IEA Heat Pump CENTRE

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第七届国际能源机构热泵会议

Heat Pumps – Better by Nature

In this issue:

Report on the 7th IEA Heat Pump Conference

IEA
OECD
heat pump
centre

In this issue

Front cover: Venue 7th IEA Heat Pump Conference, Beijng, China

The 7th IEA Heat Pump Conference

This newsletter aims to give the reader an impression of the current status of heat pumps in North America, Europe and the Asia/Pacific, as well as an update on what is happening in public research and development programmes.

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TOPICAL ARTICLE

Heat Pumps – Better by Nature 10
Report on the 7th IEA Heat Pump Conference

Jos Bouma, the Netherlands

A wealth of information about heat pump and air conditioning technology, markets and applications from all over the world became available at the 7th IEA Heat Pump Conference, which was held in Beijing, China in May 2002. Highlights of this event and trends are presented in two parts.

NON-TOPICAL ARTICLE

Measuring sound power levels 28

Andre Pierrot, Spain

Recently, a new advanced laboratory building for very accurate measurements of the sound power level of various types of HVAC equipment was completed in Madrid. The construction of the two climate rooms meets Eurovent and EN/ISO standards and requirements.

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COLOPHON

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The 7th International Energy Agency Heat Pump Conference

The 7th International Energy Agency Heat Pump Conference, held at Beijing International Convention Center, Beijing, China, from May 19 to 22, 2002, was a great success. There were more than 330 formal participants from 19 countries, of which 129 from abroad and more than 200 from China. The conference included 8 sessions, 2 technical excursions and 4 social programmes. This was the first time that the IEA Heat Pump Conference was held in a developing country. The conference offered a good opportunity for people in China to learn about heat pump technology and application experience in the world, and made it easy for international friends to appreciate China and Beijing.
Many Chinese officials from the Ministry of Science and Technology, the State Development and Planning Commission, the State Economic and Trade Commission and the Ministry of Construction were invited to attend the conference. Executives from the electric power industry, the manufacturing industry and organizations charged with the application of heat pump technology, i.e. the Architectural Society of China (ASC), the Chinese Association of Refrigeration (CAR) and the China Refrigeration and Air Conditioning Industry Association (CRAA), also participated in the conference.
The Chinese government and people have gradually realised the great challenges that go hand in hand with economic development and social progress. Therefore, a strategy of sustainable development has been put forward to improve the utilization ratio of resources, to adjust the energy infrastructure, to expand the use of electric power and to promote construction-related energy conservation.

China is eager to use sustainable and sound technologies, as they have a positive effect on energy conservation and environmental protection. The Beijing municipal government has adopted heat pump technology as one of the four supporting technologies for realising the energy and environment targets of the city. We are sure that heat pump technologies will have a bright future in China, so we welcome more cooperation in the heat pump sector and other energy efficiency areas.
We would like to take advantage of this opportunity to acknowledge the financial support provided by the conference sponsors. We would also like to extend our sincere thanks to all regional coordinators, speakers invited to the conference, session chairpersons, authors of papers, the conference secretariat and the participants, who have all supported the conference and put in a lot of hard work.

Wang Qingqin 王清勤

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Heat pump news

General

IIR News
21st International Congress of Refrigeration

The International Institute of Refrigeration (IIR) has announced that Dr. William Phillips of NIST, winner of the Nobel Prize for his work in low temperature physics, will speak at its 21st International Congress of Refrigeration (ICR2003) to be held in Washington D.C. August 17 to 22, 2003. The congress, which is held every four years, was last held in the U.S. in 1971. Recent congresses were held in Vienna (1987), Montreal (1991), The Hague (1995), and Sydney (1999).

Under the 21st congress theme "Serving the needs of mankind", special attention will be devoted to issues such as global warming, food quality and safety, preservation of human tissues, research on low temperature material properties for energy efficiency, building energy management, indoor environmental control, and development of safe and effective working fluids. The program will be of interest to researchers, educators, government officials, and equipment designers, manufacturers, installers, users, and consultants.

The conference will consist of prestigious plenary and keynote speakers, technical sessions for both industry and researchers, poster sessions, short courses with a professional educational focus, tours of research laboratories and industrial sites, and a cultural, social, and sightseeing program for attendees and accompanying persons.

A "Call for papers" was issued in May 2002 with a request for abstracts of approximately 250 words to be submitted no later than October11, 2002. For detailed information about abstract and paper preparation, content and format requirements and assessment for publication and presentation, please visit the conference website (see below).

The conference venue is the Marriott Wardman Park hotel in Washington D.C., where attendees will discover a perfect balance of landmark charm and modern sophistication in an historic setting.

For detailed information concerning the congress, visit the conference website at www.ICR2003.org

Source: US National Team

EU Framework Programme 6

The forthcoming EU 6th Framework Programme contains several new major elements compared to previous programmes. A major new feature of FP6 is the aim to bring together a critical mass of resources and skills. New means of participating, with Networks of Excellence and Integrated projects will help to pool resources and increase focus on a reduced number of priority areas. This should help to create the European research area (ERA), which is an integral part of FP6.

Universities, companies and research centres have responded to a call for Expressions of Interest and submitted more than 15,000 research ideas, including at least 4 on heat pumps. In an effort to promote partnering and collaboration, the commission will publish all expressions of interest over the summer on their web site http://www.cordis.lu/fp6/eoi-instruments/home.html. An analysis of ideas received will be made public in September 2002 and will be used as input for drafting the detailed work programmes, which form the basis for the calls for proposals to be published at the end of 2002.

Source: Cordis Focus July 2002

WSSD report

The IIR has prepared the Refrigeration Sector Achievements and Challenges Report for the Johannesburg World Summit on Sustainable Development on August 26-September 4, 2002. The report, titled "Industry as a partner for sustainable development", is one of 22 sector reports prepared under the auspices of and facilitated by UNEP. For each sector, the overall achievements and limits for the three main dimensions of sustainable development, i.e. social, economic and environmental, are described in depth and future challenges are outlined. The IEA Heat Pump Centre has contributed to the sector report drafting process. The economic scope of the heat pump sub-sector has been estimated at USD 17.8 billion of annual sales. At the launch meeting of the report on May 15, 2002, IIR Director François Billiard stressed that reducing the gap between industrialised and developing countries in terms of the availability of refrigeration equipment, knowledge and training, will undoubtedly be the main refrigeration sector challenge in years to come. The report is available at www.iifiir.org and www.uneptie.org/outreach/wssd/sectors/reports.htm

Source: IIR Newsletter June 2002

US DOE sets minimum standard

USA – The wait is over. The Department of Energy (DOE) has set the new minimum energy efficiency standard for residential central air conditioners and heat pumps for use in the USA at a heating seasonal performance factor SPF of 2.17 (7.4 HSPF) and a seasonal cooling COP of 3.52 (12 SEER - seasonal energy efficiency ratio), effective 23 January 2006. Three states, Connecticut, New York and Vermont, have filed a challenge in federal court to keep the standard at 13 SEER.

Source: The NEWS June 3, 2002

IIR – ASHRAE

A partnership agreement between ASHRAE and the IIR was signed on June 3, 2002. The agreement is seen as a win-win relationship.

Source: IIR Newsletter June 2002

ARI Guideline updated

USA - ARI Guideline T-2002, "Specifying the Thermal Performance of Cool Storage Equipment" has been updated and can be downloaded for free from: www.ari.org

T-2002 establishes the minimum information required for specifications on cool storage equipment. It applies to thermal storage equipment in systems, which may be charge and discharged with any of a variety of heat transfer fluids, and is fully factory assembled, assembled on site from factory-supplied components or field-erected in accordance with pre-established design criteria.

Source: ARI

Technology and Applications

Asphalt thermal collector

Netherlands - An innovative integrated heating and cooling system for a Dutch commercial building in Scharwoude combines asphalt heat absorbers, thermal ground storage and a heat pump system. The asphalt collector has been specifically designed to withstand surface pressure from heavy road traffic. In this application, absorbers have been installed in a road, a nearby parking lot and an outside storage area. The system is able to collect heat and cold during the relevant season for storage in an aquifer. The object to be conditioned consists of office buildings with multi-purpose workspaces. A hollow concrete floor is used for ventilation and to accommodate the building utilities, which creates a highly flexible workspace. The voids in the concrete floor are used to install the electricity network, computer and telephone cables, and the heating and cooling pipes that are connected with ceiling radiating panels. This creates a high-comfort work climate. The new office and energy system will be commissioned in summer 2003 and monitored for validation. The system will save 50% of primary energy compared to a conventional solution.

Source: DWA spring 2002 (in Dutch)

Thermoroad – Applied Peltier technology

Netherlands - Road asphalt may find another use in the near future. By applying Peltier elements in the road surface and underground, small-scale electricity can be generated. Highway tests in the Netherlands are being conducted to prove the technical concept.

In summer, the high temperature in the asphalt layer and the low temperature of the groundwater create a voltage potential, which produces electricity in the Peltier elements. In winter, the system works the other way around. Five U-shape copper prefab elements containing cables, groundwater pipes and other hardware have been installed across the road. The Peltier elements are mounted on the copper elements. A top layer of 6 mm high-conductivity, water-resistant asphalt protects the energy system. The system produces 20 kWh of electricity per m^2 of road annually, as the result of an expected temperature differential of 2 to 10°C.

Source: Techniek 28 June 2002 (in Dutch)

Micro CHP emerging

Japan - Honda Motor Co. has released information saying that it has entered the final stage of development of a compact, home-use cogeneration unit, scheduled to go on sale from March 2003. The unit's compact design (640 mm x 380 mm x 940 mm) was achieved using an efficient layout, combining the world's smallest natural gas engine, developed especially for this use, with a compact, lightweight power generation system employing the company's sine wave inverter technology to ensure electrical output on a par with commercial power sources. The driver is a 4-stroke, water-cooled, single-cylinder engine. A 3-way catalyst and oxygen feedback control is employed to reduce NO_x emissions. The unit has a thermal output of more than 3 kW and an electrical output of 1 kW, achieving an overall efficiency of 85%.

Source: Honda Press Information

Energy-efficient distillation

Netherlands - A Dutch consortium of research institutes, contractors and chemical process industry has been formed to develop highly energy efficient distillation columns within the next 4 years. Traditional distillation column designs are tall and high. By integrating the upper half of the column in the lower part, the size can be reduced substantially and energy savings of 60-90% could be possible compared to traditional designs. When compared to mechanical vapour recompression columns, energy savings of up to 50% can be achieved. The so-called Heat-Integrated Distillation Column (HIDiC) is also equipped with mechanical vapour recompression technology. Top vapour from the outer section is compressed and fed to the inner high-pressure section of the column; see

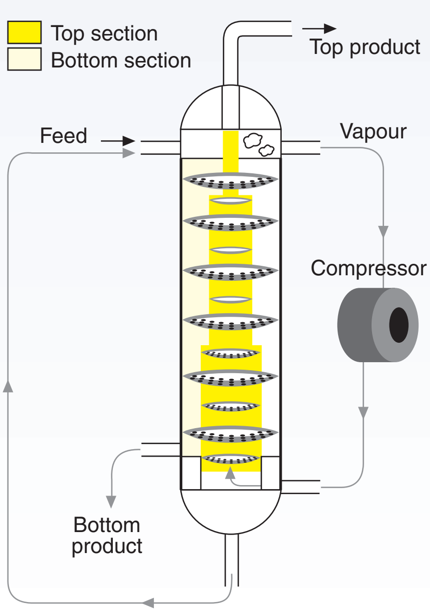

Figure 1: Heat-integrated distillation column

Figure 1. Direct internal heat transfer from the inner to the outer section results in energy savings. There is no need for traditional external heating and cooling of bottom and top vapour respectively. An additional benefit is the price: it is estimated that the initial costs are the same as for traditional designs. The development is supported by € 3 million from the EET (economy, ecology, technology) programme for breakthrough technologies.

Source: Stromen May 2002 (in Dutch)

Non-toxic heat transfer fluid

Finland - Finnish company Fortum oil & Gas Oy has introduced a non-toxic heat transfer fluid for use in heat recovery air conditioning, heat pump systems and applications in process industry. The main component of the fluid is Betain, which is a by-product of sugar beet processing, soluble in water and biodegradable. The brand name is Thermera. It comes in two forms, Thermera -15 for use at –15 to 110°C and Thermera -35 for use at –35 to 110°C. Thermal capacities are comparable to traditional glycol-based fluids.

Source: KI Luft und Kältetechnik 7/2002
Information: thermera@fortum.com

New air-to-air unitary heat pump for cold climates

USA – York has introduced a new central residential air-to-air heat pump for northern climates. The unit combines higher comfort, by delivering higher heating discharge temperatures (45°C), with a high efficiency. The unit is said to offer a heating seasonal performance factor of 2.7 (seasonal cooling COP 4.4-4.6). The higher discharge temperatures should help to reduce complaints of draft.

Source: The NEWS May 20, 2002
Information: www.york.com

Swiss retrofit heat pump prototype awarded

Switzerland – Swiss heat pump manufacturer KWT has been awarded the name *Swiss Retrofit Heat Pump* for its prototype heat pump developed under a programme by the Swiss Federal Office of Energy. The air-source heat pump produces 60 °C water for space heating in existing houses, as well as domestic water heating. The heat pump has been specifically designed for the hydronic retrofit market. The prototype has undergone a comprehensive field test in the winter of 2001-02. Commercial products have been announced for the near future.

Source: Swiss National Team

Swiss Retrofit Heat Pump

Markets

An overview of market development in North America, Asia and Europe is presented in the conference summary report.

Austrian sales up

Austria - The overall Austrian heat pump market is growing again (21% up in 2001), while the market for heat pump water heaters has grown by 10%. **Figure 1** shows the history of the overall Austrian market since 1975, expressed in annual sales and in cumulative form. It includes heat pump water heaters, space heating heat pumps smaller than 40 kW, space heating heat pumps above 40 kW with heat recovery, heat pump dehumidifiers for swimming pools and room-type air-to-air units. The most common items are heat pump water heaters (2980 in 2001) and space heating heat pumps below 40 kW (more than 2680 in 2001).

The newly installed heating capacity in 2001 was 47.1 MW, of which 3.9 MW for water heating. The total heating capacity of the Austrian heat pump stock was 834 MW, of which 159 MW for water heaters. The currently installed heat pump stock uses 66.2 GWh of renewable energy annually, which does not have to be produced by burning fossil fuels.

