to lower energy prices. With international agreements such as those on emissions reduction, the market started to expand again in the 1990s. Mr Schramm mentioned the develop-ment of the diffusion absorption heat pump, the Triathlon compression heat pump and the GAX cycle as important improvements.

Mr Kodama, Japan, indicated that for large-scale commercial buildings, gas-fuelled air conditioners already occupy a large share of the market. However, the overall share in commercial buildings is only 20%. Therefore the main aim in the short term is to improve diffusion in small and medium-sized commercial buildings. Together with the need for improved electricity and city gas load factors, technological developments that respond to market requirements may clear the way for the wider use of gas air conditioning in Japan.

Mr Fehrm (Thermia Värme AB, Sweden) discussed exhaust air heat recovery in buildings, focusing mainly on the German and Swedish situation. New building codes, resulting in tighter building envelopes, made mechanical ventilation necessary in many buildings. Exhaust air heat recovery heat pumps use the heat in the outgoing ventilation air for space and/or hot water heating. The typical coefficients of performance for four forced ventilation systems using heat pumps for heat recovery, are given in **Figure 4**.

Session 3: Technology

Jos Bouma, IEA Heat Pump Centre

The third session of the conference focused on technology issues, including refrigerants, heat sources and heat exchangers.

Refrigerants

Mr Keller (Carrier Corp, USA) gave a manufacturer's view of the issues that were addressed during the development of an R-410A air-to-air heat pump family of products for the North American market. These include designing for higher operating pressure, polyolester lubricant behaviour, refrigerant fractionation in accumulators and cross-contamination of oil during retrofit applications.

R-410A systems operate at suction and discharge pressures approximately 50-70% higher than R-22 systems. The most significant changes include:

- increased compressor shell thickness;
- increased accumulator shell thickness;
- condenser coil tubing thickness;
- reversing valve thickness;
- filter dryer shell thickness;
- minor changes to the refrigerant service valves.

A synthetic lubricant used with HFCs is derived from a category known as polyolester lubricants. These provide additional engineering challenges for the designer because they are hygroscopic and can form mild organic acids when contaminated with moisture. Lubricant/refrigerant mixtures also behave differently in the accumulator than mixtures using mineral oil. Polyolester oils are good cleansing agents and are generally used in conjunction with additives for improved lubricant performance.

Changes required in the accumulator stem from the very different behaviour of the lubricant compared to R-22/mineral oil systems. The new design incorporates a destratification device to ensure that the lubricant-rich mixture does not remain trapped in the accumulator. The accumulator is also equipped with a device to separate the two-phase refrigerant to control fractionation so that the composition of R-410A cannot become flammable, even under worst-case conditions.

Polyolester oils do a very good job in dissolving contaminants within a heat pump cycle, preferably dropping the deposits in the expansion device. However, the sudden pressure drop in the device causes some of the contaminants to drop out of the solution, leaving a black sludge. This leads to additional cleaning requirements in the manufacturing process. An R-410A compatible filter dryer is included as standard equipment on R-410A heat pumps and air conditioners.

To ensure adequate velocities for proper oil return to the compressor in inter-connecting lines of split systems, a new table with minimum vapour line sizes has been developed for R-410A, similar to the data given in the ASHRAE Refrigeration Handbook for R-22 and other refrigerants.

Extensive field testing of 14 R-410A heat pumps was conducted in the US from 1994-98. Since then, over 20,000 R-410A heat pumps have been manufactured and installed throughout the country. The reliability record of these units has been exceptional.

TEWI

The results of a TEWI analysis for residential heat pumps and air conditioners using different refrigerants (HFCs, propane and CO_2) was reported by **Mr Furuhama** (Toshiba, Japan). Two measures to reduce the TEWI value were discussed:

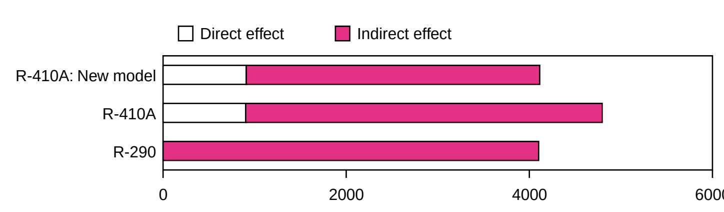
- increasing the refrigerant recovery rate;
- improving the energy efficiency of the unit.

A striking conclusion was that the TEWI value for R-410A, can be the same as for propane, providing that the heat pump is made 10% more efficient and 70% of the refrigerant is recovered. The speaker claimed that the cost of safety measures for a propane unit (20-30%) could be better used to achieve considerable efficiency improvements for R-410A units. A new generation of high-efficiency R-410A residential heat pumps had been developed with a COP of 5 under standard conditions. Efficiency was improved by:

- using a two-cylinder rotary compressor (6%);
- modifying the heat exchanger and optimising the coil circuit (4-5%);
- using smaller diameter tubes;
- reducing the pressure drop along the connecting pipes.

This unit has the same TEWI as a propane heat pump of the same capacity

▼ *Figure 1: TEWI comparison for three systems.*



(see **Figure 1**). It was also claimed that the R-410A unit would outperform a combined system of propane, with CO_2 in a secondary circuit. This statement was heavily questioned as the calculated COP of the combined system seemed to be pessimistic (95%) and based on a prototype. A more realistic value is 110%, which would lead to a less favourable conclusion for R-410A.

Naturals

Mr Bredesen (NTNU, Norway) made an interesting comparison between synthetic and natural working fluids for heat pumping applications. The international heat pump and refrigeration community, in which UNEP, IIR and IEA play an important role, seem to agree on two main strategies for the development of long-term, robust and clean solutions for working fluids (see **Table 1**).

The new category of working fluids under the chemical strategy (HFCs) is largely compatible with CFCs and HCFCs and their equipment. This appears to be an important advantage. The thermodynamic, or natural, strategy implies the use of environmentally safe natural substances that are present in the biosphere, and the challenge is to develop processes and equipment that allow their safe and efficient use.

Mr Bredesen pointed out that both strategies are needed to achieve the common goals of international agreements in the field of refrigerants. With the Kyoto agreement, the role of HFCs may soon become less important as they will probably be regulated and their use restricted. Consequently, a potentially large retrofit market will develop as most heat pumps and air conditioners will have to be converted to non-HCPCs over the next 5-10 years. This will create tremendous opportunities for natural working fluids in small and medium-sized equipment. Examples of realised heat pump installations using ammonia and hydrocarbons were given to demonstrate their safe and reliable use. Examples included:

- a 900 kW ammonia heat pump and air-conditioning system in Norway (COP 4.2);
- a 210 kW propane heat pump in Sweden (where around 15,000 propane heat pumps are in operation).

Mr Muir (Copeland, USA) discussed the impact of new refrigerants on compressors. No major impact is expected on compressor technology, but specific design details will be affected. Durability and reliability of compressors are becoming increasingly important. There is a trend towards more existing rotating technology due to high and variable-speed capabilities, high efficiency, dynamic balance etc. The use of electronic controls, advanced materials and improved manufacturing has contributed to this trend. No specific CO_2 compressor development is on the way at Copeland, while the market for hydrocarbon compressors is too small for the company to initiate a separate development.

Mr Reay (UK) discussed the potential impact of heat exchangers on heat pump system cost reduction. Two options are available for reducing costs:

- compact heat exchangers;
- heat transfer enhancement.

The most recent types of compact heat exchanger were discussed. Major steps forward have been taken, for instance with the recently introduced Chart-Marston Marbond heat exchanger. This concept combines integrity with compactness, to operate over a range of pressures and temperatures not matched by more conventional gasket or welded compact heat exchangers. The manufacturing procedures are similar to those of the printed circuit heat exchangers (chemical etching and diffusion bonding), but the construction allows the use of small passageways, which significantly increase the porosity of the heat exchanger core. A study of the implications for reducing the size of absorption cycle refrigeration plant has illustrated the benefits of multistream, multipass and multifunctional use within a single module. For clean stream duties, the volume of a Marbond heat exchanger could be as low as 5% that of the equivalent shell-and-tube heat exchanger. Compact heat exchangers and enhancement of heat transfer, as the double-effect Rotex absorption heat pump demonstrates, are both powerful tools to help cost-effectiveness of all heat pumping cycles.

Sources

Mr Berntsson (Sweden) discussed heat sources for heat pumps in buildings, district heating systems and industry, mainly for the Swedish market. Around 19,000 new residential heat pumps are being installed annually. The majority of these installations (12,000) are ground-coupled, either soil or rock. Rock-coupled systems are the most popular. Exhaust air is also a widely applied heat source (5,600), as is outside air with reversible ductless split units (900). Outside air heat pumps that distribute heat hydronically are a minority (175). New heat pumps in the medium to large capacity range are quite rare in Sweden, while the district heating market is fairly saturated. Selecting a suitable heat source for industry is much more complex and depends on many factors. Pinch technology is an important and powerful instrument for selecting both heat source and heat sink.

Table 1: Differences between main strategies for finding alternative working fluids.

Main issues	Chemical strategy	Natural strategy
Precondition	Use standard Evans-Perkin cycle form 1834 and standard pressure limits	Use naturally and ecologically safe fluids as refrigerants
Development task	Find new synthesised fluids to fit this cycle	Adapt thermodynamic cycle and equipment to fluid and condition of the application
Goals	Obtain efficiency and safety equal to, or higher than, CFC systems	
Environmental characteristics	Both known negative environmental effects and possibly unforeseen consequences	No unforeseen environmental effects

Session 4: Heat pump systems

Gerdi Breembroek, IEA Heat Pump Centre

Various items were discussed during this session, including refrigerants, supermarket refrigeration, progress on CO_2 systems, gas-fired and absorption systems. Poster presentations covered an even broader scope, including Stirling systems, electro-osmosis, high-temperature heat recovery and more general subjects such as performance monitoring and control strategies.

Mr Yoshida (Matsushita, Japan) presented a paper concerning the acceptability of R-32/hydrocarbon mixtures for residential air conditioners. The HFC R-32 is a slightly flammable refrigerant with a low global warming potential (GWP). Its high discharge temperature in air-conditioning applications raises concerns about lubricant stability. Mixtures of R-32 and hydrocarbons (isobutane, butane) were studied to see if they were more compatible. These mixtures can usually be handled as azeotropic and are in the same flammability category as R-32 (slightly flammable ASHRAE, non-flammable Japan).

Two existing systems, a 2.8 kW room air conditioner and a 10 kW multisplit, both designed for R-410A, were tested with four refrigerants:

- R-410A;
- R-32;
- 95/5 R-32/R-600 mixture;
- 95/5 R-32/R-600a mixture.

For the multisplit unit, 90/10 mixtures were used as well. A mineral oil was applied to the systems using mixtures and an ester used with the pure R-32 and R-410A. Compared to R-410A the mixtures showed an improved efficiency (up to 8-9%) and they are also compatible with conventional oils.

Mr Halm (FKW Hannover, Germany) and **Mr Bobbo** (CNR-ITEF, Italy) discussed the possibilities for controlling heat pump capacity by changing the composition of the refrigerant mixture (zeotropic) using rectification. This allows continuous control of the heat pump capacity. Speed control of the inverter-driven compressors applied in modern heat pumps cannot be used at very low capacities. On/off control compromises the efficiency, as pressure buildup is required when the system is switched on.

A chlorine-free mixture of R-32, R-125 and R-236fa (higher boiling component, with lower capacity) was tested at FKW. VLE (vapour liquid equilibria) properties were measured at CNR-ITEF. Tests showed that it is possible to control the capacity by changing the composition of the mixture at an ambient temperature of between -4°C and +4°C, for typical hydronic heating systems in Europe. Combined with inverter-controlled compressors, the efficiency of the heat pump will not be compromised over a large ambient temperature range.

CO_2 applications

Mr Nekså (SINTEF Energy Research, Norway) presented an overview of the current status of CO_2 technology. An increasing number of researchers and manufacturers are becoming involved in these developments, as CO_2 can be an excellent refrigerant, is nonflammable and has no additional GWP. CO_2 heat pumps for water heating, space heating, space heating and cooling, ventilation air heating, high-temperature space heating, and drying were mentioned. Prototypes had been tested for various applications. **Figure 1** shows the efficiency of a prototype CO_2 heat pump water heater (HPWH) as a function of evaporation temperature.

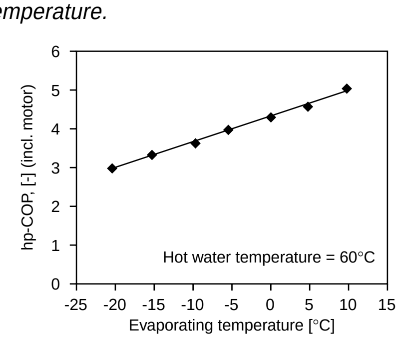
Experimental results show that CO_2 may be successfully used as a working fluid and gives very competitive performance provided that the system is properly designed. The experimental results agree with the theory. Very promising simulation results are available for application areas where no experimental work has been done yet. There are good reasons to continue this work.

Supermarket refrigeration

Mr Laverrenz (Tyler Refrigeration Corporation, USA) gave an overview of the developments in supermarket refrigeration. The 30,000 supermarkets in the USA use 4% of the nation's power. This sector is characterised by widely varying needs, which also change with time. As an illustration, the increasing popularity of pre-prepared meals generates a bigger demand for cooled spaces where the temperature does not rise above 5°C.

The equipment consists mostly of direct expansion R-22, R-404A or R-507 units, with R-22 or R-141b used for insulated panel blowing. Much has been done to reduce refrigerant charges. Secondary systems are available, but so far these have not proved popular. With regard to compressors, scrolls are gaining market share, while reciprocating and screw compressors also have a good future. Both optimised system design and

▼ Figure 1: COP of a CO_2 heat pump water heater as a function of evaporation temperature.



distributed systems are used to increase overall efficiency. Heat recovery opportunities, supermarket dehumidification and air conditioning were important areas for future progress.

Sorption systems

Mr Hendriks (Nefit Fasto, a condensing boiler manufacturer in the Netherlands) presented their work on diffusion absorption heat pumps (DAWP). The strict standards foreseen for new houses in the Netherlands in 2002 promote a heating system that is more efficient than a condensing boiler – a heat pump. Nefit Fasto is currently conducting field tests, and has installed 100 residential heat pumps, with various heat sources, at customers in the Netherlands and Germany. The aim is to produce a heating system that is 20% more efficient than a condensing boiler.

Mr Ziegler (ZAE Bayern, Germany) summarised international trends in sorption technology as discussed at the conference held in March 1999. The working pairs H_2O/LiBr (or derivatives) and NH_3/H_2O still dominate. Cycles discussed included solid sorption cycles, compression-sorption hybrids, and open desiccant cycles. Applications focus on gas cooling, cooling with low-grade or waste heat, car air conditioning, solar cooling and heat pumps.

Mr Ziegler felt that sorption chilling will remain strong in those countries that suffer from a heavy mid-afternoon peak. Sorption systems will not become mainstream applications in other countries but will fill certain niches, e.g. total refrigeration systems, industrial heat recovery, solar cooling, and refrigeration. Large numbers of heating systems may be sold once the step is taken to get beyond the condensing boiler, though the all-electric house remains a strong competitor.