Source: Prof. G. Faninger,
IFF - Progress report 2001 prepared for Bundesverband Wärmepumpe Österreich

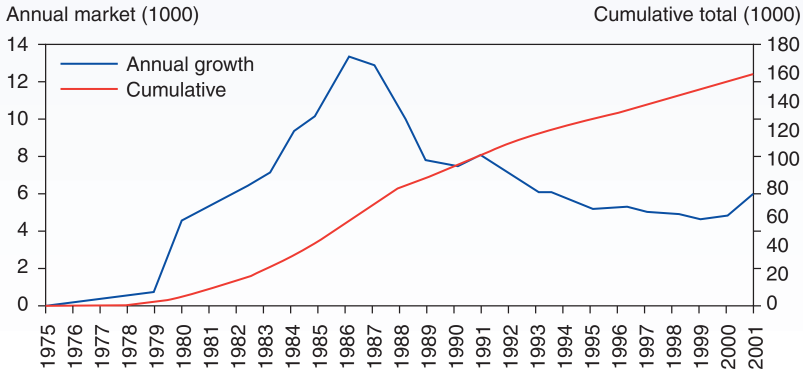

Figure 1: Austrian heat pump market history 1975-2001.

US air-source heat pump market growth

USA – ARI reported that unitary heat pump shipment in May totalled more than 173,490 units, 6% up from May last year, but in June it dropped to 165,178 units, 9% down from June 2001. With the housing market expected to continue at a strong pace and with sales by May 7% up from 2001, US sales for the entire year is expected to see a further growth relative to 2001. In the next 20 years a strong growth in immigrant and minority households is foreseen. More than 85% of single-family homes are built with central air conditioning. With an estimated 60-70 million units in service, the industry expects to deliver tens of millions of replacement units over the next decade.

Source: Koldfax July and August 2002

Bulgarian heat pump market awakes

Bulgaria – The heat pump market in Bulgaria, a S. East European country with cold winters, has developed in a positive way during the last 6 years. The main market is for single-room air-to-air heat pumps (window-type and split units) imported from Asia and the US. Attempts to introduce ground-coupled heat pumps have failed due to a lack of know-how and experience, but there are pro-active companies trying to develop and implement improved ground-coupled systems using modern design tools and handbooks. Statistical data on the Bulgarian market is not available.

Source: European Heat Pump News June 2002

Working Fluids

F-gases to be regulated in EU

The Commission of the European Union is preparing regulation on fluorinated gases, including HFCs, as part of the EU commitment to the Kyoto Protocol. Governments of EU member states, international and non-governmental organisations and industry stakeholder are actively involved in the preparatory consulting phase. It is expected that the proposed regulation will be presented in October 2002. The regulation will be enforced in EU member states.

Source: IIR Newsletter June 2002

Standards

The European Commission is investigating an accusation into whether multinational companies have obtained undue influence on the committees which set the standards for air conditioning and refrigeration equipment. The complaint has been brought by a group of independent experts, green groups and companies marketing environmentally benign and cheaper alternatives to chemical working fluids. The group claims amongst others that unless action is taken, Europe's attempts to combat global warming will be undermined and consumers will pay more.

Source: UK

No-loss campaign

On 26 April, a refrigerant NO-LOSS Campaign was launched in New Zealand. The campaign is a joint effort of the New Zealand Climate Change project in conjunction with the Ministry of the Environment and IRHACE, the Institute of Refrigeration, Heating & Air Conditioning Engineers of New Zealand. The campaign aims to support competent certified engineers and to encourage system owners to use such engineers, who are trained in preventing loss of refrigerant from systems.

Source: IRHACE Journal May/June 2002-07-29

ASHRAE ammonia position statement

The continued use of ammonia is necessary for food preservation and air conditioning, according to the Ammonia as a Refrigerant Position Document adopted by ASHRAE. The document commits ASHRAE to several initiatives:

- promote authoritative information on ammonia;
- continue research on ammonia topics including new technology;
- maintain and develop standards and guidelines for practical and safe application in refrigeration systems;
- provide programmes and publications on innovative designs and applications;
- advise governments and code officials regarding ammonia.

Source: ASHRAE Journal April 2002

IEA Heat Pump Programme

“Translating case studies” methodology

The HPC Internet site *www.heatpumpcentre.org* has recently been extended with a methodology to “translate” case studies from one country to another. The methodology, in Microsoft® Excel worksheet, can be downloaded at no cost. Default data of Austria, France, Japan, Netherlands, Norway, Switzerland, United Kingdom and United States are contained in the file, but users can also specify their own data.

Case studies are extremely useful in proving the maturity of heat pump technology and illustrating the benefits. The HPC project “Successful heat pump installations; dissemination of example projects” has resulted in a number of heat pump installation examples on the Internet. But users may wonder, “How can the results of a case study abroad be translated to my country and still give a reliable prediction of the performance of the system?” To tackle this issue, the HPC member countries requested that a methodology for translating case studies be developed. BSRIA (UK) and the HPC jointly developed the methodology.

The methodology is a simplified tool for evaluating the performance of a residential heat pump under conditions that apply in another country. It provides an indication of energy and CO_2 emissions savings. The method assumes that the heat source, the heat pump and the distribution system remain the same. Climatic data and characteristics of the residence are imposed for the new situation. The methodology does not allow for translating domestic hot water data or the performance of a secondary system.

The methodology can be downloaded from the HPC Internet site, by going to the Case studies directly from the homepage or through “Publications and project results”. Please note that it should not be used as a sizing tool, but only to estimate heat pump performance under specified conditions.

Source: IEA Heat Pump Centre

Reducing carbon emissions with heat pumps, the UK potential – report available

The IEA Heat Pump Programme has initiated a countrywide study under the co-ordination of the HPC with the aim of giving policy makers insight into the contribution that heat pumps can provide to CO_2 emissions reduction. This first country assessment has been conducted focussing on the UK. Other country assessments may follow.

The computer model that has been developed for this study by Building Research Establishment in the UK provides a flexible tool for analysis purposes. Base year for the calculations is 2000. CO_2 emission reduction projections have been made for the period until 2020 with 5-year intervals. Non-CO_2 global warming gas emissions are not included, except those from HCFC and HFC refrigerants. The assumptions that have been made for the assessment are country-specific and realistic. They are based on published predictions and projections for the UK commercial building market sector growth, heat pump penetration rates, average CO_2 emission figures for power generation accounting for a growing proportion of renewable power, etc.

Anticipated increases in SPF of heat pump systems and the projected growth in commercial/institutional sector building floor area serviced with packaged air conditioning/heat pump systems lead to increased $CO_{2\ equivalent}$ reductions of emissions in future years. The total potential savings for this building sector was estimated at 0.15 Mt $CO_{2\ equivalent}$ in the year 2000 for the base case, rising to 0.92 Mt $CO_{2\ equivalent}$ in 2020 for enhanced heat pump penetration rates. Savings were shown to be greatest for the office building sub-sector, as offices currently account for the greatest proportion of packaged air-conditioning systems. The retail outlet sector showed the largest percentage increase in potential savings due to strong projected growth rate in the demand for air-conditioning in this building sub-sector.

A second scenario was used to investigate the sensitivity of the results to heat pump thermal performance. This scenario assumed more modest increases in SPF, and these results showed CO_2 emission reductions varying between 0.10 Mt $CO_{2\ equivalent}$ in 2000 up to 0.73 Mt $CO_{2\ equivalent}$ in 2020.

A comparison was also made between the potential contribution of heat pumps and the greenhouse gas emission target set for the UK, which requires a 12.5% reduction from 1990 levels by the year 2010. Heat pumps were shown to have the potential of making a significant contribution to the reduction of CO_2 emissions in the UK commercial/institutional building service sector over the next 20 years. The results from this analysis show that the potential growth in packaged heat pumps to replace gas boilers in commercial/institutional building applications in the UK could produce CO_2 emission reductions from 0.149 Mt in the year 2000 to as much as 0.924 Mt by 2020 (a more than 500% increase). In 2010, the corresponding CO_2 emission reduction would be 0.441 Mt, which is about 3% of the total reduction required for the UK under its Kyoto Protocol target obligations (based on the time frame of 2000 to 2010).

The report can be ordered under number HPC AR-15 via the website.

Source: IEA Heat Pump Centre

Refrigerant recovery, recycling and reclamation – part 1 assessment available

The HPC has conducted a study to gather information on the refrigerant recovery, recycling, and reclamation policies being pursued in representative countries of major markets located in Asia, Europe, and North America. The study was aimed at comparing and contrasting the effectiveness of different approaches, and where possible quantifying subsequent environmental and cost benefits.

Input on the relevant issues covering policies, practices and national plans was obtained directly by questionnaire from experts within the various countries, with some additional material being provided by an international project Technical Advisory Group. The information obtained from the survey has been analysed, and the key issues have been condensed into a single tabulation for each country, to facilitate rapid comparison of different policy approaches. Some country programmes are described in more detail where more information was available.

The effectiveness of such programmes on refrigerant emission reductions is not precise, since there are no official assessments to provide data for before and after introduction of control measures. However, there are more recent data available from some countries, e.g. the Netherlands and France, which give strong indications of increasing levels of recovered product year over year and evidence of a continued decrease of refrigerant leakage from equipment.

A workshop was held August 31, 2001 in Dubrovnik, Croatia, to discuss issues relating to this study. There was general agreement that government regulation is crucial for the success of refrigerant recovery, recycling, and reclamation programmes. The importance of technical training and education of personnel was emphasised by many participants as being the most critical element. The involvement of industry from the start of any programme is also vital, so that adequate time is available for trade and industry organisations to accommodate new procedures and make appropriate adjustments to their long-term strategic plans.

The report resulting from the study serves to highlight the diversity of approaches with regard to policies, regulations, and practices for accomplishing recovery, recycling, and reclamation of refrigerants in different countries within major market areas. A brief summary of the main issues discussed at the above workshop is also presented. The report can be ordered under number HPC AR-11 via the website (restricted availability to non-HPC countries).

Source: IEA Heat Pump Centre

Collaboration with EHPA

The Heat Pump Programme and the European Heat Pump Association have agreed to collaborate on heat pumps. By collaborating in specific areas, both organisations should benefit and be able to realise their common goals more easily. A formal agreement is being developed by Mr Roar Rose and will be signed by representatives of both organisations.

Source: IEA Heat Pump Centre

Ongoing Annexes

Red text indicates Operating Agent.

Annex 25 Year-round Residential Space Conditioning and Comfort Control Using Heat Pumps	FR, NL, SE, US
Annex 26 Advanced Supermarket Refrigeration/Heat Recovery Systems	CA, DK, SE, UK, US
Annex 27 Selected Issues on CO_2 as a Working Fluid in Compression Systems	CH, JP, NO, SE, UK, US

IEA Heat Pump Programme participating countries: Austria (AT), 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). All countrie are member of the IEA Heat Pump Centre (HPC). The Netherlands is Operating Agent of the HPC.

Germany strengthens ties with IEA HPP

BMWi, the federal ministry of economic affairs (represented by Research Centre Jülich) and IZW e.V. have together joined the IEA Heat Pump Programme to represent German interests for the benefit of the German heat pump and refrigeration industry, effective January 2002. This is in fact an historical achievement, marking the closure of a circle that began in 1982 with Germany's participation in the IEA Heat Pump Programme. A close and beneficial collaboration is anticipated in the area of Annexes, the newsletter and other activities (the HPC is looking forward to a fruitful collaboration –ed.).

Source: Wärmepumpe Aktuell – 2/2002

Heat Pumps – Better by Nature

Report on the 7th IEA Heat Pump Conference

Jos Bouma, IEA Heat Pump Centre, Netherlands

Introduction

The 7th IEA Heat Pump Conference in Beijing, China, was a challenge, an experience, and a great success. The China Daily newspaper of Monday 27 May reported on it with "Energy experts promote heat pump applications".

In a country like China, with a rapidly developing economy and a mind-boggling level of activity in the building sector, conditions are ideal for the development of an emerging heat pump and air-conditioning market. And there are many challenges for metropolitan Beijing, which is at the core of these developments. Beijing has an open eye for a better environment going hand in hand with city expansion and living and working space for its inhabitants and visitors. For the first time in the history of the IEA Heat Pump Programme, the conference was held in a country outside the IEA group of nations. But this may soon change, as China has announced that it plans to join the programme in the near future.

This overview article on the 7th Heat Pump Conference will focus on conference highlights and present some of the material submitted as well as the results of some of the discussions that took place. It consists of two parts: part 1 presents an overview of international market developments per region, with China, France and Sweden being highlighted, as well as a discussion of the energy and environment rationale behind using heat pumps; part 2 discusses various technological and related market developments and ground-source heat pumps in particular.

Opening

Professor **Wu Yuanwei** of the China Academy of Building Research (CABR) and Mr **John Ryan** of the United States Department of Energy (DOE), chairman of the National and International Organising Committee respectively, opened the conference. Secretary General Mr **Shi Dinghuan** of the China Ministry of Science and Technology and Mr **Chen Yiuing** of the China Ministry of Construction welcomed the more than 330 participants.

The IEA representative at the conference, Mr **Hanns-Joachim Neef**, underlined the IEA members' primary goals: energy security, economic growth and environmental protection for a sustainable (energy consuming) society. He recalled China's challenging goal of ongoing zero growth in energy consumption by 2040, with energy efficiency being one of the main building blocks in China's energy policy. High-efficiency heat pumps can play an important role in achieving this goal.

ASHRAE president Mr **Bill Coad** used a lesson in thermodynamic history to underline his statement that *'There is no turning back'* and that '*Change is a fact of life that has resulted in a higher quality of life for mankind'*. The greatest challenge to the human race will be to maintain and advance its quality of life in the face of dwindling energy reserves and an environment that is continually being degraded. It is the engineering community that faces the challenge of designing equipment and systems that use less energy to accomplish the same goals. There is also considerable scope for reduction of consumption. The opportunities for a sustainable future are there, and heat pumps can play a

Opening Session, featuring the keynote speakers major role by using renewable energy as well as power generated by renewable energy sources such as wind and hydro.

The Tokyo Electric Power Company has been one of the forerunners in the use of heat pumps in several sectors of society. They led the way and played a key role in the success of heat pump and air conditioner use in Japan. In his keynote presentation, Mr **Katsuhiko Narita** discussed how heat pump technology has contributed to Japan's modernisation. Being a Japanese champion in promoting heat pump technology, he described the entire history of heat pump technology, starting in the 17th century. During the last decade, global warming has become a major concern. Protecting resources and the environment is more relevant than ever, while at the same time, a growing number of people need to improve their living conditions, and the need for more comfort continues to grow. Humanity must reflect on how it uses its energy resources and on its commitment to sustainable development.

Mr Narita told the audience that against the background of future constraints on resources and the environment, heat pump technology will play a major role in the 21st century. He considers further improvement in heat pump technology and an expansion of its range of applications to the very realistic possibilities. Recent technical progress shows that air-source heat pumps can achieve a Coefficient Of Performance (COP) of nearly 6. This is the result of the so-called Top Runner initiative, aimed at improved equipment performance. More can and should be done to popularise heat pump technology in mature markets. It creates a pleasant urban living environment. Wider use of heat pump technology should be promoted as a matter of policy. A social system that effectively takes advantage of the diversity in time and temperature of its energy resources for heating and cooling buildings will be able to create a more pleasant urban living environment for its members.