Posters: Advanced systems

Two posters on Stirling systems were presented: one concerning a laboratory prototype for residential use (**Mr Sakamoto**), and a prototype of a Stirling heat pump/gas-engine combination (**Mr Yagyu**), providing 2.6 kW cooling and 4.5 kW heating. Another poster from Japan (**Mr Morita**) presented metal hydrides for high-temperature heat recovery. Waste heat at 160ºC and 90ºC is used to generate H_2 at high pressure, which can then be used for cold and warm water production at another location. **Mr Yoshioka** showed that 28-39% energy saving and 20-40% load levelling had been realised by equipment developed within the ‘Eco-energy city’ project. **Mr Van der Stoel** discussed the concept of the electro-osmotic heat pump, which uses a membrane-electrode assembly to compress the refrigerant.

Compression absorption systems were discussed in two posters. One focused on compression and oil selection for high-temperature applications (up to 100ºC) (**Mr Heidelck**). The other discussed the development of a system using low-grade heat at night to produce ice for thermal storage (**Mr Karimata**). Continuing with thermal storage, the impressive application at the new Gelredome stadium was described by **Mr Snijders**. This system features a heat pump combined with aquifer thermal storage (see Newsletter 16/2).

Performance and control

A standard monitoring system was the subject of a poster presented by **Mr Geelen**, to obtain comparable data on heat pump performance in residences. A somewhat related subject was addressed by **Mr van der Sluis**, that of the proposed energy efficiency labelling of air-to-air heat pumps in Europe. On the other side of the world, TEPCO have realised a laboratory for heat pump performance measurement (**Mr Tsubota**), which aims to promote energy efficiency and load levelling.

Various simulation and control topics were included in the systems poster session. **Mr Thorbergsen** demonstrated the advantages of the Frigosim program. Simulating the frosting process of air-source heat pump units was the subject of a poster presented by **Mr Wang**. **Mr Wimmer** highlighted a new control strategy for low-energy houses and buildings, based on pulse-width modulation, showing simulation results for two control strategies.

Residences

Two posters, both from Germany, covered heat pumps in low-energy houses. One showed various strategies for selecting a heating system from a CO_2 reduction point of view (**Mr Schraps**). **Mr Wobst** studied several heat pump systems for space heating in low-energy houses and compared different refrigerants.

Refrigerants

Progress on developing a propane heat pump for small-scale commercial applications in southern Europe was discussed by **Mr Corberán**. Propane was also used as refrigerant in the outdoor unit profiled by **Mr Hecker**, which showed a system using direct condensation of R-134a in a floor heating system. **Mr Zaulichnyi** presented an air system using a special gas- and energy-dividing device as one of the main elements. The switch from R-22 to R-410A (for room air conditioners) and R-407C (for packaged air conditioners) was the topic of a poster presented by **Mr Suzuki**.

Two papers discussed CO_2. A German paper (**Mr Brandes**) highlighted tests on high-temperature CO_2 heat pumps for retrofitting in residences (hydronic distribution) and a Norwegian paper (**Nekså**) gave further details of the prototype CO_2 heat pump water heater mentioned in the presentation by the same author during the plenary session.

Conclusion

In conclusion, working fluids, particularly CO_2, and thermally activated systems were the main highlights of the systems session. In the poster session, additional focus was on performance and control.

Session 5: Applications

Hanneke van de Ven, IEA Heat Pump Centre

The fifth session of the conference focused on innovative applications of heat pump technology and thus provided some examples of the environmental benefits that can result from the various applications. The first part of the session covered heat pumps for heating and cooling in low-energy houses, thermal storage applications and high-temperature heat pumps for retrofitting hydronic heating systems in existing buildings and for waste heat recovery in industry. The second part covered benefits of load levelling using heat pumps, plus example applications of gas-driven absorption heat pumps and heat pumps in distillation processes.

In Europe, the specific energy demand for heating will be in the range of 160 MJ/m^2a or less over the next 10 years. Ventilation losses will be much higher than transmission losses, and hot water generation will be 30-50% of the total energy demand for heating. **Mr Afjei** presented the results of activities in Switzerland, Austria and Germany for heat pump applications in low-energy houses. He emphasised the importance of concentrating on integrated systems for heating, hot water, ventilation and cooling/dehumidification. These systems lead to higher comfort, better efficiency at equal or lower costs, and less environmental damage.

Thermal storage

Mr Kleefkens discussed thermal storage technology and heat pumps in the Netherlands. He mentioned that with 60 thermal storage projects, cold storage aquifer technology is now considered a proven technology in the Netherlands. However, the combination of cold storage and heat pumps is newer and can still be optimised.
The main questions at the moment are:

- how can we control the system most efficiently?
- what is the best arrangement for the complete system?

With regard to office buildings, this combination has proven efficient in the offices of the insurance company Anova, which resulted in energy savings of 40-50%. Aquifer systems can also serve as an alternative energy source for residential heat pumps in larger building projects. New example projects are starting for groups of commercial buildings along the Eastern Trade Wharf in Amsterdam, for a combination of small industrial and commercial buildings in the Hesserpoort area in Zwolle, and for new houses in Broekpolder.

Mr Kleefkens concluded his presentation with the statement that cost reductions of 40% for aquifer systems can be achieved by standardising the system design, standardising heat pump systems for residences and by integrating energy systems in commercial buildings and light industrial areas.

High-temperature HPs

The presentation given by **Mr Brandes**, Germany, covered high-temperature heat pumps for retrofitting hydronic heating systems in existing buildings, plus waste heat recovery in industry, with the emphasis on working fluids. For industrial applications (up to 70°C) R-134a can replace R-12, while water can be used above 120°C. To find a suitable alternative for R-114 at temperature levels bridging this gap, a theoretical study was performed that compared HCs and HFCs for two different cycles. As a single fluid, R236-ca seems to be the most interesting substitute. Several mixtures lead to even higher COPs and volumetric heating capacities than R-114 under the normal parameters of limited pressures. Ammonia/water in a combined absorption/compression cycle could also be an alternative.

For residential retrofit heat pumps, the typical supply and return temperatures are 90/70°C and 70/50°C. These temperatures cannot be achieved with the heat pumps currently available on the market. Mr Brandes discussed transcritical cycles using CO_2, which were studied within the context of a European project (COHEPS).

Load levelling

Mr Katakura opened the second part of the session with a presentation on heat pump applications for load levelling, mentioning six applications that could contribute to higher load ratios. These included district heating and cooling using unused energy, thermal storage systems and eco-ice air-conditioning systems, which are particularly suitable for existing buildings as they are smaller. He also mentioned multifunction heat pumps providing conventional cooling, heating and domestic hot water, bathroom drying and reheating bath water. Power consumption for daytime air conditioning can be reduced up to 40%. The eco-showcase is an energy-saving freezer/ refrigerator that levels the load by reducing lighting and raising the temperature of the cooling blower, resulting in total power savings of 10-12%. A similar development is the eco-vendor, an energy-saving vending machine (for soft drinks) with improved insulation, which switches off during the peak period, reducing peak power consumption by 90%.

Compared to conventional equipment, thermal storage systems reduce CO_2

emissions by approximately 25%, because they use night-time electricity – a low proportion of power generated using fossil fuels - as well as achieving direct energy savings. Compared to a cogeneration system (power generation efficiency 20% and heat recovery efficiency 44%), a thermal storage air-conditioning system with a heat pump efficiency (COP) of 3.5, reduces CO_2 emissions by 42% and NO_x emissions by 70%.

Mr Stahlberg's presentation described four applications of gas-driven absorption heat pumps in Germany:

1. an application in a detached house in Koblenz;
2. a brine-to-water gas-driven absorption heat pump in a three-apartment building in Dortmund, where the facade and foundations are used as the heat source. Monitoring over five years showed energy savings of 33% compared to a conventional gas boiler;
3. an office building in Waghäusel;
4. four indoor swimming pools in Münster using gas-driven absorption heat pumps. The payback period for these applications is three years, as the energy savings are approximately 50% those of conventional systems.