In developing countries, where a substantial growth in energy demand is anticipated, it is important, for economic and environmental reasons, to start using energy saving technology. Not only on an individual level, but also in future urban infrastructure. The technology should be stimulated enabling a social system that has both cooling and heating functions. The industrialised nations are in a position to share information and experience and to help transform the new markets.

Part 1

International heat pump status and trends

North America

In the *USA*, unitary heat pump sales have been increasing over the last two years. The main reasons are a higher residential building activity in regions where heat pumps are an attractive option and a growing replacement market. Another important factor is the concern over future fuel availability and cost. The US market for heat pumps and air conditioning units for residential and commercial buildings continues to be one of the strongest in the world. Annual factory shipments comprise 6.2 million units of which more than 1.4 million are air-source heat pumps. **Figure 1** illustrates the evolution of the US unitary air conditioning and heat pump market over the last 25 years. The figure includes only central air-source units and excludes room-type air conditioners and water-source heat pumps. Heat pumps consistently represent around 20% of the unitary shipments. The dips in the curve relate to periods of economic downturn with reduced house building activity. The decline in shipments during the last two years is also due to cooler summers.

Heat pump sales are aided by stronger home building activity in milder regions of the US (South, Southwest), and by a growing replacement market. In addition, homeowners want more fuel security so they buy a heat pump together with a natural gas furnace. Replacements are needed as most of the heat pumps sold in the 1970s and 1980s are reaching the end of their economic life. **Figure 2** compares heat pumps sold for new buildings with those sold for add-on or replacement. It shows a growth in the replacement market. The market is now dominated by replacement and add-on sales.

The ground-coupled heat pump market gradually increased from 28,000 units in 1994 to nearly 50,000 units in 1999. This growth is partly due to government and utility technology development and marketing efforts. The strongest growth occurred in the commercial and institutional sectors, especially schools and governmental buildings. The DOE

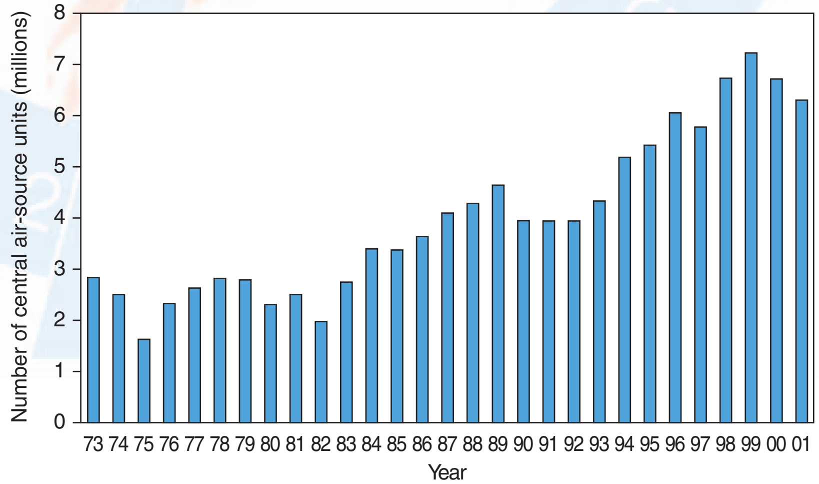

Figure 1: Unitary air conditioner and heat pump shipment history in the USA

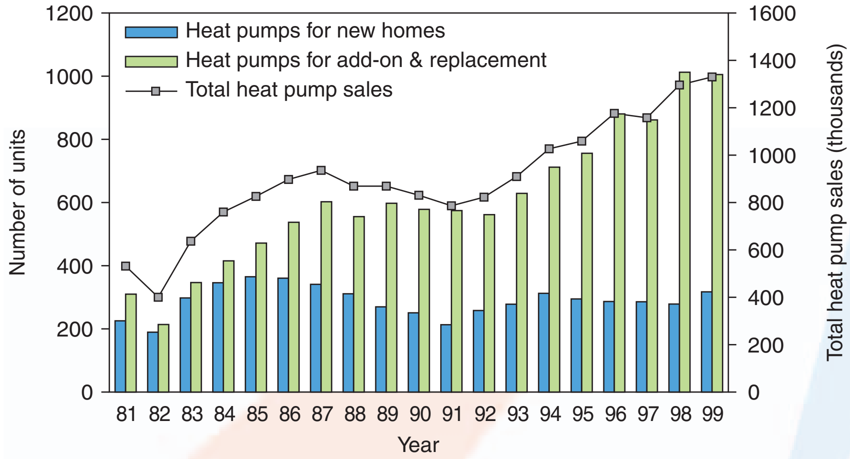

Figure 2: US heat pump sales for new homes and for add-on/replacement

has reduced its support for this technology. However, it continues to support market deployment in federal government facilities and through community mobilisation efforts. Electric utilities have significantly reduced their efforts due to the liberalisation of the energy sector. However, there are several companies that continue to support the technology. The US government continues to support R&D programmes for new heat pump technologies, including heat pump water heaters, ground-source heat pumps and thermally activated heat pumps. For instance, a new residential heat pump water heater with a 2.47 COP rating was introduced as a drop-in unit last year. The total annual production of the three main producers is 2,700 units annually. Moderate growth is expected.

Another effective policy instrument applied by the federal government is the introduction of minimum energy efficiency standards for products on the US market. Because of the existing mandatory performance standards, manufacturers are obliged to improve products that have been on the market since before 1990. The shipment-weighted efficiencies presented as seasonal COPs are shown in **Figure 3**. Federal minimum efficiency standards became effective in 1992. Minimum efficiency standards for residential air conditioners and heat pumps are in the process of being revised. For the split systems in the US, the revised standard will raise the energy efficiency by at least 20% for cooling and 9% for heating. The new required Seasonal Performance Factor for heating is 2.2 (for cooling 3.5) and will be effective January 23, 2006. The heat pumps that meet the new standard are estimated to have a payback period of less than 3 years. The federal government is also considering tax credits in 2003.

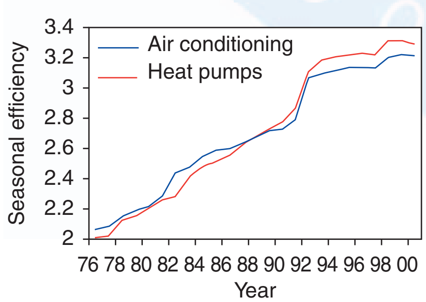

Figure 3: History of US products seasonal efficiency

The US is confident that with continuing effort from the DOE and utilities, the goal of bringing small gas-fired heat pumps for space heating and cooling to the market will be achieved within the next few years. Three consortia of manufacturers and gas utilities plan to introduce a range of gas air conditioners and space heating/cooling heat pumps for commercial and residential use (10-18 kW). The gas cooling units will be introduced in 2003. Their efficiency is 0.7 PER (Primary Energy Ratio) cooling at 35°C, and 1.4 PER heating at 8.3°C.

Other new heat pump market opportunities in the US include clothes dryers, hydronic heat distribution systems and applications in electric hybrid and fuel cell vehicles.

The heat pump market in *Canada* is significantly different from the US. Some 30,000 ground-source heat pump units were installed annually in Canada in the 1990s, of which 20% in the commercial/institutional sector, especially in schools. Annual sales peaked in the early 1990s, primarily as a result of utility support in the province of Ontario. Most heat pump systems were ground-coupled. During the second half of the 90s, the market was sluggish with sales of approximately 25,000 units annually.

Inefficient equipment is eliminated from the market through regulatory measures. Test standards for heat pumps are mandated through Canada's Energy Efficiency Regulations. Ground or water-source heat pumps with a rated capacity of less than 35 kW must have a minimum COP of 3.0. Canadian standards for ground-source heat pump equipment and design and installation practices have been recently revised in order to reinforce industry performance standards and increase confidence in the technology. ISO Standard 13256-1:1998 was used to adapt the standards for testing and performance of water-source heat pumps. A new Canadian standard has also been developed for the design and installation of ground-source heat pump systems. Canada also has an energy efficiency rating system for residential heating and cooling equipment. The EnerGuide Rating System is a voluntary programme for equipment manufacturers. It includes energy efficiency rating for their products in their brochures. Currently, only residential air-source heat pumps are included in this system. Discussions to include water-source heat pumps are underway. The marketing infrastructure for ground-source and/or water-source heat pump systems would be reinforced if such systems were also included in the recently introduced Energy Star labelling programme, which promotes high efficiency energy using products, and the relevant technical training took place in accordance with Canadian Standards for design and installation practices.

Canada today encourages greater use of renewable energy and energy-efficient technology. Geothermal energy using technology fits in this policy. Ground-source heat pumps, also called geothermal heat pumps in North America are a promising technology because they tap a renewable energy source. A recent study indicates that the market potential of ground-source heat pumps is half the available market in new construction and replacement in the residential and commercial/institutional building sectors. It is estimated that the total Canadian market for ground-source heat pumps could reach CAD 1.6 billion annually.

Canada's approach to conditioning, mobilising and transforming the marketplace for ground-source heat pump systems is driven by economic and environmental benefits. The promotion of ground-source heat pump technology through the utilities is a critical factor. A collaborative effort from Canadian electric and gas utilities, the heat pump industry and federal government would effectively contribute to the rapid diffusion of ground-source heat pumps in Canada. In the US, this proved to be an effective approach in the 90s. A similar strategy is contemplated for Canada. The utility-led coalition would become the forum in which marketing barriers would be overcome and the industry strengthened.

Asia and Pacific

In the Asia-Pacific region the market for air conditioners and heat pumps experienced a remarkable growth during the last decade. This can be explained by economic development in the region. This development brought with it a new challenge in some East Asian countries: a growing demand for electric power, with a sharp peak demand in summer and deterioration of the power load factor.

Some annual sales numbers from 2000 (unitary air conditioners and heat pumps):

Estimated world market: 42 million units
Estimated market Asia-Pacific: 22 million units:
China: 9.3 million units (reversible heat pump share 60%)
Japan: 7.7 million units (reversible heat pump share 95%)
India: 0.6 million units
Rest of East Asia: 3.5 million units
Oceania: 0.5 million units

Typical for the Asia-Pacific region is that heating-only heat pumps are hardly to be found. An insignificant number of units are used for water heating and industrial process operations, predominantly for drying lumber, fish and agricultural products in New Zealand, Singapore, China and Japan.

A breakdown into national markets for the year 2000 is given in **Table 1** (source: JARN).

Table 1: Unitary air conditioner and heat pump shipment breakdown Asia-Pacific 2000.

	RACs[1)]	PACs[2)]
China	8,200,000	1,100,000
Korea	1,100,000	
Japan	7,000,000	700,000
India	550,000	30,000
Malaysia	300,000	
Singapore	190,000	
Indonesia	140,000	
Thailand	350,000	
Philippines	270,000	
Other East Asia	1,200,000	
Australia and New Zealand	500,000	
Total Asia-Pacific	21,630,000	

1) RAC: room air conditioner (including reversible heat pumps and cooling-only units)
2) PAC: packaged air conditioner (including reversible heat pumps and cooling-only units)

The history of the markets in Asia-Pacific, North America and Europe since 1990 is shown in **Figure 4** (includes room air conditioners). In the residential sector, electric mini-split air conditioners and heat pumps are increasingly dominating the market, replacing window-type units. In the commercial building sector, the market share of multi-split variable refrigerant flow systems is growing.

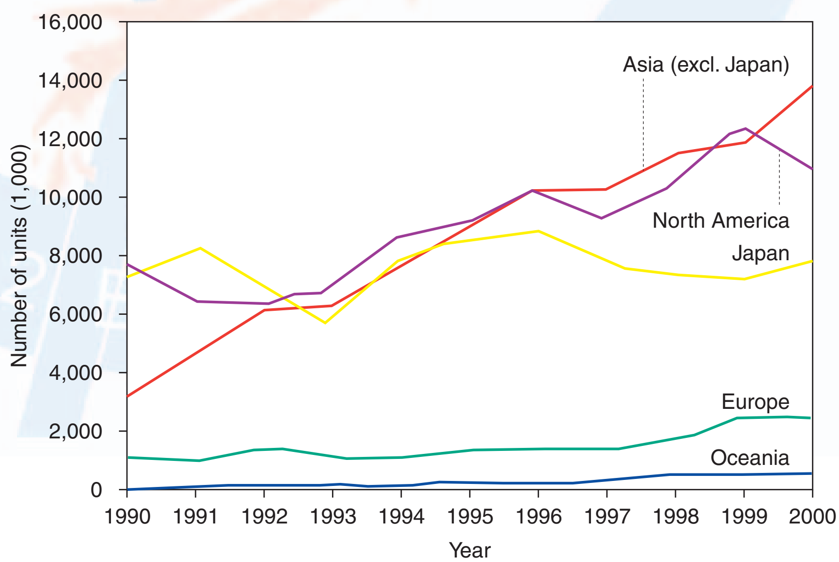

Figure 4: Market history of unitary heat pumps and air conditioners

Asia stands out when it comes to thermally activated machines for air conditioning. The current market size is approximately 8,400 systems annually. Main markets are China, Korea, India and Japan with 93% of the world market. The main application is as absorption chiller in offices and district cooling plants. As **Figure 5** shows, the market for gas-engine-driven heat pumps has successfully developed in Japan with a current market of almost 50,000 units annually. These units are mainly applied in light commercial and institutional buildings. The main reason for the success of these thermally activated machines is the need for electric power load levelling in summer. The use of absorption chillers is also stimulated by the need to re-use waste heat from industry and co-generation systems.

Another increasingly popular method of reducing peak electric loads is the use of combined heat pumps and thermal (mostly ice and water) storage systems. Japan is leading this market with more than 10,000 installations annually. **Figure 6** shows how the market has developed until 2000.

As in the US, regulatory measures are being used to improve the energy efficiency of air conditioners and heat pumps. Such measures have been put in place in Japan (the Top Runner campaign), and in Thailand. Beside generic R&D efforts to advance compression and sorption systems, specific areas of development can be distinguished in the Asia-Pacific region:

- air-source heat pumps for operation down to –20°C outside air temperature (Japan);
- CO_2 heat pump water heater (Japan);
- ice slurry production for air conditioning (Japan);
- residential gas-fired absorption heat pumps (Korea/Japan);
- low-temperature absorption chiller (Japan);
- humidity control for hot and humid climates (S.E. Asia);
- ground-source heat pumps (Australia, China, Japan);
- solar-assisted heat pumps (Australia, New Zealand).
- desiccant cooling for supermarkets;
- applications in the food processing, fish and timber industry.

Technology development for improved energy efficiency and environmentally sound working fluids is becoming a major necessity. The market potential for air conditioners and heat pumps in the Asia-Pacific region is enormous, and energy consumption causes environmental pressure. The IEA Heat Pump Programme is expected to contribute to the further development of heat pump technology with the active involvement of countries in the Asia-Pacific region.

China – an emerging market

China has a population of around 1.3 billion people (2002), of which 31% live in cities and 69% in rural areas. The country has a vast territory with 9.6 million square kilometres of land. Most of the region has a monsoon climate with cold winters, 5 to 18°C colder than most countries located at the same latitude. Summer temperatures are about 2°C higher. China has 5 climate zones, ranging from severe cold to hot in summer and warm in winter.

Air pollution (SO_2, No_x) is a serious problem. Seventy-five percent of China's cities cannot meet the national standard for air pollution and around 30% of the country suffers from acid rain caused mainly by coal usage. In 1998 the primary fuel was still coal with a share of almost 70%. It is used widely for cooking, space heating and power production. Natural gas has a share of only 2%. This should grow to 10% in 2020.

Heat pumps and air conditioners are driven by electricity and heat. Due to an electricity shortage and a rapid growth of the air conditioning market in 1996-97, the use of absorption systems peaked. Today new power stations are available and supply and demand is in balance. China has rich natural gas resources, but most of these are located in the northwest region, far away from metropolitan areas. A plan to pipe gas to eastern China has been implemented. This will enable growth of the absorption chiller market.

The building sector in China can best be characterised by its high speed of new construction, both residential and commercial/institutional. This was already the case in 1980, with 700-800 million m^2 of floor area added every year increasing to 1,000 million m^2 in 1999. In recent years, this has increased to 1,600-1,700 million m^2 each year. For instance, 1,709 million m^2 was completed in 1998, of which 477 million for residential buildings in cities, 799 million for residential buildings in the countryside and 433 million for commercial/institutional and industrial buildings, mainly in cities. Around 100 million m^2 of industrial buildings are realised annually.

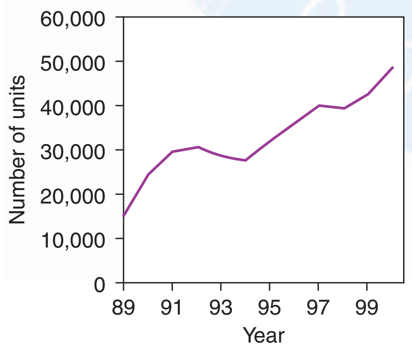

Figure 5: Annual sales of gas engine heat pumps in Japan

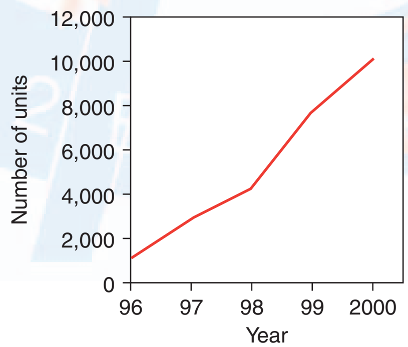

Figure 6: Annual sales of split ice storage heat pump systems in Japan

Some 800 million m² of residential and commercial/institutional buildings need heating and cooling, a large potential market for heat pumps and air conditioning. Residential buildings in cities are usually multi-storey buildings with some high-rise buildings. New residential construction is considered a national corner stone industry.

As a result of solid policy and planning, building standards in China have dramatically improved during the past decade. Building energy conservation is one of the key areas of construction-related science and technology for the current 5-year plan. Measures range from heat metering to applying modern technologies such as solar and ground-coupled heating of buildings. The 2008 Green Olympics fit well in this strategy. Olympic facilities will be using these technologies. China has a very large number of existing buildings, most of which are not energy efficient. A major plan exists to renovate residential buildings, starting in major cities and following up in medium and small cities.

Heat pump development history in China goes back to the 1950s. The first Chinese window-type reversible heat pump came on the market in 1965. The first air-to-air heat pumps for railway passenger cars were tested in 1965. Air-cooled heat pumps for buildings were first applied in the central part of China in the Yangtze River basin, a region with a booming economy and suitable climate for heat pumps. Water-source heat pumps came into use in the early 80s, mainly in buildings of foreign investment enterprises. In the late 90s, around 50 buildings were equipped with closed loop water-source heat pump systems (water loop heat pumps). Residential water-source heat pumps were developed in 1999. However, as groundwater use is restricted in China, closed loop ground-coupled heat pumps have become more popular.

China's air conditioning and refrigeration industry today produces all types of small, medium and large-size equipment and systems of much higher quality and performance than before reform began. Statistical data on products and producers were presented at the conference. The technical gap between products made in China and abroad is being narrowed. The country is now the third largest refrigeration and air conditioning equipment manufacturer in the world, behind the US and Japan.

In 1999 the total installed cooling capacity in China was 45 GW. Some 60% of this capacity is provided by room air conditioners of which 60% are reversible heat pumps. Split-type and other types of room air conditioner became popular when living standards improved as a result of economic growth. This process began in the 1980s. These heat pumps are popular in hot summer and cold winter zones. They are also used in cold zones but only during shoulder seasons. Room air conditioners are also applied in some commercial buildings with lower standards, because they are easy to install and use. More recently, multi-zone systems with variable refrigerant flow have been applied. **Figure 7** shows the history of room air conditioner production, mostly split units.

Large capacity (> 350 kW cooling) air-source heat pumps are being increasingly used in central China (Yangtze River and Shanghai). They are used in public buildings for heating and cooling. Several high-rise buildings in Shanghai are equipped with these systems. For instance, in the period 1996-98, 30 to 37% of the high-rise buildings had an air-source heat pump. By 2002, more than 1,000 air-source heat pumps were in operation in Shanghai alone.

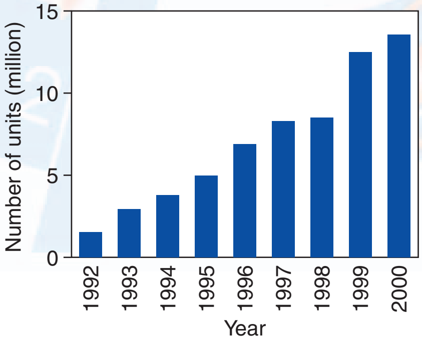

Figure 7: History of room air conditioner production in China

More recently, water-to-water and ground-coupled heat pumps have become popular, as they don't need defrosting and are generally more efficient. They are used in colder regions such as northern and north-eastern China and in Beijing. Their application is still in the initial stages.

Current heat pump R&D in China focuses on three areas:

- improved air-source heat pumps for colder climates and quieter operation; recent developments have resulted in systems that provide higher heating capacities and prolonged operation down to temperatures of -10 to -15°C;
- improved defrost technology for operation under high (>75%) humidity;
- improved ground-coupled heat pump technology (borehole backfilling, system design, heat exchanger performance).

The rapid development of the building sector and the heating, ventilation and air conditioning industry has outstripped the availability of educated technical professionals. Design and construction engineers as well as operating and maintenance technicians are in short supply. However, there is confidence that with the improved educational system for rural areas, professionally trained people will soon be available to fill this gap.

Europe

Heat pump market development in Europe has been steady and prosperous (especially in Sweden, Switzerland and Spain). In recent years, new markets have begun to develop, for example in Finland, Czech Republic and Estonia. **Figure 8** shows market growth over the past three years in most countries.

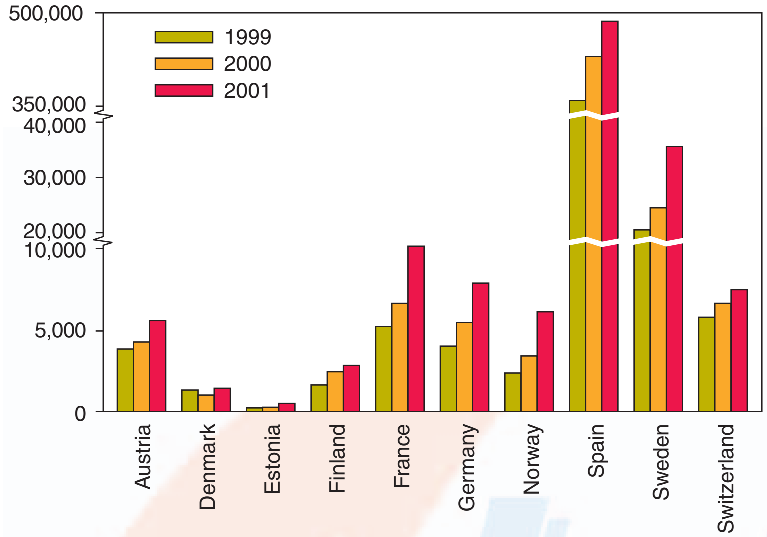

Figure 8: Residential heat pump market development in Europe 1999-2001

Outstanding market growth can be found in Sweden, France and Norway. On a per capita base, Sweden leads Europe and is followed by Austria.

The European heat pump industry, organised in the European Heat Pump Association (EHPA), has made notable contributions to this upswing. An important achievement was giving heat pumps their rightful place on the agenda of the EU in Brussels. The EHPA, a consortium of national heat pump associations, utilities, energy agencies and installers plays an active role in promoting heat pumps in Europe, not only by influencing policy makers in Brussels, but also through market transformation efforts, certification and labelling initiatives. The efficiency of heat pumps in the European market is increasing, as depicted in **Figure 9**. Obviously, system efficiencies are lower.

The 4.5 million residential and 1.5 million commercial building heat pumps installed in Europe in 2001, excluding Eastern Europe, include a wide variety of systems and applications. In Northern Europe, residential heat pumps are mainly sold for (both water and space) heating purposes. In Southern Europe heat pumps are sized to provide space cooling. The main market barriers in Europe remain lack of awareness, high initial cost and low energy prices. In some countries, education and training is still a concern.

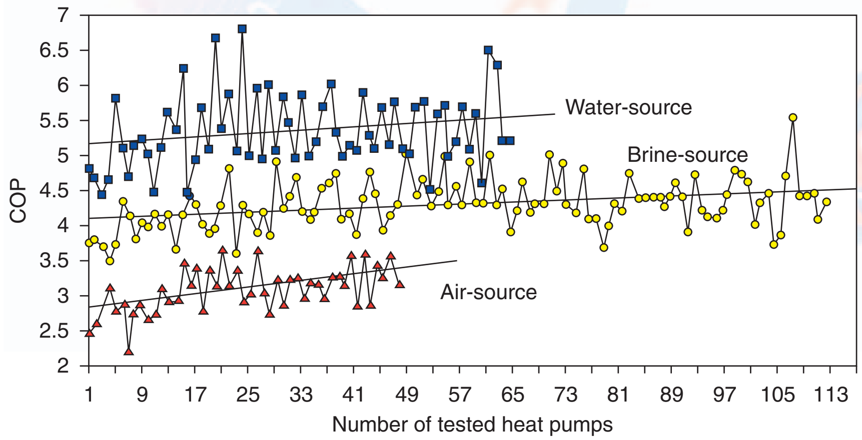

Figure 9: Development of COP (source: Töss)

The EHPA predicts that the residential heat pump market in Europe will grow to some nine million systems in 2010, assuming continued proportional growth over the next eight years.
A market analysis by the EHPA shows a much larger scope for residential heat pumps in 2010. Consequently, the EHPA made a recommendation to the EU and national governments that a target of 15 million units in 2010 would be feasible, if appropriate policy and market transformation measures were implemented and the market was actively approached. This requires a common EU strategy and national policy plans aimed at removing barriers and at promoting awareness. The EHPA is ready to work towards achieving this goal and has proposed joining forces with the IEA Heat Pump Programme for mutual benefit.

France

Heat pump markets can develop quickly when the right strategy is implemented, as is demonstrated in France. As part of an initiative for high quality electric heating for new homes, EDF launched a heat pump development programme in 1997. The market has grown from 1,500 heat pump systems for space heating and/or domestic water heating before 1997 to 15,000 installed systems by 2001. Between 2000 and 2001 alone, the market increased by more than 50%.

The key word for this success is VIVRELEC, a set of high quality electric heating solutions for well-insulated new homes that provide year-round comfort to the inhabitants. The heat pump provides heating or heating and cooling. The background for this French initiative was the decreasing market for direct electric heating in new homes and the growing use of gas heating.

To stimulate the market specific actions were taken:

- the supply of heat pumps was broadened;
- quality assurance – the Promotelec

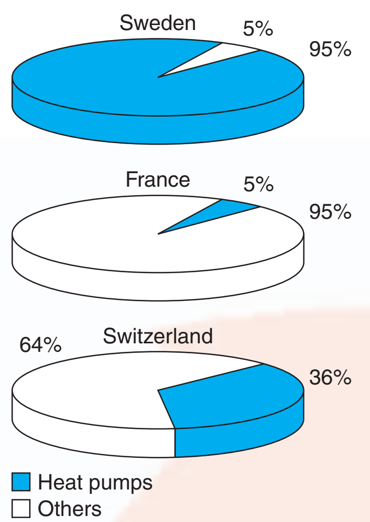

Figure 10: Market share of heat pumps in new houses

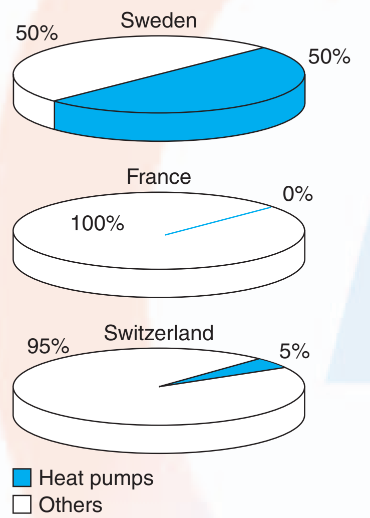

Figure 11: Market share of heat pumps for retrofitting

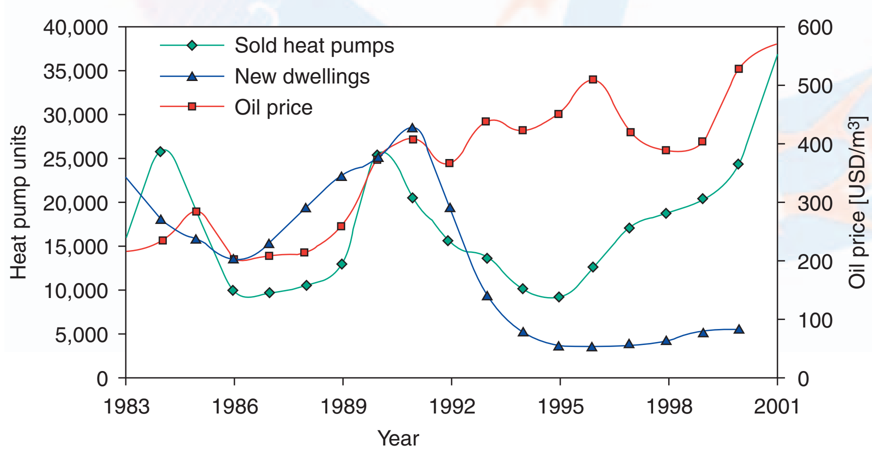

Figure 12: Market development in Sweden 1983-2001

label is used for heat pumps certified under the EDF-Eurovent certification programme;

- a voluntary "secure package offer" for design, installation and monitoring was introduced;
- EDF financial aids, consisting of size- and performance-related subsidies and loans, were offered;
- government support consisting of a tax rebate.