Industrial

Several presentations in the accompanying poster session covered industrial applications**. Mr Bailer** described a 14 MW heat pump for a municipal waste burning plant in Umea, Sweden. The heat pump uses R-134a as refrigerant and supplies hot water (at up to 75°C) to a district heating system, achieving a COP of 5. **Mr Grandum** evaluated an absorption/compression-type heat pump for implementation in the process industry. The heat pump is currently being tested and upgrades waste heat. It has the potential to reach higher temperatures than with conventional vapour compression systems.

Mr Nakanishi presented a heat-integrated distillation column (HIDiC) to reduce losses in distillation processes. The system must be operated at a higher pressure in the rectifying section to ensure that the temperature is higher than the parallel stripping section. The energy for the reboiler can be saved due to vaporisation in the stripping section and condensation in the rectifying section. It is claimed that this method can lead to energy savings of over 30%. **Mr Lazarrin** analysed the application of an open-cycle absorption heat pump in industrial convection drying. He argued that this sorption dehumidification heat pump can be very effective in reducing energy consumption. For onion drying, for example, savings of 40% can be expected, with a payback period of only two years on the investment. The paper by **Mr Susai** also considered one application using an absorption system in a distillation process, and another in a waste incineration plant.

Two poster presentations came from **Mr de Wit,** the Netherlands. He described the application of heat pumps in the Dutch flower bulb industry, which have the advantage that the entire process can be performed using one system. A COP of 4-5 can be reached, while decentralised heat pumps seemed to be more beneficial than central heat pumps. Energy consumption can be halved, and costs will be reduced correspondingly.

The second poster covered heat pump applications in utility centres for large industrial areas in the Netherlands. He concluded that in the Rijnmond district, a potential 9.9 PJ can be saved for the period 1997-2007 by industrial heat pump applications. For the period 2007-2017 Mr de Wit estimates that there is an additional saving potential of 20 PJ.

Residential

Mr Bühring described a simulation tool that can support the construction industry in designing a compact ventilation device with an integrated exhaust-air heat pump for heating residences. The tool is based on catalogue or tender data from component manufacturers and has proven useful, especially before the first prototype is built. **Mr Buschmann** described an air-source heat pump system with ground registers and air conditioning. The energy source for heating is a mixture of streams utilising outdoor and indoor air. High COPs are reached, even if it is cold outside. In summer a simple air-conditioning system can be realised by cooling the air in the ground registers. **Mr Primus** showed how a massive concrete absorber can serve as a heat source, coupled to the air or ground. Several demonstration projects in Germany have proven that this technology works.

A new Chinese concept for cooling applications was described in the poster by **Mr Kunxiong**, which is suitable for subtropical climates. The concept involves using a cooling tower to extract heat from ambient air as the heat source.

Although the demand for cooling in residences has been quite low in the Netherlands, trends indicate that this might be changing. TNO is developing a heat pump system for both heating and cooling, where the cooling function requires only marginal energy use.

Other topics

The results from Annex 22 of the IEA Heat Pump Programme regarding the use of natural working fluids in compression heat pumps were presented by **Mr Stene** (see article on page 24 in this issue). **Ms Breembroek** of the IEA Heat Pump Centre presented the results of an analysis study on the environmental benefits of heat pumps. A research and development programme carried out by **Mr Eggen** focused on NH_3/CO_2 commercial refrigeration plants. For the Eco-Energy City project in Japan, **Mr Omata** described the main developments in heat pump technology. The final presentation was a dynamic installation and building simulation method developed by TNO, the Netherlands.

Session 6: Market strategies

Jos Bouma, IEA Heat Pump Centre

Mr Ehrtinger (Carrier, USA) discussed the future market for chillers. Since 1975 the cooling efficiency of chillers has increased by 35%. Improvements have been achieved through: more effective heat transfer, advanced evaporators, enhanced cycles, subcooling, economising and throttle-loss power recovery. The manufacturing process was emphasised as the key to further advancements. Future improvements will probably come from improved aerodynamic efficiency and better part-load operation. The market for chillers is expanding positively, particularly for retrofit situations.

Mr Watanabe (MITI, Japan) discussed the shift that can be seen, from simple heat pump installations to combined heat pump and thermal storage systems, for both residential and commercial/ institutional buildings. The electricity grid load factor is low (55%) in Japan. The government and utility policy aiming at improving the load factor by stimulating both chilled water and ice thermal storage systems. Chilled water is mainly used in large buildings with central air conditioning. Ice storage systems are predominantly used for individual air conditioning systems in medium-sized and tenant buildings. Shipments have been steadily increasing since 1994, as can be seen in **Table 1**.

Electric utilities are offering incentives, plus special rates and customer contracts. Other powerful instruments include energy servicing, where the utility handles everything from installation to operation, maintenance and leasing. Government policy measures focus on information campaigns, encouraging the use of gas-fired equipment and promoting thermal storage combined with heat pumps. A budget of over USD 25 million (JPY 3 billion) was made available in 1998 and 1999 for projects and promotion. Besides incentives, the government also offers tax deductions on investments for thermal storage systems. In the long run, heat pumps and gas-fired cooling equipment contribute 3.5 and 2.4 million kW respectively to the overall load-levelling goal of nearly 17 million kW.

▼ *Table 1: Shipments of thermal storage systems.*

Year	1994	1995	1996	1997
Individual systems	122	417	1,500	3,067
Central systems	91	93	153	180

Mr Göricke (Germany) discussed market strategies for residential heat pumps in German-speaking countries. Heat pumps are starting to conquer the market, but intensified marketing campaigns targeting all market players are still required. Heat pumps are slowly losing their image of being exotic and unreliable. Today heating-only heat pumps have COPs ranging between 3.5 and 4.5. In many countries installers and contractors are still the weakest links in the chain. More (and better) training is essential for success. Organisations offering marketing concepts and strategies for utilities have entered the market in Germany, while the German Heat Pump Initiative Group actively promotes the technology through advertising, information, training etc. The joint effort with Austria and Switzerland to develop the heat pump quality label was an important breakthrough in achieving high-quality heat pump installations.

Posters

In a poster by an industry association from the *State of North Rhine Westphalia*, Germany an important joint initiative is referred to as ‘one-stop system solutions’. This industry initiative is aimed at removing institutional obstacles to contracting and provides training for ground-source heat pump system (sub) contractors. Manufacturers, drilling contractors, installing contractors, electrical contractors and the State Energy Agency NRW have joined forces to cover the whole heat pump system installation through one single contracting party which communicates with the customer.

Under the European Union SAVE II programme, a poster prepared by *ADPM, France* described the European work proceeding in this area. The overall objective is to develop a certification system that will guarantee the performance of products as well as the competence of those who install heat pump systems, which leads to an overall acceptable system quality. The consortium formed for this EU project consists of ADPM and EUROVENT Certification, complemented with heat pump manufacturer associations in Europe, as well as organisations working on designing and installing (UCF), training of technicians (TWK) and research (Sintef Energy). Additional support and input is provided by French Energy and Environmental Agency ADEME and the national French electric utility EdF.

The guidelines for this project have been provided by the European Heat Pump Network. The actual participants in the certification project, which will be completed halfway through 2000, are France, Norway and Germany. Certification of equipment (based on CEN test standards) is basically a labelling initiative with information about energy efficiency and the equipment itself. Ultimately the various actions of the European Heat Pump Network will culminate in the so-called European Charter of Warranty on Heat Pumps and will be available in print and on CD-ROM.

Global warming impacts of ground-source heat pumps compared to other systems

Douglas Cane, Canada

Heat pumps can significantly reduce primary energy use for building heating and cooling. The renewable component, anywhere from as low as 33% (air-source) to 66% (ground-source), depending on location (climate), displaces the need for primary fuels. This article describes the result of an analysis that was undertaken by Caneta on behalf of the Renewable and Electrical Energy Division of Natural Resources Canada. It aimed to estimate the total equivalent (global) warming impact (TEWI) of ground-source heat pumps (GSHP) compared to other heating and cooling systems in residential, commercial and institutional buildings. The modelling results showed significant emission reductions in major cities across Canada.

TEWI analysis can determine the overall contribution to global warming from energy-using equipment over its operating lifetime. The greenhouse gases released from fossil fuel electricity production and combustion are referred to as the **indirect** TEWI effect. The leakage of refrigerants into the atmosphere is referred to as the **direct** effect. The global warming potential of released or leaked refrigerants is much greater than that of carbon dioxide.

The fuel used for electricity generation determines whether the electricity production results in large emissions of CO_2. In Canada, hydropower plants produced 64% of the total electricity generated in 1996, with another 16% from nuclear sources. Generation from combustion and fossil fuel steam plants accounted for only 20% of the total electricity generated in the same year. The latter are large producers of CO_2, while the former produce none.

The electricity generation mix varies widely across Canada. In British Columbia and Quebec, 90% of the electricity is generated via hydropower plants. In Ontario, around 50% of the power is produced in nuclear plants, with the remaining 50% almost equally split between fossil fuel and hydropower plants. In Alberta, Saskatchewan and Nova Scotia over 80% of the power is produced in fossil fuel steam plants.

Energy modelling

The **residential** house model had a window area of 23 m^2, 230 m^2 of floor area above the ground surface and a basement. Assumptions were made for insulation levels of the walls of the house and the basement. The windows were double-glazed. The energy consumption of the competing **heating systems** was determined using the HVAC Advisor computer program. The ground-source heat pump was closed-loop. Heating impacts alone were examined in residential buildings, whereas both heating and cooling impacts were examined in commercial and institutional buildings.

A small multi-unit residential building (MURB) and primary school building were two **commercial/institutional building** models that were analysed here. The MURB model is a four-storey, 44-suite building, with an underground parking garage. The primary school is a two-storey building with 4,260 m^2 of floor space. The total energy use of these buildings was determined using the US DOE (Department of Energy) 2.1E energy analysis program.

The energy-efficiency characteristics of the residential heating equipment, ground-source heat pump, chiller and boiler used in the models are summarised in **Table 1**. The residential heating equipment, with the exception of the oil furnace, has a high efficiency. The ground-source heat pumps used in both the MURB and primary school models are high-efficiency commercial units, available in the marketplace.

Residential

The results of the residential TEWI analysis are presented in **Table 2**. The **ground-source heat pump** has the lowest TEWI or total equivalent mass of CO_2 over the 20-year lifetime, in all the cities examined. The **high-efficiency air-source** heat pump has the second lowest TEWI in Vancouver and Toronto. In Montreal, due to the very large amount of hydropower electricity generation, the electric furnace has the second lowest TEWI caused by the direct effect of refrigerant leakage from the air-source heat pump. Using refrigerants that are not greenhouse gases would change this ranking to that observed in the other cities. In Halifax, the oil furnace has a slightly smaller TEWI than the high-efficiency air-source heat pump.

The **electric furnace** has a lower TEWI than the oil furnace and high-efficiency natural gas furnace in Vancouver, Toronto and Montreal. This is due to the relatively small fraction of fossil fuel electricity generation in these areas. In Halifax, where over 80% of electricity production is from fossil fuel, the oil furnace has the second lowest TEWI, just below the high-efficiency

Table 1: Equipment energy-efficiency characteristics.

Residential heating equipment		**Assumption**
electric furnace		Annual eff.: 100%
oil furnace		Annual eff.: 78%
high-efficiency air-source heat pump		SPF: 2.0
ground-source heat pump		COP: 3.3
high-efficiency natural gas furnace		Annual eff.: 90%
Commercial/institutional equipment		
MURB	**Cooling**	**Heating**
reciprocating chiller	COP: 3.8	—
boiler	—	Comb. eff. 80%
ground-source heat pumps	COP: 4.5	COP: 3.4
Primary school		
reciprocating chiller	COP: 4.2	—
boiler	—	Comb. Eff.: 80%
ground-source heat pumps	COP: 4.5	COP – 3.4

Table 2: Comparison for residential applications of the total equivalent mass of CO_2 [kg].

System	Vancouver	Toronto	Montreal	Halifax
Electric furnace	12,324	61,366	6,143	374,865
Oil furnace	84,234	143,094	155,666	157,587
Hi. eff. air-source HP	9,086	33,355	8,368	161,854
GSHP	6,314	23,333	4,330	131,811
Hi. eff. natural gas furnace	54,467	90,811	97,577	104,994

Table 3: Comparison for commercial applications of the total equivalent mass of CO_2 [kg].

	Vancouver	Toronto	Montreal	Halifax
Primary schools				
Central VAV	2,334,165	4,001,070	2,373,120	11,343,505
GSHP	783,985	1,821,715	542,630	8,486,370
MURB				
4-pipe/ chiller/boiler	–	3,272,394	1,282,035	11,689,058
GSHP	–	2,140,839	603,962	11,140,109

air-source heat pump, but still higher than the ground-source heat pump.

In Vancouver, the **oil furnace**, which currently meets the Canadian national regulated minimum annual efficiency of 78%, will produce over 13 times the equivalent CO_2 emissions of the ground-source heat pump. In Toronto, this is reduced to six times.

In Vancouver, the **high-efficiency natural gas furnace** produces over eight times the lifetime greenhouse gas emissions of the high-efficiency ground-source heat pump. In Toronto, this is reduced to 3.5 times.

Only in Halifax, where significant electrical generation is from fossil fuels, do conventional furnaces have comparable TEWIs to ground-source heat pumps.

Commercial buildings

The results of the commercial/ institutional building TEWI analysis are presented in **Table 3**. Here, **total** building energy use is included in the indirect TEWI effect.

The **GSHP** system building has the lowest total equivalent mass of CO_2 or TEWI impact, in both the MURB and primary school buildings, in all cities.

The magnitude of the reduction depends on the base case system efficiency and the electrical generation mix. It varies from a high of 77% in the Montreal primary school to only 15% in Regina, where electricity is mainly produced via fossil fuel steam plants. The direct effect, due to an assumed higher refrigerant leakage rate, is higher for the GSHP packaged system than for the modern central reciprocating chillers in the base case.

Conclusions

Significant emission reductions can be achieved by using ground-source heat pumps in both residential and commercial buildings. For the examples presented here, residential fossil fuel heating systems produced anywhere from 1.2 to 36 times the equivalent CO_2 emissions of ground-source heat pumps. In the commercial/ institutional sectors examined, CO_2 emission reductions from 15% to 77% were achieved by using ground-source heat pumps.

Ground-source heat pump equipment is widely available throughout Canada. The equipment is competitive on a life-cycle cost basis with those systems examined here, particularly in those markets where air conditioning is desired.

There is unlikely to be a potentially larger mitigating effect on greenhouse gas emissions and the resulting global warming impact of buildings from any other currently available single technology, than from ground-source heat pumps.

Mr Douglas Cane
Caneta Research Inc.
7145 West Credit Avenue
Suite 102, Building 2
Mississauga, Ontario
L5N 6J7, Canada

Out now: International heat pump status and policy review

Gerdi Breembroek, IEA Heat Pump Centre

Four years after the publication of the *International Heat Pump Status and Policy Review 1989-92*, the IEA Heat Pump Centre has compiled an update of this analysis work. The current update reviews developments during 1993-96 and provides an outlook of future prospects. This article presents the highlights.