In support of the VIVRELEC initiative, EDF facilitated extensive marketing and technical support ranging from developing reference material, internal and external sales training, and sales monitoring to system design, testing and partnerships with selected manufacturers. Five years after the start of the programme, it can be concluded that:

- France has become one of the leading heat pump markets in Europe with the majority of systems being applied in new detached homes: 45% air-to-water, 30% ground-source and 25% air-to-air;
- customer surveys show very high rates (97%) of satisfied customers even though initial costs are considered high;
- heat pumps are mainly deployed in the new housing market with 5% market share; the retrofit market is large but still has to be developed. **Figures 10** and **11** show both markets for the three leading heat pump countries in Europe (Sweden, France, Switzerland);
- marketing of heat pumps could be focussed more on environmental benefits rather than on year-round comfort and reduced running cost alone;
- customers prefer to deal with one single contractor for the entire system;
- more than 10,000 technical guides have been distributed;
- dedicated training of sales people and installers needs to be strengthened to further reduce the rate of poorly functioning installations (1.3% of stock since 1997);
- end-user service needs to be extended (financing, energy saving guarantees, round-the-clock emergency service etc.);
- quality procedure (installers) needs improvement;
- a public consortium of all partners involved should be established to develop the market further in the next 10 years;
- the size of the programme requires a project-type organisation, and better use should be made of foreign programme experiences to improve effectiveness.

Sweden

With more than 90% of new homes being equipped with a heat pump and 36,000 units sold last year, the Swedish residential heat pump market is number one in Europe. Heat pumps are no longer a curiosity in this country. On its way to public recognition, the market has seen several ups and downs (see **Figure 12**) - for various reasons. In the early 90s, it was the generous subsidy system that caused the market to flourish for a short period of time. Then the effect of poor designs surfaced, and the oil price drop accelerated market decline in 1986. At the end of the 80s, the oil price went up and many new houses were built, marking the beginning of a short market recovery. In the early 90s, recession struck Sweden and the housing market was down. When recession ended, the market started to recover, and heat a pump design competition contributed substantially to market growth in the second half of the 90s.

The predominant system solution today is different from what it was in 1984. In 1984, air-to-water systems were the mainstream, with air-to-air systems making up only 2% of the sales. By 1990, exhaust air heat pumps already had 44% of the Swedish market with air-to-air units taking 45% of the market. The market in 2001 shows another major shift from air-to-air (1% of the market) to closed groundloop-to-water systems (72%) and exhaust air systems (26%). The exhaust air heat pump market is stable and will probably grow further as a result of increased new construction in future and of replacements for older exhaust air systems. Ground-source heat pumps find application in older houses with relatively high heat demands, where they replace oil burners and electric resistance heaters. These heat pumps provide both space and domestic water heating.

The Swedish heat pump market is now self-sustaining with three major national manufacturers competing on the market (Nibe, IVT and Thermia). However, the refrigeration industry, sometimes owned by internationally operating companies, could pose a threat to the existing manufacturers.

A utility's view

The Swedish utility Vattenfall operates in the most mature heat pump market (heating mainly) in Europe. That is not a coincidence. The company is one of the energy suppliers that continued stimulating the use of heat pumps after the deregulation in 1996. The key to their heat pump success was that they marketed heat pumps within their solar energy programme.

Electricity offered by Vattenfall in 1999 was mainly from nuclear and hydropower, increasing the environmental benefits resulting from use of the heat pumps. In the initial part of the 20-year period they have worked with heat pumps, Vattenfall was involved in equipment testing and (re)designing. Later they focussed on retaining customers, providing information, and influencing and promoting system R&D. The results have paid off for both the company and the Swedish customers. Deregulation of the energy sector has resulted in retail electricity prices dropping considerably since 1997. Consequently, utility profits decreased and utilities were forced to consider new strategies, focusing on core business and carefully choosing new product areas. As the Swedish market is mature now, heat pump market support is less crucial.

Today heat pumps in Sweden are mainly used in the process industry (160 MW thermal), for district heating (7 TWh thermal annually) and in the residential sector (6 TWh thermal annually). Around 75% of the residential heat pumps are ground-coupled. The Swedish heat pump heating market stands out in Europe on a per capita basis (40 heat pumps per 1000 inhabitants). This success is the result of several factors, but the main explanation is the concerted approach by government, manufacturers, utilities and end-users/owners. As Vattenfall puts it: Having a healthy technical economic potential is not enough; (customer) acceptance and penetration power is as important.

Vattenfall is continuing its heat pump strategy focusing on system efficiency, environmental benefit and economy for both the customer and the company.

Energy and environment

Why heat pumps?

Energy efficiency and environmental benefit are the key drivers for heat pump application and further research and development. A simple projection of world energy consumption and dwindling energy sources in the next decades shows that society faces a major challenge. There is a general awareness of this rapidly approaching problem, but society as a whole does not seem to be responding accordingly, assuming that there is sufficient time to find solutions. However, it is encouraging to see that there is a growing interest in applying energy-efficient technology in developing countries and economies in transition. Although costs are an obstacle for applying modern technology, the industrialised world seems increasingly prepared to look for new ways of information and technology transfer to these developing parts of the world.

How important are heat pumps in relation to the environment? Any thermodynamic specialist or heating/cooling engineer will have no problem in quickly answering this question. The numbers on COPs and SPFs as well as specific CO_2 emission levels are available and can lead to only one conclusion: an increasing application of heat pumps without delay is very important!

It is frequently argued that the refrigerants used in heat pumps today are safe and that their impact on the environment during the equipment life cycle is negligible. That may be true and significant as well, but the fact remains that a much better job can be done. There is significant scope for improved performance and initial cost reduction. Both will lead to a better environment and decreased energy consumption.

Worldwide, approximately 100 million heat pumps are now installed. Their total annual thermal output is around 1,300 TWh. This represents an annual equivalent CO_2 emission reduction of 0.13 Gt (0.6%), against the backdrop of an annual global emission of CO_2 of more than 22 Gt. However, the current reduction potential of heat pumps is 6% of global CO_2 emission, and improved technology could increase this to 16% in future.

Achieving Kyoto targets

To what extent can heat pumps help a country achieve its domestic Kyoto Protocol targets? That's a question the HPC tried to answer in a study for the UK. Quantifying the equivalent CO_2 emission reduction that can be realized by using heat pumps instead of conventional space heating methods provides important information for governmental policy makers.

In the UK, heat pumps have mainly found application in the commercial/institutional sector, with an installed base in 2000 of some 600,000 systems. Current annual sales in the UK are estimated at 70,000 systems. These are mostly reverse cycle split systems. In the residential market around 380 units were sold in 2000 and a market is emerging for residential ground-source heat pumps. Thus, the commercial/institutional market is expected to be the major area of heat pump application in the UK for the time frame 2000-2020. A model was developed that distinguishes ten sub-sectors.
The model takes into account anticipated trends in construction, in the penetration of air conditioning, equipment replacement rates, changing fuel mix for electricity generation and improvements in the performance of heat pumps and fossil fuel boilers (the common heating system in the UK). Different refrigerants and SPFs (Seasonal Performance Factors) were used to calculate the direct and indirect components of the Total Equivalent Warming Impact (TEWI). **Figure 13** shows that the sub-sector with the greatest potential to reduce CO_2 emissions is the office buildings sector with a reduction of 0.2 Mt in 2020.

Stimulating the use of heat pumps in the commercial/institutional sector by implementing policy and support measures could lead to emission reductions relative to gas boilers ranging from 5.5% by 2010 to 24% by 2020. As a result, the equivalent CO_2 emission reduction in the UK would go from 282 kt in the year 2005 to as much as 924 kt by 2020, assuming a 2% annual compounded market uptake; see **Figure 14**. The corresponding emission reduction in 2010, the year in which the UK committed itself to reduce 12.5% from 1990 levels, is about 3% (441 kt) of the remaining CO_2 emission reduction required in that year under the Kyoto protocol targets established for the UK.

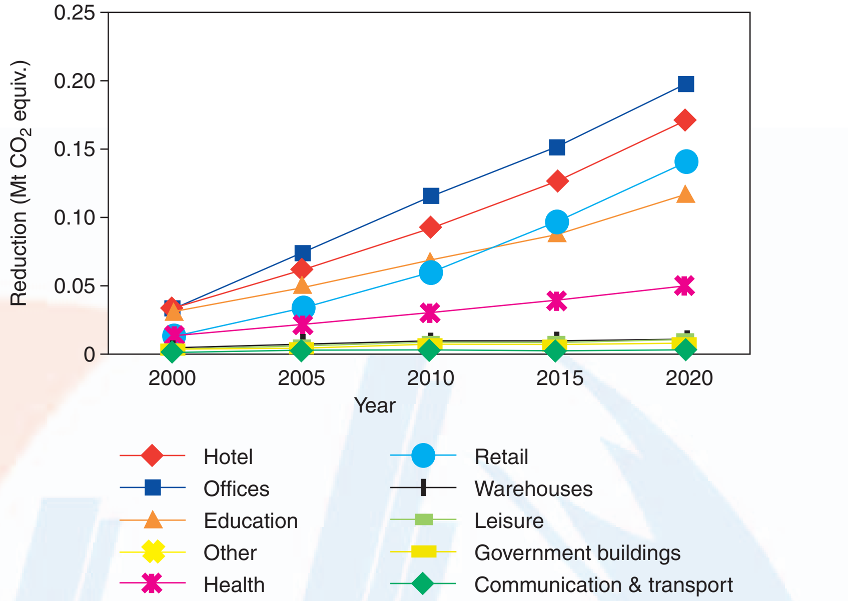

Figure 13: CO_2 emission reduction due to use of heat pumps for different sub-sectors in UK

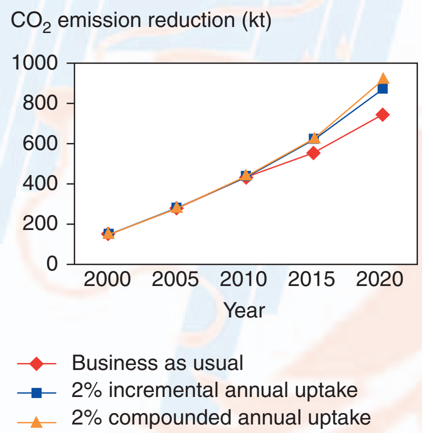

Figure 14: Equivalent CO_2 emission reduction due to heat pumps in commercial/institutional buildings (UK)

Part 2

Technological and related market developments

Two of the conference sessions were devoted to components and systems. Almost 30 technology posters had been prepared, underlining the amount of research effort aimed at advancing the technology.

Technology topic areas included:

- CO_2 heat pumps and compressors;
- heat pump system control;
- advanced plate-type heat exchangers;
- residential gas engine and absorption heat pumps;
- ice thermal storage multi-split air conditioners;
- ground-coupled heat pumps;
- cycles;
- thermal-physical properties;
- frost formation, coil defrost and defrost control;
- variable speed and variable discharge volume compressors;
- chemical and liquid desiccant heat pumps;
- solar-assisted heat pumps;
- etc.

Automotive air conditioning

New forces are driving technological innovation in the automotive air conditioning industry, namely increased fuel economy and reduced emission of global warming gases, involving leakage of CO_2 at the exhaust pipe and of refrigerant through hoses and compressor seal. Increased engine efficiency and the introduction of electric vehicles have reduced excess heat in cars. This has created an interest in using mobile air conditioning systems as a heat pump in winter. The car industry faces choices that appear risky and threatening, as they place high values on system reliability. A consortium of manufacturers have embarked on a programme of testing and evaluation of competing systems including R-134a, advanced R-134a, transcritical CO_2 and propane with secondary loop.

Choices being considered are:

- transition to hermetically-sealed electrically driven systems;
- abandoning the sub-critical thermodynamic cycle in favour of the transcritical cycle;
- obtaining supplemental heat by reversing the cooling cycle.

All of these changes require that components be substantially redesigned. Sealed systems appear to have the advantage that they can make use of packaged components and do not have to be placed in the engine compartment. Such systems can work with R-410A and CO_2. For efficiency reasons, CO_2 systems require an internal heat exchanger, and the high pressure requires the use of microchannel evaporators instead of plate-fin types. Finding an acceptable heat source is not easy. The obvious choice, the engine coolant, could be a problem when starting in cold weather: if much heat is extracted, it will take longer for the engine to reach proper operating temperature and emissions will increase.
Other potential heat sources are the exhaust gases downstream of the catalytic converter and the air passing over the outdoor air heat exchanger. **Figure 15** shows results from experiments on an early prototype air-to-air CO_2 system in heating mode. Even though the heat exchanger was far from ideal for this purpose, the essential features are clear: capacity is highest at start-up, at least three times higher than what could be obtained from an electric heater. Capacity and efficiency decline slowly as the car warms up and heat becomes available from engine coolant.

Other problems that have not been addressed in conjunction with microchannel heat exchangers are the frost and ice formation that comes from air and water splashed on the coil from the road. Flat-tube microchannel automotive heat exchangers are used on most cars today. These tubes must be oriented vertically for any air-source heat pump to adequately defrost and drain condensate, regardless of the refrigerant choice. A counterflow configuration offers significant advantages for CO_2 and R-410A at near-critical operating conditions, as it achieves small approach temperature differences (< 2°C).

Other components that require redesigning are automotive compressors. They are mostly made of aluminium to minimise weight and are designed for short lifetimes (approximately less than 1000 hours). The typical wobble plate designs are losing popularity, with scroll types replacing them. The scrolls produce less noise and vibrations. If heat pumps are installed in future vehicles, the design lifetime will probably increase from hundreds to thousands of hours. If CO_2 is selected as the primary refrigerant, leakage may be tolerated and unlicensed workers might do recharging.

Many commitments to new component technology are being deferred until decisions are made about whether to opt for heat pumps, hermetic systems or new refrigerants. At the same time the stationary air conditioning industry places increasing emphasis on heat pumps. It also feels the need to make heat exchangers more compact because the conventional approach of adding surface area has reached a costly stage of diminishing returns.

Advanced plate heat exchanger

Plate heat exchangers are today widely used in heat pumps and air conditioners. They are more compact than conventional shell and tube heat exchangers. However, the typical plate heat exchangers of today have a large

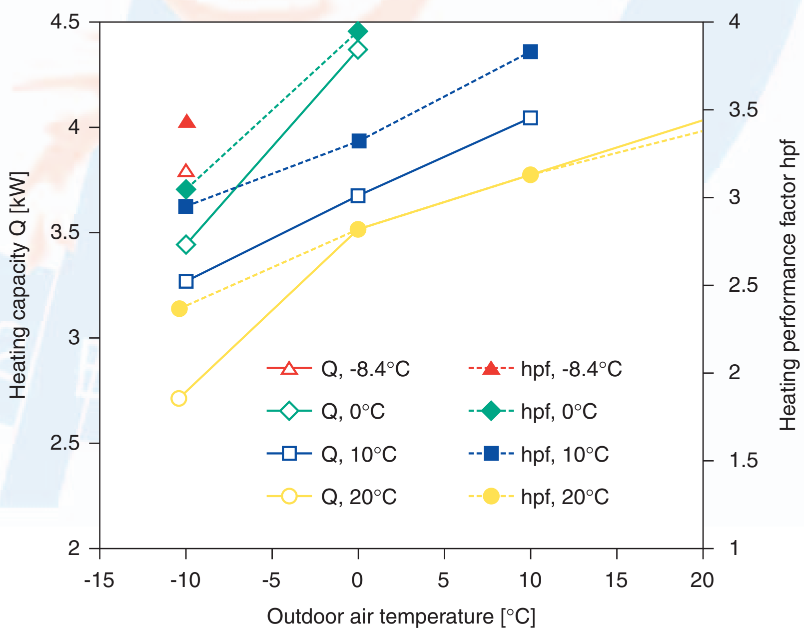

Figure 15: Automotive heat pump performance at different indoor and outdoor conditions

pressure drop on the waterside and a lower refrigerant heat transfer coefficient on the refrigerant side.
A new type of extended surface plate heat exchanger for water-refrigerant heat exchange has been developed in Japan. It uses a plate pattern with a pyramid-like structure (**Figure 16).**
The new structure creates a concave pattern at the top and a convex pattern at the bottom of each flow channel.
This new type of heat exchanger was tested with R-22 for different channel heights and found to be superior to conventional plate heat exchangers in terms of thermophysical properties.
Evaporation heat transfer coefficients are about 1.5-2 times higher than for conventional plate heat exchangers.
The pressure drop of the plates with the highest channel (1.5-mm) was the same as the pressure drop of conventional plate heat exchangers. Smaller channel heights (1.0 and 1.2-mm) show 50% smaller pressure losses than the 1.5-mm design. The new design with a 1-mm plate height is practically the most attractive as it combines lower pressure drop with compactness for the same cooling capacity.

CO_2 water heating

Undoubtedly one of the key research areas today, CO_2 technology development has resulted in a new Japanese product entering the domestic market: a residential CO_2 heat pump water heater with an annual average COP of more than 3.0. The new product, which has been developed by a consortium led by Tokyo Electric Power Company, is environmentally sound and serves an important energy-consuming household market, which is expected to show strong growth in Japan. Domestic hot water in Japan accounts for one third of residential energy consumption. Hot water supply capacity is variable due to the use of an inverter motor-driven hermetic scroll compressor. The storage-type water heater features decreased operating cost by using low tariff electricity during the night.
Page 10 of the 2002 March issue of the Heat Pump Centre newsletter gives a schematic diagram and an extensive description of the unit, as well as its specifications.

CO_2 compressor

Unlike the commercial product described earlier, another Japanese CO_2 heat pump water heater design is equipped with a twin-rolling piston type, two-stage compressor. It features high discharge pressure and suppressed vibration and noise. In addition to the water heater, which produces 90°C water in cold weather regions, the compressor will be applied in drinks vending machines. The application in vending machines combines several simultaneous functions including water heating, water cooling and ice production, which makes this potentially an energy-efficient device.

Figure 17 shows the arrangement of the two-stage compressor with superimposed gas flows. It has been field tested in a 4.5 kW heat pump water heater under cold climate conditions in Japan (Sapporo district). **Figure 18** shows the COP of the unit at below zero ambient temperatures when supplying a water temperature of 90°C. The water inlet temperature varied between 3 and 4°C. The figure also shows the effect of defrosting. When these data are extrapolated to above zero ambient temperatures, COPs of 3.1- 3.4 at 25°C are achieved for inlet water temperatures of 3-15°C.

The prototype vending machine demonstrated a COP of 2.19 when supplying hot water under normal conditions. If hot water supply and ice making are performed simultaneously, the model showed a COP of 2.35.

CO_2 system design

The use of CO_2 as a refrigerant raises a number of technical challenges in designing, building and controlling the operating parameters. Selecting an

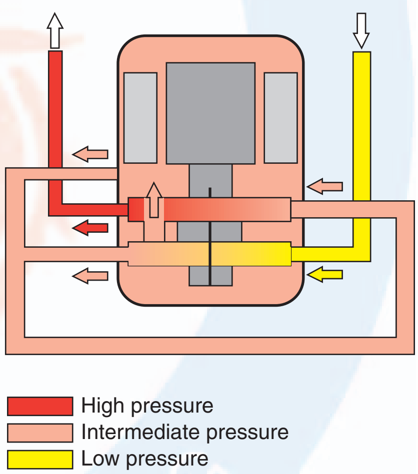

Figure 17: Schematic of two-stage compressor with gas flows superimposed

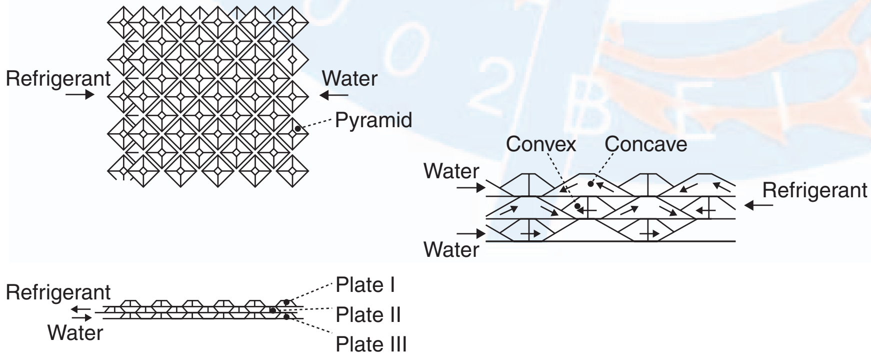

Figure 16: Plate heat exchanger with pyramid-like structure

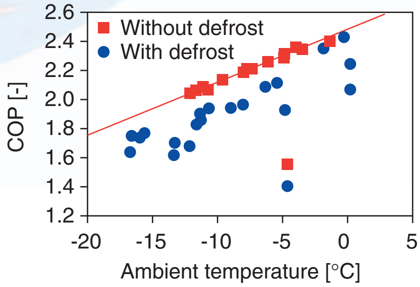

Figure 18: CO_2 heat pump in field test

application, a system configuration and the operating conditions needs careful consideration. The compressor and system design is very specific to each application. CO_2 properties have large variations around the critical point and in the gas domain. Means to control the charge inventory are very important. Analytical studies have been conducted in the US to predict the behaviour of transcritical CO_2 systems, using two-stage and single-stage compressors. Criteria to select operating parameters have been analysed. It was concluded that the compression polytropic coefficient is a factor to be used in designing the system in response to ambient and load changes.

CO_2 research

Potential application areas for CO_2 refrigerant include air conditioning and heat pump systems, transport refrigeration and refrigeration systems. Application sectors include buildings, transportation and process industry. Since the 1999 heat pump conference in Berlin, Germany, much progress has been made and CO_2 technology is now being commercialised, notably in Japan and Norway.

System research on space heating applications is ongoing. No concrete commercial choices have been made regarding the type of system. However, system studies predict promising results with SPFs between 4 and 6 for ground-to-air heat pump systems in Austria. For the retrofit market with high heat distribution temperatures, CO_2 heat pumps could be a strong candidate as well. Prototype residential air conditioning systems that provide both cooling and heating have been built in various countries including Norway. Experiments have also been carried out with domestic heat pump dryers. COPs in the range 5.5 and energy savings of 55% have been reported.

Other research areas on advanced applications of CO_2 systems are commercial distributed refrigeration with heat recovery for space and water heating in supermarkets. System simulations show an energy saving potential of more than 30% in Southern Europe compared to an R-22 system. **Figure 19** shows a diagram of a supermarket refrigeration system with self-contained display cabinets with CO_2 refrigeration units.

System control

A new control approach for heating-only residential heat pump systems has been developed in Switzerland. Conventional control concepts use the heat pump supply or return water temperature as a function of the outdoor temperature. The new control concept uses pulse width modulation and enables the direct delivery of heat energy to the house in suitable portions. It takes into account the steady-state energy demand and the thermal dynamics of the house. The advantage of this approach is improved anticipation of the electricity tariff structure (low and high rates) and the electricity cut-off periods. The result is a significant reduction of energy costs without loss of comfort. The control concept has been successfully tested in a commercially available controller of a heat pump in a single-family house in Switzerland.

Gas heat pumps

Gas heat pumps for the residential and commercial building sector have long been an R&D topic. Few systems and products, especially in the residential sector, have reached the commercial stage. The major impediment for market success is the initial cost. At previous IEA Heat Pump conferences, development progress was reported, but breakthroughs are still lacking. In Japan however, gas engine driven heat pumps for cooling and heating in small commercial applications have become a success. They reached a market share of 11% and sales are increasing steadily.

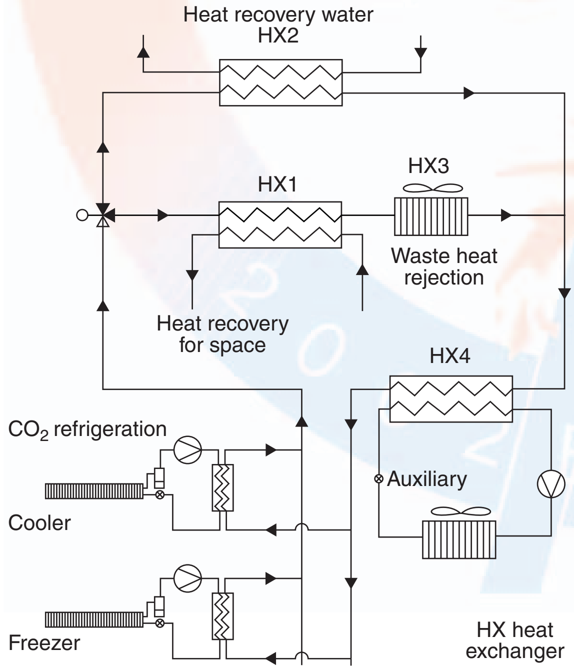

Figure 19: Distributed CO_2 supermarket refrigeration system with central heat recovery

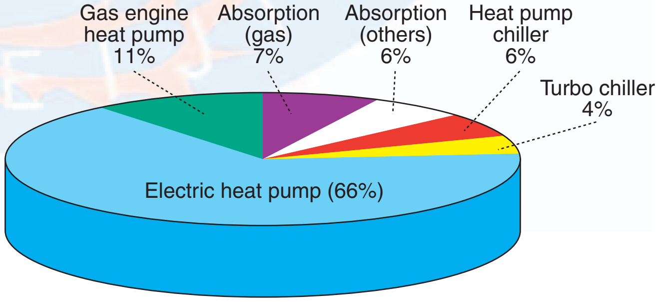

Figure 20: Breakdown of air conditioning market in product type (Japan)

Their success is explained by the fact that they do not use electricity to drive the compressor. Hence, they are not affected by peak loading problems in the electricity network. **Figure 20** shows a breakdown of product sales in the Japanese gas air conditioning market.

Today, the Japanese economy is still recovering. As a consequence, construction activity in Japan is down. Moreover, there is a surplus of commercial building capacity. Manufacturers of air conditioning equipment are relocating production to other countries with cheaper labour in an effort to reduce manufacturing cost and secure business. However, there is an increasing interest from the construction sector and the air conditioning industry in renovating existing buildings. This could become a growing market, as there is a substantial energy saving potential left in this sector.

Because the electricity and gas prices in Japan are among the highest in the world, the government has taken initiatives to bring the price down in an attempt to boost the economy and revitalise the industry. One action is to reduce energy regulations and introduce a free energy market. Another key action is promoting load levelling of electricity, which could favour gas engine and absorption heat pumps.

In small to medium size buildings in Japan, central air conditioning systems are increasingly being replaced by local air conditioning. Central systems, including heat pump chillers, turbo chillers and central absorption systems, are losing market share, which is only 23% at the moment (Figure 20). Small residential absorption air conditioners cannot compete on the Japanese market with their electric competitor due to higher initial cost and a more complicated installation.

The performance of gas engine heat pumps has been further improved in the past three years. The main features are a high heating PER of 1.5 (cooling PER 1.3) and a relatively short payback time in Japan of 3-5 years. Ongoing research aims at improved (partial load) efficiency and reduced nitrogen oxide emission. This is achieved through engine improvement, heat exchange improvement and refrigerant replacement of HCFC by HFC (R-407C). The prospects of gas engine heat pump systems for cooling and heating in the light commercial market are expected to continue to grow.

The US DOE supported private sector efforts in gas cooling and heating absorption systems for several years. Except for large absorption chillers, the technology has largely been sold to niche markets in Asia. As demonstrated by Japan, advancing and implementing new technology takes time and patience. Key activities involve several types of systems, such as ammonia-based residential heat pumps, chillers and light commercial gas absorption heat pumps. The recently developed triple-effect prototype chillers that use the water-lithium bromide working pair [York, Trane] add significant cooling capacity, result in higher cooling COPs (30% increase) and demonstrate the use of recovered heat for large commercial building applications. A promising development is the integration of systems by combining absorption heating, cooling and power applications.

GAX technology

In the residential and light commercial sector, the GAX (generator-absorber heat exchange) concept has been developed and earmarked as a significant mainstream product in the near future. However, it appeared very difficult to organise interest from the US industry in manufacturing these products. Three separate organisations are now trying to bring GAX technology to the market: Robur, Cooling Technologies Inc. and Ambian. The first two companies focus on GAX chiller deployment while newcomer Ambian aims at commercialising GAX technology for high-efficiency gas heating and cooling. Ambian is owned by several major gas utilities and pipeline companies and includes three manufacturing partners. Key features for the Ambian products include a cooling COP of 0.7 at 35°C, a heating COP of 1.4 at 8.3°C and multi-temperature capability for zoning. The company plans to manufacture several products including a 17.5 kW and a 10.5 kW absorption heat pump. Production will begin in 2003.

The second generation of residential and light commercial absorption ammonia-water products is referred to as Hi-Cool. The programme aims to improve cooling performance by an additional 30% compared to GAX technology. This means heating PER targets of 1.8-2.0 (1.0-1.2 for cooling). A 28 kW breadboard prototype has been built by Energy Concepts with a gas heating PER of 1.4 at –8.3°C. A 10.5 kW multi-stage solid vapour sorption heat pump laboratory prototype by Rocky Research achieved similar performance.

Ice thermal storage air conditioning

Ice thermal storage air conditioners have been spreading rapidly in Japan and other Asian countries. The main thrust behind this phenomenon is the imbalance in the electricity network. Dedicated products using R-407C have been developed in Japan to tackle this problem. These units use inexpensive nighttime electricity, which is to a large extent produced from non-fossil fuel sources in base load. Ice is produced for space cooling during daytime.