In 1997 there were roughly 85 million heat pumps in operation worldwide. With 55 million in 1992, this corresponds to an annual growth of 11%. From the global heat pump stock, 58 million units are in Japan, 11 million in the USA and 11 million in China. The southern European countries also represent an important heat pump region (together around 3.5% of the world heat pump stock). Canada, northern and central Europe, and South Korea are relatively small heat pump markets.

The analysis is based on a survey of the heat pump situation in 18 countries: Austria, Canada, China, Denmark, France, Germany, Greece, Italy, Japan, the Netherlands, Norway, South Africa, South Korea, Spain, Sweden, Switzerland, the UK and the USA. The study comes in two parts. In Part 1 (95 pages), surveys from all these countries are brought together, compared and analysed. The information is derived from detailed reviews of the situation in individual countries, the *National Position Papers*. Part 2 (350 pages) comprises these detailed reviews.

Basic factors

The basic factors section discusses the development of primary energy use worldwide, electricity generation, end-use energy prices and the building stock in the various countries. The review shows that the amount of fossil fuels used for electricity generation is falling in most countries. There is a shift towards natural gas, and the percentage of coal-fired capacity is decreasing. Energy prices have remained low over the entire period (1993-96).

Policy measures

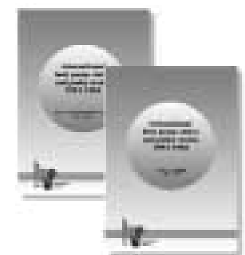
Stimulating heat pumps as an energy-efficient technology, or the rational use of electricity or gas, can be in the interest of both governments and utilities. A growing number of governments include heat pumps in their *renewable* energy policy.

The study confirmed that an important factor influencing the attitude of utilities is the deregulation of the energy sector in many developed countries. The heat pump market is affected by deregulation in two ways: through changes in energy prices and market strategies. The predicted electricity price changes will not cause a major breakthrough in the heat pump market. As for the future role of utilities, it is generally expected that they will provide additional energy services to satisfy and retain customers and gain market share.

Working fluids

The use of CFCs in all new equipment has been forbidden in developed countries since 1996. This is reflected in the decreasing amount of CFC equipment since the previous study. Worldwide, HCFC-22 dominates as working fluid. The stock of HFCs, NH_3 and other working fluids (hydrocarbons) has increased since 1996. Sweden reported the highest market penetration of HFCs (51%). In Germany, hydrocarbons have a significant market share for new heating-only installations (1996).

The energy efficiency of heat pumps has gradually increased over the last four years. The average SPF of electrically driven air-to-air heat pumps (the most



popular type) improved between 0 and 0.5 in the various countries (up to $SPF_{heating}$ = 4.5 in Japan). Ground-, water- and waste-heat-source heat pumps showed greater efficiency progress, ranging between 0.4 and 1.3.

Markets

The report provides a wealth of details on the various markets, distinguishing between residential, commercial and industrial end-users, market shares of various drive energies, heat sources etc. The articles on pages 10 and 12 provide a summary of the market developments in several regions.

In 1992 it was reported that the heat demand met by heat pumps was never more than 5% of the total heat demand in all market sectors. This study reveals that market penetration has greatly increased in specific countries. Overall, the heat pump market developed favourably during the period 1993-96. For 1997 and 1998, this development continued in northern and central Europe, and the USA.

Ordering information

The report can be ordered using the response card stapled in this Newsletter (product code HPC-AR7) and costs NLG 480 (2 volumes) (NLG 160 for HPC member countries, see back cover).

Natural working fluids – a safe and energy-efficient alternative in compression heat pumping systems

Jørn Stene, Norway

In January 1995 eight countries participating in the IEA Heat Pump Programme joined forces in Annex 22 to develop the technology, expand the knowledge base and prove the maturity of compression heat pump, air conditioning and refrigerating systems with natural working fluids. The collaborative project "Compression Systems with Natural Working Fluids" was officially closed in July 1998 after 3.5 years of operation. This article summarises the activities and findings of the Annex.

Set-up and goals

The following countries participated in Annex 22: Canada, Denmark, Japan, the Netherlands, Norway, Switzerland, the United Kingdom and the USA. Norway was designated Operating Agent, acting through SINTEF Energy Research. The Annex mainly focused on residential and commercial heat pumping systems using natural working fluids such as ammonia, hydrocarbons, carbon dioxide (CO_2), water and air.

The main objectives of Annex 22 were to:

- evaluate and promote the use of natural working fluids in heat pumping systems;
- identify key technical challenges, and carry out relevant R&D projects;
- gather relevant existing information, and make it readily available.

Core activities included information dissemination, organising three work-shops, completing 25 R&D projects, and preparing proceedings and reports. The total value of these activities has been estimated at USD 2 million.

The main report from Annex 22, "Final Report – Guidelines for Design and Operation of Compression Heat Pump, Air Conditioning and Refrigerating Systems with Natural Working Fluids" was published in June 1999 (see **Figure 1**). The report describes the findings of the Annex and is aimed at scientists, manufacturers, suppliers, contractors, consultants, installers, operating personnel, end-users, policy makers, organisations for protecting the environment, and others who are interested in environmentally safe and energy-efficient heat pumping systems.

Safety issues

The Annex clearly demonstrated that flammable, toxic and high-pressure working fluids such as hydrocarbons, ammonia and CO_2 can be safely applied in residential and commercial heat pumping systems, as long as those systems are designed, installed, operated and maintained according to prevailing safety standards. The main important sapects that have been considered are principles of the quantitative risk analysis (QRA) and risk evaluation using indices, important physical properties and the safety parameters of the fluids, main classification criteria and recent results from a number of completed risk analyses.

Ammonia

Ammonia is the most well known alternative among the natural working fluids, since it has been used extensively in industrial refrigerating plants and other large-scale applications for over a century. Until now, strict standards and regulations for the construction and operation of ammonia heat pumping plants have hampered its use in commercial and residential applications. However, in recent years great efforts have been made to develop simple, automatic, low-charge and more reasonably priced systems that can be safely applied in buildings situated in densely populated areas. This approach has resulted in a renewed interest in theammonia technology.

Figure 1: Front cover of the Annex 22 Final Report.

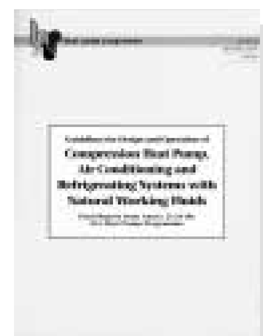


Figure 2: Ammonia heat pump in a commercial building in Norway.

- 2 x 450 kW heating capacity
- Low charge unit - 0.2 kg ammonia per kW heating capacity
- Safety measures:
  - Gastight machinery room
  - Emergency exits
  - Self-closing doors
  - Gas detectors/alarm system
  - Fail-safe ventilation
  - Ammonia scrubber

A detailed comparison of ammonia and commonly used HFCs (R-134a, R-507A, R-407C, R-410A) has been made with regard to important physical/thermophysical properties, dimensions of pipelines, valves and pumps, required compressor volume, discharge gas temperatures, heat transfer properties, as well as system energy efficiency. Important aspects regarding safe, reliable and energy-efficient design and operation were taken into consideration when compiling this overview of ammonia heat pump systems.

Within the Annex, examples of heat pumping applications using ammonia were gathered from Denmark, Germany, the Netherlands, Norway (see **Figure 2**), Sweden, Switzerland, and the USA. These examples prove the maturity of ammonia technology, and include supermarket refrigeration systems (indirect systems using brines, binary ice and CO_2), water chillers in commercial buildings, and heat pumps in residences, commercial buildings, district heating/cooling systems and industry.