The cooling COP and the improvement of the latest series of units, a multi-split system air conditioner, is shown in **Figure 21.** Features of this generation of products include a constant speed and an inverter compressor providing a high peak shift ratio (55%) during heavy load conditions and reduced energy consumption, applying a so-called multi-path refrigerant mixing circuit, and improved ice making efficiency by applying R-407C, a non-azeotropic

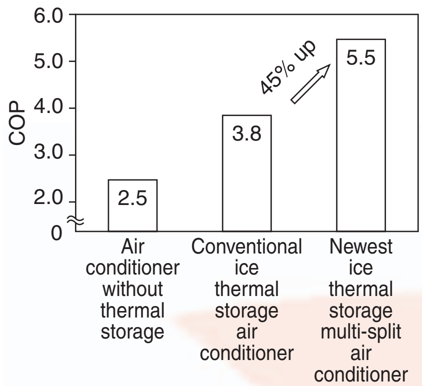

Figure 21: Performance development of ice thermal storage multi-split air conditioner (Japan)

refrigerant mixture (NARM). Specific refrigerant-related features of the design are:

- uniform ice layer along the tube;
- reduction of suction pressure loss by adopting an asymmetrical scroll compressor (**Figure 22);** refrigerant gas flows directly to the suction part of the scroll;
- **a**pplying a new inner groove design (N-shape) of the heat exchanger tubes, promoting evaporation and condensation of NARM.

The overall result of these improvements is an energy efficiency increase of more than 45% compared to conventional ice thermal storage air conditioners. An operating cost reduction of 45% compared to air conditioners without ice thermal storage is achieved with the new system in Japan.

Properly designed ice thermal storage systems that are fully integrated with the building design can also result in lower initial cost compared to non-storage systems. This has been demonstrated in China, where the implementation of these systems is encouraged by attractive economic incentives. The State Power Management Building in Beijing is just one example. In addition to cheaper chillers and cooling towers, the main cost savings are obtained through reduced pumping, piping, and air handling units and ductwork. The initial cost savings is more than 6%. Costly connection charges can also be reduced, as the peak electric power is reduced substantially. Other Chinese examples of ice thermal storage systems can be found at the Shanghai Science and Technology Museum, the Shanghai Children's Hospital, the Hangzhou Construction Bank, and the Northwest Electric Power Management Communications Building.

Retrofit heat pumps

Replacing heating boilers and other heating systems with hydronic heat distribution in older houses by a heat pump requires specific technical solutions. Typically, older hydronic heat distribution systems (radiators) operate at high temperatures. The heat pump cycle needs to be adapted for sufficient heating capacity at higher temperature lifts and for high-energy efficiencies. Technical options include a two-stage cycle with dual compressor, economiser vapour injection, and a dual cycle with condensate sub-cooling, and an ammonia cycle with oil-cooled compression.

These system concepts are being studied and developed in the Swiss Retrofit Heat Pump Programme. The goal is to develop retrofit heat pumps for small capacities, i.e. below 25 kW heating capacity. To involve the industry, a design competition has been organised, and supporting research is initiated into thermodynamic challenges and controls.

The thermodynamically most promising solution is a two-stage dual compressor cycle with R-407C refrigerant. Compared to a single-stage heat pump, this cycle offers a 50% increase in heating capacity and a 14% increase in COP at maximum temperature lift. However, the design is complex and it is not likely to be able to compete with a boiler. A substantial COP improvement could also be achieved if a scroll compressor with a specific vapour injection port were available on the market. Measurements on a prototype R-407C system, as shown in **Figure 23**, showed a heating capacity increase of 30% and a COP increase of 15% at –7°C/60°C.
To develop such a retrofit heat pump, a specific scroll design is needed to accommodate vapour injection. The dual cycle with sub-cooling showed less promising results and is better suited for larger systems. The ammonia

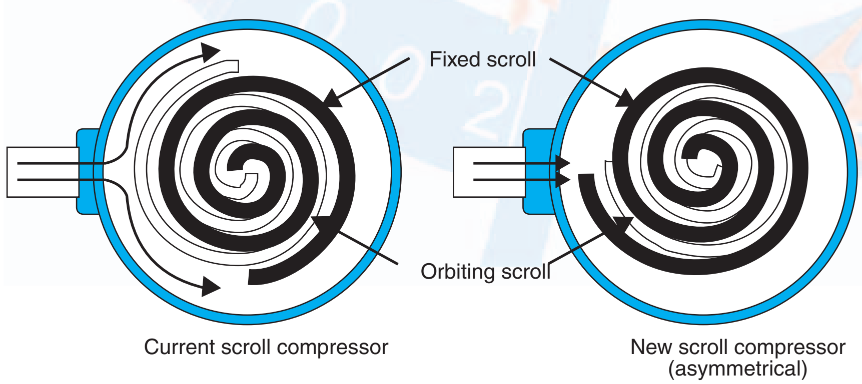

Figure 22: Improved (asymmetrical) scroll design

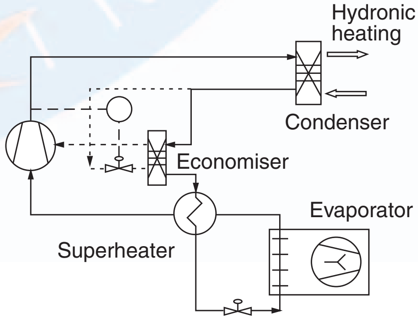

Figure 23: Two-stage dual compressor system for retrofit application

compression cycle, which uses a rotary vane compressor with oil cooling, needs additional research and development. Given the large retrofit market potential for houses with hydronic heat distribution, scroll compressor manufacturers might do well to take up the challenge of developing specific products for this market.

Working fluids

Much research has been and continues to be carried out in the field of new and alternative refrigerants and their application in air conditioning, heat pumping and refrigeration. Readers of this newsletter have been kept up to date on this topic. It might by now be superfluous to emphasise the importance of selecting the optimum refrigerant so as to achieve the design performance of a system under safe and environmentally benign operating conditions. It is obvious that the air conditioning and refrigeration industry have been impacted by environmental regulations to an extent not heard of before.

Under current circumstances, the conclusion is that no single fluid can be recommended as the best optimum solution for air conditioning, heat pumping and refrigeration systems. This means that designers are continuously faced with the problem of evaluating several refrigerants and trying to select the best one for any specific application. However, it is expected that in future environmental factors will increasingly influence the selection process.

Refrigerant experts also believe that the diversity of fluids that are to be examined will continue to grow to meet future emerging technology needs. For the short and medium term, HFC mixtures are likely to be adopted as mainstream refrigerants. Ammonia, hydrocarbons and carbon dioxide will see wider use in various applications. Even though the choice of the right refrigerant in the right place is essential, the importance of saving energy should not be underestimated.

Ground-source heat pumps

Ground-source heat pumps have become a success story in several countries and climates, especially in colder regions. Market growth estimates range from 10 to 30% annually. Development of this technology has made significant progress during the past decade. However, further improvements in designing and reducing costs can be made. Reduction of initial cost has mainly been achieved through improved performance, which allows smaller, less costly heat exchangers, and more accurate design analyses. The conference devoted an entire session to this topic.

Ground-source heat pumps have not only seen significant market growth and broadened application; they are becoming recognised as a cost-effective standard for energy conservation. Key factors behind this success are soundness of the technology, improved design and installation infrastructure and the response of the heat pump industry.
Current developments focus on five areas:

- reducing initial costs of ground heat exchangers;
- determining soil thermal properties;
- modelling ground-source heat pump systems;
- development of hybrid systems (ground heat exchanger combined with above ground heat rejecter/ absorber);
- further development of design methodologies;
- faster, lower cost pipe-joining methods;
- new pumping configurations (variable speed, multiple and zoned on-off pumps).

In the US, there are three ARI certification standards, which rate so-called water-source heat pumps (water source, groundwater source and ground-source closed loop). The worldwide installed capacity and energy produced with ground-source heat pump systems is estimated at 6,675 MW and 23,270 TJ annually respectively. The US market represents 4,800 MW (about 500,000 units) and 12,000 TJ annually of the total worldwide market.

The non-residential market is beginning to dominate in terms of installed capacity. For instance, in the US over 600 schools use this technology.
The US federal government stimulates large-scale residential applications. For example, it installed over 4000 units in a military base.

Even though ground-source technology is reliable and cost-effective, continued research is needed to further lower the variable cost and broaden the applicability of ground-source heat pump systems. Research areas include:

- computationally efficient simulation methods for ground loop heat exchangers, especially horizontal designs with above ground interaction;
- more cost-effective vertical heat exchangers;
- lower cost methods for estimating soil thermal properties;
- design methodologies that incorporate system simulation, allowing interactions between the building system and the heat rejecter/exchanger system;
- optimised fluid pumping system configurations and controls for reduced variable costs.

Several organisations have been active in transferring the technology to the market, which has significantly improved awareness by architects and engineers. However, more is needed to make ground-source heat pump systems a widely accepted technology.

Policy makers in the US took notice of the potential energy savings of 3% of total US consumption, and several programmes were launched under the auspices of the DOE to support mainstreaming the use of ground-coupled heat pumps. In 1994 the National Earth Comfort Programme was established with USD 35 million from the DOE and USD 65 million from the electric utilities. The goal was to boost sales to 400,000 units by 2000. This goal was not achieved, partly because utilities were restructured, resulting in withdrawal of their support and marketing. Nevertheless, under this programme sales nearly doubled from 40,000 in 1994 to 80,000 in 1999, accelerating the growth of the industry.

In late 1998, the Federal Energy Management Programme established its ground-coupled heat pump technology initiative. Shipments in the US increased more than ten-fold from 1999 to 2001. It is the most cost-effective component of the overall DOE ground-coupled heat pumps programme that remains active today.

Ground-coupled heat pumps in the US remain possibly the best technology available today for reducing energy consumption from space heating and cooling, and from water heating: "Managing Btu's with ground-coupled heat pumps - by moving them from room to room, from air conditioners to water heaters, or storing them in the ground for the winter - is a more prudent use of energy than dumping thermal energy into the air as virtually all conventional air conditioners do today".

Most governments focus all of their resources on R&D. However, governments would get a much higher return on their energy and environment investments if they would invest about 10% of the R&D funds in expanding adoption of energy-efficient and renewable energy technologies - technologies that substantially reduce energy consumption and emissions, have a credible base and momentum, are commercially available, cost-effective, wanted by customers, and easily accessible. Even in the US, more applied research is needed to provide customers with all the guides and tools needed to make ground-coupled heat pump projects no more difficult to develop and implement than conventional heating and cooling projects.

Ground-coupled heat pump systems for commercial/institutional buildings have now successfully been introduced in China, even in cold climate regions. Measured seasonal average COPs range from 3.1 in cold regions to 3.3 in milder regions. Few projects have been realised yet, but plans exist for new installations in metropolitan areas and for the Olympics in 2008 in Beijing. Problems encountered in China include lengthy borehole drilling and installation processes, lack of suitable water-source heat pump products and limited availability of appropriate equipment and qualified installation personnel.

As for Europe, ground-coupled heat pumps are mainly applied as heating-only systems. Heat source systems include bedrock, ground, sea and lake water, groundwater, combinations of these sources and ventilation air. **Figure 24** shows countries with significant sales of ground-coupled heat pumps (the first number represents million of inhabitants, the second number the heat pump sales per 1000 inhabitants). Sales in other European countries are less than 0.1 heat pumps per 1000 inhabitants.

In 2001, of the total sales in Europe of 41,000 ground-coupled heat pump systems, 27,000 were installed in Sweden. For the next 3-5 years, market growth rates have been estimated by industry as shown in **Table 2**.

Table 2: Ground-coupled heat pump market Europe.

Country	Sales 2001	Growth, %
Austria	4,800	8
Czech Republic	350	25
Denmark	150	>100
Finland	1,250	10
France	850	10
Germany	3,600	20
Netherlands	400	>25
Norway	650	10
Poland	500	5
Sweden	27,000	6
Switzerland	2,800	6
UK	150	>100

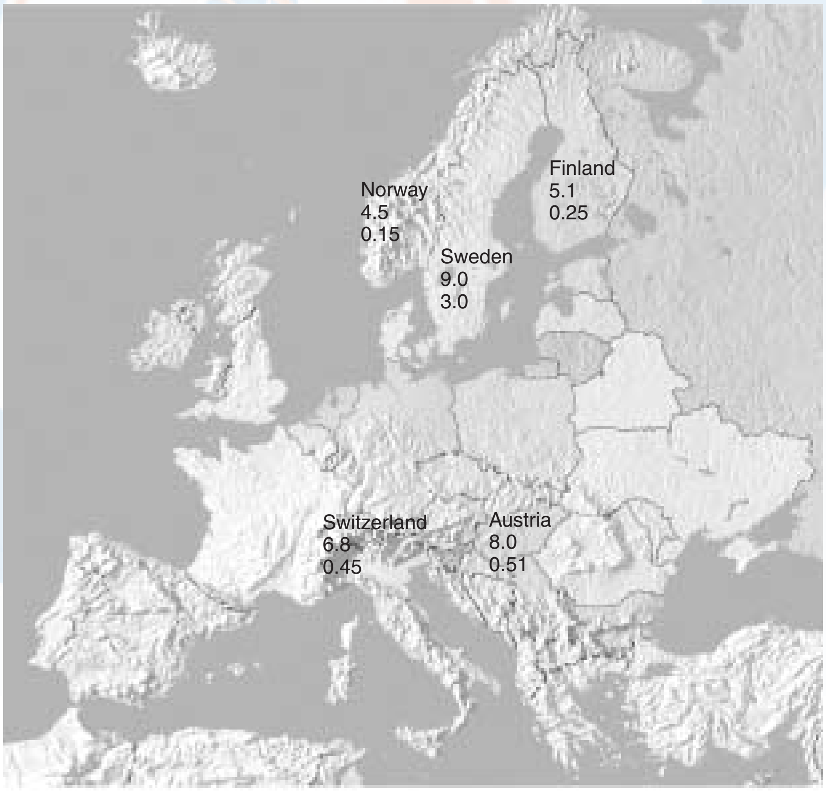

Figure 24: Ground-coupled heat pump market Europe.

Bedrock-source systems are mainly applied in the Nordic countries and Switzerland. Typical drilling depths are 70-200 m with diameters of 125 mm. For a house, one hole is usually sufficient. Boreholes are not filled with grouting material. They are filled with groundwater for good thermal coupling, also under freezing conditions. Grouting is applied in other regions of Europe, notably Switzerland and Austria, and in areas with unstable bedrock. In the Nordic countries usually two loops (40 mm) are inserted in each borehole; elsewhere 4 loops are sometimes applied (32 mm).

New houses can benefit from so-called ‘free cooling’, if a ground-coupled heat pump is applied. During the summer, cold brine is simply pumped to the house without operating the heat pump. The heated water is recharging the heat pump’s heat source. This concept has become popular in some countries, stimulating the use of heat pumps.

Conclusion

The 7th IEA Heat Pump Conference was a success. It provided a clear view and update with respect to the market status and technological status of heat pumps as well as many fruitful discussions. It also made clear that heat pumps are really beginning to break through market and other barriers and that all markets are showing signs of growth. China and Europe are good examples of significantly growing markets. “Heat pumps are where the action is” certainly applies to China with its booming construction sector and HVAC industry. Of course, the success of the conference was also the result of thorough preparation, the excellent location and the participation of over 300 people who came from all over the world.

The status of heat pumps can best be characterised by the diversity in technology, markets and developments. Examples are gas heat pumps, combined heat pumps and thermal storage, advances in CO_2 technology for water heating, diversity in system design, and the broadly applied and expanding ground-coupled heat pump markets. New competing technologies are emerging, such as micro-CHP and fuel cells in residences and light commercial applications. There is no single solution available and this provides excellent opportunities for countries to collaborate and learn from each other.

As the chairman of the International Organising Committee of the conference, Mr **John Ryan** of the US DOE put it:

“The conference helps us as a beginning, not an ending. We should not continue to apply the so-called direct line-model that governments are no longer prepared to support. We should adopt the teamwork model to reach our common goal, as was proposed by Prof. **Bredesen** of NTNU, Trondheim, Norway, for both the chemical and natural working fluid strategies. By accepting that there are two different approaches, but one common team of players with the same objective, it will be possible to come up with the solutions society needs and asks for. Society will eventually decide”.

International organisations like the IEA have an important role to play in bringing forward new energy solutions for a cleaner world.

The proceedings of the conference can be ordered from the HPC; for price information, see the Publications section of the website.

Jos Bouma
IEA Heat Pump Centre

Conference organisers

Measuring sound power levels

Andre Pierrot, Spain

A directive can be expected from the European Union regulating the permissible noise levels for various products and equipment. Eurovent already includes sound power among the characteristics it certifies for its Directory of Certified Products. Recently, a new advanced laboratory building was completed in Madrid, which is used for very accurate measurements of the sound power levels produced by various types of equipment.

Introduction

In recent years, authorities and society in general have begun to show growing concern about what could be considered a new polluting agent: noise. The phenomenon itself is not very new, but it's characterization as a polluting agent is relatively recent. Noise is a level of sound that is not desired. The level of irritation produced is related to the time of exposure and the intensity. The harmful effects to the health of human beings caused by too much noise include problems with sleep, increased stress, loss of concentration in daily work, and even loss of hearing ability when the levels are very high or continue for long periods of time.

The noise levels in cities have been increasing year over year, and these increases could, within a few decades, lead to an environment so noisy as to have a harmful effect on the health of residents and to a reduction in their quality of life. For this reason, the level of acoustic pollution caused by equipment is an important factor to be considered. The 'noise' level of equipment can also provide a competitive advantage to one producer over another.

Measuring acoustic pollution

On a European Union level, a directive on noise can be expected, which will set limits to the amount of noise generated by various products and equipment. Eurovent, aware of this situation, decided very early on to introduce sound power as a certified characteristic, which is published in its Directory of Certified Products.

To evaluate acoustic pollution, the sound power emitted by a sound source must be measured. This must be done in such a way that any kind of noise source, regardless of where it will later be used, can be quantified. One of the most accurate methods for measuring the sound power of small and medium sound sources is described in standard EN ISO 3741:1999 "Acoustics. Determination of sound power levels of noise source using sound pressure. Precision methods for reverberation rooms". Eurovent chose this measurement method for the certification programme for air conditioners.

In 1994, the heat pump laboratory of CEIS (*Centro de Ensayos, Innovación y Servicios, S.L.)* was selected by Eurovent as an independent laboratory to perform the above measurements. The actual sound power measurements are carried out by the external laboratory UPLA at the Polytechnic University of Madrid.

In 2000, CEIS decided to study the possibility of building a new laboratory with two main objectives:

- to perform acoustic measurements under optimum control of test conditions;
- to improve the possibilities of testing for performance measurements, both in terms of capacity and type of units tested.

The decision was taken to erect a new building for this advanced laboratory.

The new facility

The main specifications of the project were:

- very low background noise, no vibration transmission;
- double acoustic insulation of the reverberation rooms;
- ideal proportions for the reverberant rooms, possibly in a new building;
- a minimum of parallel surfaces in the reverberation rooms;
- twin reverberation rooms to measure indoor and outdoor sides simultaneously;
- two additional rooms to install the units and measure in-duct sound;
- good control of the test conditions (temperatures, humidity and flows).

Additionally, the laboratory was also meant to allow determination of the coefficient of sound absorption of materials in accordance with EN 20354:1993 "Acoustics. Measurement of the sound absorption in a reverberant room (ISO 354:1985)".

The new laboratory has two twin reverberation rooms of 225 m^3 and 235 m^3 and two climate rooms. A water-to-water heat pump maintains two water tanks at steady state low and high temperature, and two air-handling units with humidifiers ensure constant temperature and humidity conditions in the climate and reverberation rooms. The system is completely automated and allows a range of temperatures from + 7 to + 46°C. The installations are equipped with hermetic closures, so possible variations in testing conditions that might occur during measurements can be controlled within limits.

Calculation of acoustic power is based on measurement of sound pressure level and reverberation time of the testing room. Because it is necessary to measure the level of sound pressure, a low level of a background noise is an essential requirement to be able to offer the best testing results. To achieve this, the reverberation rooms are isolated from the surroundings by a double wall. The first wall is of a heavy construction, so an optimum isolation is ensured against aerial noise. The second wall (interior of the reverberant rooms) not only improves the isolation by providing more mass to the construction; its design also gives rise to a very wide sound field (an essential condition for the correct calculation of the sound power level from the sound pressure level).

First, an enclosure was built to form the perimeter of the exterior rooms. Then the inner walls of the reverberation rooms were raised to favour the diffusion conditions in the sound field. Between both structures, an acoustic insulation material was installed; see **Figure 1**.

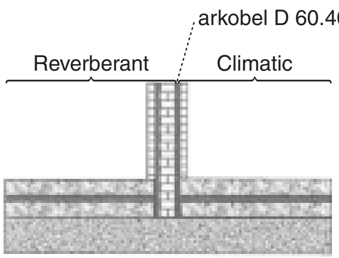

Figure 1: Cross-section of reverberating room and climate room walls.

To prevent noise transmission from vibration of the structures, the floors of the rooms are separated from the building foundations by acoustic and thermal insulation material. The reverberation rooms are "floating". The ceiling of the reverberation rooms is decoupled from the rest of the laboratory structure.

The construction of the two climate rooms, in which ducted units are tested according to Eurovent requirements, or EN/ISO standards, and which are close to the reverberation rooms, have been designed using a similar acoustic isolation approach to that of the reverberation rooms. The climate rooms have been designed taking into account the specific requirements and equipment installation characteristics of air conditioners and heat pumps available in the market. Acoustic tests for several types of equipment require that the rooms have windows that allow correct installation and operation of the equipments under testing. This is the case, for instance, for window-type units, and for in-duct measurements. These are hermetically sealed acoustic windows in order to maintain the required acoustic isolation for the measurement of less noisy machines, and they have a sound attenuation superior to 45 dBA.

The test facilities allow for carrying out acoustic testing of air-to-air, air-to-water, water-to- air and water-to-water products with a cooling capacity of up to 50 kW, with the exception of roof top units and liquid chiller packages with remote condenser. To test these types of units, the laboratory is equipped with two air loops of 14,000 m^3/h, and two water loops of 12 m^3/h, with controlled flows and temperatures conditions.

The project was completed with financial support from IMADE (Development Institute of Madrid) and the Spanish Ministry of Science and Technology through its programme PROFIT.

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Books & software

Special issue: Heat pumps – Status and Trends
IIR – International Journal of Refrigeration, Vol. 25, No. 4, June 2002
Published by Elsevier Science Ltd, Oxford, UK
Contact IIR, Paris
177 Bd Malesherbes
75017 Paris
Tel: +33 1 4227 3235
Fax: +33 1 4763 1798
Email: iifiir@iifiir.org

This special issue includes 10 articles on heat pump technology and markets. Most articles are updated or extended versions of papers presented at the 6th IEA Heat Pump Conference in Berlin in 1999.

Global Comparative Analysis of HFC and Alternative Technologies for Refrigeration, Air Conditioning, Foam, Solvent, Aerosol Propellant, and Fire Protection Applications
Report by Arthur D. Little
For information and orders: www.arap.org

The report concludes that HFCs have become the "preferred replacement" for HVAC&R and other applications because of their safety characteristics and the potential to provide substantial cost savings. This new report is an update of a version first published in August 1999. It documents the performance of HFCs compared to other fluids and technologies in those application areas where HFCs have emerged as replacements for CFCs and HCFCs. The report also concludes that HFCs generally provide the lowest net global warming impact, as measured by Life Cycle Climate Performance. The use of primary alternatives such as hydrocarbons, carbon dioxide and ammonia require safety measures that vary with the application, increasing the cost of the application. Worldwide cost savings by using HFCs, without projecting market growth, are estimated at USD 36 million annually.

Assessment of the Commercial Implications of ASHRAE A3 Flammable Refrigerants Used in Air Conditioning and Refrigeration Systems
Report by Arthur D. Little
Available for free from: www.arti-21cr.org

This report has been released by the ARTI's HVAC&R Research for the 21st Century Program (21-CR). It summarises current knowledge regarding risk, benefits, cost and regulatory issues associated with using flammable refrigerants in air conditioning and refrigeration systems. The report will assist manufacturers and other customers in better understanding the safety, performance and regulatory implications for products using flammable refrigerants.

JARN Directory 2002-2003
Published by JARN Ltd.
Hosokawa Bldg., 1-1-16, Akasaka, Minato-ku, Tokyo 107-0052, Japan
Tel: + 81 3 3584 4704
Fax: +81 3 3584 4708
Email: jarn@jarn.co.jp
Price: USD 72 (air mail), USD 65 (sea mail)

Includes Japan HVAC&R Buyers' Guide (products, services, importers, exporters, associations, overseas manufacturing facilities) and Industry Statistics, companies in Asia-Oceania region (including Australia, China, India, Korea, New Zealand, Thailand, Middle East etc.), worldwide network of key companies and major producers of key components (including compressors, controls, heat exchangers, motors, refrigerants etc.).

Eurovent Directory of certified products, Feb. 2002-Feb. 2003
Published by Eurovent Certification Company
62, Bd de Sébastopol, 75003 Paris, France
Tel: +33 1 4996 6980
Fax: +33 1 4996 4510
Email: info@eurovent-certification.com
Information and available from: www.eurovent-certification.com

The directory contains a list of companies that are committed to the certification of their products (air conditioners up to 100 kW, including reverse cycle), listed according to Eurovent classification. Performance data have been verified by testing of selected units in independent laboratories. The directory includes a list of discontinued but certified products. These models are no longer produced but stock is still available.

National Training on Good Practices in Refrigeration – A Support Guide for National Ozone Units
Published by UNEP DTIE OzonAction Programme
ISBN 92-807-2020-1
Order for free from:
SMI Ltd, PO Box 119 Stevenage, Hertfordshire SG1 4TP England, or
www.earthprint.com

Good practices in the refrigeration-servicing sector need to be applied in order to significantly reduce emissions of ozone-depleting refrigerants. The guide is designed to help achieve this goal and assist developing countries to meet their compliance obligations under the Montreal protocol. Translations will be available in Arabic, Chinese, French and Spanish.

World Radiator Market
BSRIA press release
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The study was published in February 2002 covering 24 countries. The report was compiled from 240 interviews with key manufacturers, importers and suppliers. It is 120 pages long.

The world market rose to USD 3.4 billion and 71 million units in 2001 and is expected to grow at 3% over the next few years. In the period 1999-2004, the market in China, which already accounts for 30% of the world market, is expected to increase by 6 million units. Russia is the world's fastest growing volume market, expected to add 2 million units over the same period, whereas after China, the UK shows the largest increase by value.

2002

HFCs and Synthetic Lubricants
23 October 2002, Paris, France
Contact: Secrétariat SFT
Ecole Centrale Paris
Grande Voie des Vignes
92295 Châtenay-Malabry Cedex, France

Symposium Erdgekoppelte Wärmepumpen
8 November 2002 / Waren, Germany
Contact: Geothermische Vereinigung
Gartenstrasze 36
49744 Geeste, Germany
Tel: +49 5907 545
Fax: +49 5907 7379
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Deutsche Kälte und Klima Tagung 2002
20-22 November 2002, Magdeburg, Germany
Contact: DKV-Geschäftstelle
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Fax: +711 685 3242
E-mail: dkv@itw.uni-stuttgart.de

ACRA-2002 Asian Conference on Refrigeration and Air Conditioning (IIR co-sponsored)
4 December 2002 / Kobe, Japan
Contact: Fumio Takemura
University of Tokyo, Dept. Of Mech. Engineering
7-3-1 Hongo, Bunkyo-ku,
Tokyo 113 8656, Japan
Fax: +81 3 5841 6349
Internet: http://www.thml.t.u-tokyo.ac.jp/ACRA2002/

2003

Thermodynamics Heat and Mass Transfer of Refrigeration Machines and Heat Pumps – Eurotherm Seminar
31 March – 2 April 2003 / Valencia, Spain
Contact: Prof Rafael Royo
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Email: rroyo@ter.upv.es
Internet: http://www.imst.upv.es/eu_seminar.htm

Cold Climate HVAC 2003, The 4th international Conference on Cold Climate Heating, Ventilation and Air-Conditioning
15-18 June 2003 / Trondheim, Norway
Contact: Conference Secretariat
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21st IIR International Congress of Refrigeration (see information on p. 4)
17-22 August 2003 / Washington DC, US
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Tel.: +1-301-984-9450 x11
Fax: +1-301-984-9441
Internet: http://www.icr2003.org

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

Next Issue

Review IEA Heat Pump Programme Activities

Volume 20 - No. 3/2002

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among its 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

International collaboration for energy efficient heating, refrigeration and air-conditioning

Vision

The Programme is the foremost world-wide source of independent information & expertise on heat pump, refrigeration and air–conditioning systems for buildings, commerce and industry. Its international collaborative activities to improve energy efficiency and minimise adverse environmental impact are highly valued by stakeholders.

Mission

The Programme serves the needs of policy makers, national and international energy & environmental agencies, utilities, manufacturers, designers & researchers. It also works through national agencies to influence installers and end-users.

The Programme develops and disseminates factual, balanced information to achieve environmental and energy efficiency benefit through deployment of appropriate high quality heat pump, refrigeration & air-conditioning technologies.

IEA Heat Pump Centre

A central role within the programme is played by the IEA Heat Pump Centre (HPC). 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 heat pumps and the IEA Heat Pump Programme, contact your National Team or the address below.

The IEA Heat Pump Centre is operated by

Novem

Netherlands agency for energy and the environment

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