Hydrocarbons

Hydrocarbons have been used in large refrigerating plants for many years, notably in the petrochemical industry, where the handling of flammable fluids is customary. In recent years domestic refrigerators using isobutane have taken a considerable market share in certain European countries. Due to the flammable characteristics of the hydrocarbons, they are mainly regarded as viable options in low-charge heat pumping systems. Hydrocarbon heat pumps are mostly found in Germany, the United Kingdom, Sweden, the Netherlands, Austria and Switzerland. Most units have a charge of less than 1 kg, and propane is the dominating working fluid.

As with ammonia, a detailed comparison was made of propane, propene and the most commonly used HFCs. Owing to the remarkable thermophysical properties of hydrocarbons, excellent energy efficiency can be achieved for all types of heat pumping systems. Important aspects that have been evaluated are the purity of hydrocarbon working fluids, lubricants, compressors, plate heat exchangers, as well as low-charge packaged liquid chillers, unitary heat pumps and air-conditioning units.

The main argument against installing hydrocarbon heat pumping systems in residential and commercial buildings is the possibility of fires/explosions, plus related injuries and material damage. An overview has been made which classifies these hazardous areas, and gives ways to attain safe systems by implementing various risk-reducing measures. These include low-charge units, minimising leakage, special electrical apparatus, safe compressor design, ventilation requirements and leak detection (see **Figure 3.**) Emphasises the importance of professionally trained staff to design, manufacture, install, repair and maintain the equipment .

Examples of such installations were collected from Austria (see **Figure 4**), Germany, Sweden and the United Kingdom, to prove the maturity of hydrocarbon technology. These included liquid chillers in supermarket refrigeration (indirect systems using brine and CO_2), water chillers in commercial buildings, and heat pumps in residential and commercial buildings.

Figure 3: Possible risk-reducing measures for a hydrocarbon heat pumping installation.

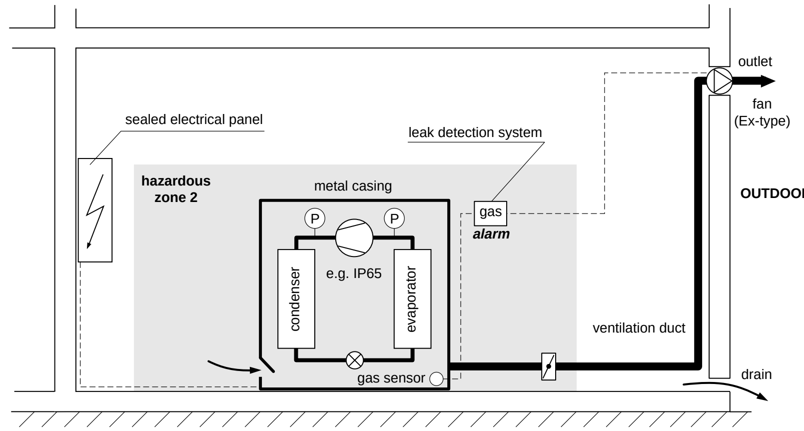
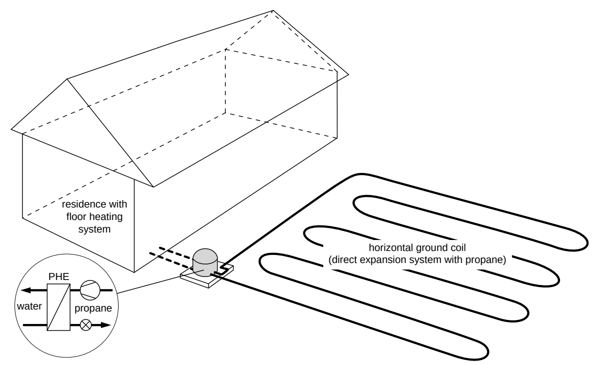


Figure 4: Residential ground-coupled propane heat pump unit in Austria.

- Direct-evaporation horizontal ground-coupled system
- Hermetically sealed unit
- The outdoor installation eliminates the risk of fire and explosion
- High energy efficiency, SPF > 4.0



Carbon dioxide

Carbon dioxide (CO_2) is a nonflammable and nontoxic working fluid that does not contribute to ozone depletion or global warming. CO_2 was “rediscovered” as a working fluid when several projects concerning CO_2 heat pump water heaters and mobile air-conditioning systems were initiated at SINTEF Energy Research, Norway in the early 1990s. More recently, interest in CO_2 has been growing rapidly and it

▼ *Figure 5: A 50 kW prototypeCO_2 heat pump water heater.*

- 50 kW installation
- Transcritical heat rejection
- Supply temperatures 60-90ºC without operational problems
- COP of 4 - 4.5 at various supply and evaporation temperatures

is now regarded as a promising long-term alternative in a number of heat-pumping applications.

Since many are unfamiliar with CO_2 as a working fluid, the final report gives the most important physical and thermo-physical properties of CO_2 as well as the main characteristics of the transcritical process. Required compressor volume, pressure drop in pipelines and components, heat transfer properties and system energy efficiency (compared to HFCs) are also discussed, together with the current technological status of compressors, lubricants and heat exchangers.

There are currently no commercial installations using CO_2 as a working fluid, but a number of prototypes have shown very promising results. An example is given in **Figure 5**. The most promising applications are heat pump water heaters, mobile air-conditioning units, unitary air conditioners and heat pumps, residential and commercial heat pumps, heat pump dryers and refrigeration systems in supermarkets (cascade or direct expansion).

Indirect systems

Some Annex activities concentrated on the design and application of indirect (dual loop) heat pumping systems. A large number of single-phase and phase-changing heat transfer (secondary) fluids were compared with respect to thermo-physical properties and other important parameters. The application side focused on refrigeration systems in supermarkets. Indirect systems have many advantages over direct expansion (DX) systems. The main argument against the former is the larger temperature lifts owing to the extra heat exchanger(s) installed between the evaporator/condenser and the substance to be cooled/heated. In turn this may result in an energy penalty compared to DX systems using HFCs. However, both ammonia and propane/propene are working fluids with superior thermodynamic properties, and the results clearly demonstrate that excellent energy efficiency can be achieved as long as the plants are correctly designed/operated and high-quality secondary fluids are applied (e.g. potassium formate, CO_2, or binary ice).

Report

The Annex 22 Final Report can be ordered from the IEA Heat Pump Centre. **Please note that until 5 June 2001, this report will only be sold to those living in countries that participated in Annex 22.**

Author:
Mr Jørn Stene
SINTEF Energy Research
7465 Trondheim, NORWAY
Tel.: +47-73-591642
Fax: +47-73-593950
E-mail: Jorn.Stene@energy.sintef.no

Warmepumpen in der Heizungstechnik
Available from: C.F. Müller Verlag, Hüthig Gmbh, PO Box 1025869, 69018 Heidelberg, Germany. Fax: +49-6221-489450. E-mail: dfmueller@huethig.de ISBN: 3-7880-7664-X.
Price: DM 58, 144 pages. In German language.
This is a practical handbook aimed at installers and planners, and contains information that will enable them to judge the possibility of listing of a heat pump heating system.

Eurovent Directory of Certified Products
1. Fan Coil Units and Liquid Chilling Packages (Febr. 1999 – Jan. 2000)
2. Air Conditioners and Close Control Air Conditioners (Febr. 1999 – Jan. 2000)
Available from: EUROVENT Certification Company, 15, rue Montorgueil, 75001 Paris, France. Fax: +33-1-40137544.
E-mail: eurovent-cert@wanadoo.fr
Both publications include data on the products of more than 120 equipment manufacturers that were covered in the Eurovent Certification Programme, including the guaranteed true performance data for most of the products on the market.

SwEWS Software package (menus in German)
Available from: Nova Energie GmbH
Phone +41-62-834 03 03, Fax: +41-62-834 03 23
E-Mail:beratung@infoenergie.ch
Price: CHF 215
This computer program is described on page 6. A handbook is included in the price.

1998 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee
Available from: UNEP, SMI Distribution Services, PO Box 119, Stevenage, Hertfordshire SG14TP, UK. Fax: +44-1438-748844.
E-mail: enquire@smibooks.com
Price: USD 45, ISBN 92-807-1704-9.
In 1998 a re-assessment of heat pumping technologies was made for the Montreal Protocol on substances that deplete the ozone layer. The results are presented in this report, which gives information on the Montreal Protocol process, the recent global CFC and HCFC production and consumption data and estimates for short-term usage of flurochemicals. It also covers the domestic, commercial industrial and transport refrigeration, cold storage and food processing, air conditioning, heat pumps and refrigerant conservation.

Available from the HPC

PLEASE USE THE ATTACHED RESPONSE CARD WHEN ORDERING HPC PRODUCTS

International Heat Pump Status and Policy Review: 1993-1996
Analysis Study, August 1999
Order No. HPC-AR-7, NLG 480 or NLG 160 in HPC member countries

Guidelines for Design and Operation of Compression Heat Pump, Air Conditioning and Refrigerating Systems with Natural Working Fluids
Final Report, December 1998
Order No. HPP-AN22-4, NLG 100 in Ca, Ch, Dk, Jp, Nl, No, UK and US. (Not available for other countries until 5 June 2001)

Environmental Benefits of Heat Pumping Technologies
Analysis Study, April 1999
Order No. HPC-AR-6, NLG 240 or NLG 80 in HPC member countries and Ca, It and Se

Ab-Sorption Machines for Heating and Cooling in Future Energy Systems
Workshop Proceedings, April 1999
Order No. HPP-AN24-2, NLG 180 or NLG 60 in HPC member countries

The Role of Heat Pumps in a Deregulated Energy Market
Analysis Study, October 1998
Order No. HPC-AR-5, NLG 240 or NLG 80 in HPC member countries

Heat Pump Systems for Single-Room Applications
Final report, January 1999
Order No. HPP-AN23-2
Price NLG 300, or NLG 100 for HPC member countries and Ca, Fr and Se.

For further publications and events, visit the HPC Internet site at http://www.heatpumpcentre.org

20th IIR International Congress of Refrigeration
Refrigeration into the 21st century
19-24 September 1999 / Sydney, Australia
Contact: ICR99 Secretariat,
52 Rosslyn Street,
West Melbourne, Vic 3003,
Australia
Tel.: +61-3-93282399
Fax: +61-3-93284116
E-mail: icr99@airah.org.au
Internet: http://www.airah.org.au/icr99

European Geothermal Conference Basel '99
28-30 September 1999 / Basel, Switzerland
Contact: OC Secretary EGC Basel '99,
Bureau Inter-Prax,
Dufourstrasse 87,
CH-2502 Biel/Bienne,
Switzerland
Fax: +41-32-3414565
E-mail: interprax@bluewin.ch

1999 Annual GeoExchange Industry Conference and Expo
26-29 September 1999 / Sacramento, California
Contact: International Ground-Source Heat Pump Association (IGSHPA)
Tel.: +1-800-6264747
Fax: +1-405-7445283
Internet: http://www.igshpa.okstate.edu

Kyoto Protocol: Reduction of HFC Emissions- Increase of Efficiency
A dual approach for refrigeration/air conditioning industry
6 October 1999 / Essen, Germany
Contact: ASERCOM, Motzstrasse 91,
D-10779 Berlin, Germany
Fax: +49-30-21479871

Geothermal Heat Pump Consortium 1999 Annual Meeting and Conference
20-22 October 1999 / Atlanta, Georgia
Contact: GHPC,
Tel: +1-202-5085500
Internet: http://www.ghpc.org

Heat Pump Training Programmes
8 November 1999 / Paris, France
In conjunction with Interclima
Contact: European Heat Pump Network,
Mr Lehmann
Tel.: +49-72-47808351
E-mail: ale@fiz-karlsruhe.de

IIR Gustav Lorentzen Conference
25-28 July 2000 / West Lafayette, Indiana, USA
Contact: IIR, 177 Boulevard Malesherbes,
75017 Paris, France
Fax: +33-1-47631798
E-mail: iifiir@ibm.net

Heat pipes, heat pumps and refrigerators
September 2000 / Minsk, Belarus
Contact: CIS Countries Association Heat Pipes
Luikov Heat and Mass Transfer Institute,
220072, P.Brovka 15, ITMO, Minsk, Belarus
Fax: +375-172322513
E-mail: allusr@avtlab.itmo.by

ACHRB 2000 - Air conditioning in high-rise buildings
October 2000 / Shanghai, China
Contact: IIR, 177 Boulevard Malesherbes,
75017 Paris, France
Fax: +33-1-47631798
E-mail: iifiir@ibm.net

IEA Heat Pump Programme Events

Natural Working Fluids - a challenge for the future
9 November 1999 / Paris, France
Joint Workshop by the EU Heat Pump Network and the IEA Heat Pump Centre
In conjunction with Interclima.
Contact: European Heat Pump Network,
Mr Lehmann
Tel.: +49-72-47808351
E-mail: ale@fiz-karlsruhe.de or the HPC,
or contact Mr Kleefkens (see back cover).

Next Issue

Industrial Heat Pumps
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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 cooperation among its 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. In the member countries (see right), activities are coordinated by National Teams. For further information on HPC products and activities, or for general enquiries on the IEA Heat Pump Programme, contact your National Team or the address below.

The IEA Heat Pump Centre is operated by

Netherlands agency for energy and the environment

National Team Contacts

Austria
Mr Hermann Halozan
TU Graz, Inffeldgasse 25
A-8010 Graz
Austria
Tel.: +43-316-8737303
Fax: +43-316-8737305
E-mail: halozan@iwt.tu-graz.ac.at

Japan
Mr Takeshi Yoshii
Heat Pump & Thermal Storage
Technology Center of Japan
Kakigara-cho F Bldg.(6F)
28-5, Nihonbashi Kakigara-cho 1-chome
Chuo-ku, Tokyo 103-0014,Japan
Tel.: +81-3-56432401
Fax: +81-3-56414501
E-mail: yoshii@host2.hptcj-unet.ocn.ne.jp

The Netherlands
Mr Onno Kleefkens
Novem, PO Box 8242
3503 RE Utrecht
The Netherlands
Tel.: +31-30-2393449
Fax: +31-30-2316491
E-mail: O.Kleefkens@novem.nl

Norway
Ms Trude Tokle
Sintef Energy Research
Refrigeration and Air Conditioning
N-7465 Trondheim, Norway
Tel.: +47-73-591636
Fax: +47-73-593950
E-mail: Trude.Tokle@energy.sintef.no

Switzerland
Mr Thomas Afjei, c/o INFEL/FWS
Lagerstrasse 1, Postfach,
CH-8021 Zürich, Switzerland
Tel.: +41-1-2994141,
Fax: +41-1-2994140
E-mail: afjei@infel.ch
Internet: www.waermepumpe.ch/hpc

United Kingdom
Mr Jeremy Tait
ETSU
Harwell, Oxon
Oxfordshire OX11 0RA, UK
Tel.: +44-1235-433611
Fax: +44-1235-433727
E-mail: jeremy.tait@aeat.co.uk

USA
Ms Julia Kelley
Oak Ridge National Laboratory
Building 3147, PO Box 2008
Oak Ridge, TN 37831-6070, USA
Tel.: +1-423-5741013
Fax: +1-423-5749338
E-mail: j4u@ornl.gov

IEA Heat Pump Centre
Novem bv, PO Box 17
6130 AA Sittard, the Netherlands
Tel.: +31-46-4202236
Fax: +31-46-4510389
E-mail: hpc@heatpumpcentre.org
Internet: http://www.heatpumpcentre.org