1982-2002

20 YEARS

Heat Pump Centre

Review IEA Heat Pump Programme Activities

IEA
OECD
heat pump centre

In this issue

Review IEA Heat Pump Programme Activities

Since its inception in 1978, the IEA Heat Pump Programme has developed many activities in the area of heat pump, air conditioning and refrigeration systems and applications. Improved energy efficiency and environmental benefits play a central role in the Programme. This newsletter gives an overview of the activities and accomplishments over the past 15 years.

Front cover: Twenty years HPC

COLOPHON

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HEAT PUMP NEWS

FEATURES

TOPICAL ARTICLE

The ExCo chairman reviews the Annexes and other activities of the Programme since its inception in 1978. Accomplishments, benefits and successes are assessed and the new direction of the Programme is presented.

In 2002 the Heat Pump Centre exists 20 years. The article reviews activities, services and accomplishments of the Heat Pump Centre and explains the new operational approach and strengthened membership base.

The Operating Agent of Annex 26 discusses the energy savings and environmental benefits of advanced supermarket refrigeration systems with integrated HVAC functions. The activities of participating countries are described and analysed.

Direct expansion ground-coupled heat pump systems have become popular in Austrian homes and their performance is very good. The author discusses pros and cons of direct expansion systems in comparison with secondary loop systems.

Twenty years HPC

The year 2002 is a special year for the IEA Heat Pump Centre and for the IEA Heat Pump Programme. It was 20 years ago that the Heat Pump Centre was established as Annex 4 of the Programme. Organised under a special working arrangement with an Information Centre located in Karlsruhe, Germany and an Analysis Centre in Graz, Austria, the Heat Pump Centre began its pioneering work for six participating countries: Austria, Germany, Italy, the Netherlands, Sweden and the USA. Belgium, Canada, Finland, Japan and Norway joined later during the first decade of operation. At that time, information dissemination and technical analysis were physically separated. The basic concept of information exchange through an international network, consisting of National Teams and the Heat Pump Centre, still exists today and continues to be a strong model with major benefits.

Since 1982, four newsletters have been published annually, several analytical studies have been conducted, and international workshops have been organised. A wealth of information on heat pump technology, applications and - later on - markets has been generated and disseminated.

In 1990 the Heat Pump Centre started operating as Annex 16 from Sittard, the Netherlands, with eight participating countries: Austria, Canada, Italy, Japan, Netherlands, Norway, Sweden and the USA.

During the last two decades, much has changed and improved in the field of energy saving and energy efficiency. A major change was the shift of emphasis from energy saving to reducing the environmental impact of energy use and reducing global warming. For heat pump technology, this is a major challenge as well as an opportunity, not only with regard to performance improvement but also concerning alternative refrigerants needed to pump heat.

The IEA Heat Pump Programme and the Heat Pump Centre have made an important contribution to advancing the technology and accelerating market deployment. However, the unrealised energy-and-cost-saving potential of heat pumps in the building and industry sectors is so great that it justifies continuing international collaboration in this field for several additional years. Therefore, the participating countries have agreed to continue the programme for at least five more years. After a major restructuring, with the result that all 14 countries in the Programme are now a member, the Heat Pump Centre is ready to continue its information dissemination task, with new élan, towards a society based on sustainable energy.

Jos W.J. Bouma
Manager IEA Heat Pump Centre

NON-TOPICAL ARTICLE

Norway has reorganised its programme on energy saving and environmentally friendly natural gas applications. A new agency has been established (ENOVA), which is responsible for implementing the programme. The article describes the agency's strategic objectives, tasks and approach.

The article is a summary of Phase 2 of the project. Two different heat pump controls have been equipped with a new control strategy, which has been developed in Phase 1, and tested in a residential building in Switzerland. The results are discussed by the author.

Heat pump news

General

Guidelines for ground-coupled energy storage

Netherlands – Heat and cold storage in aquifers has evolved into a mature technology since the early 80s. The technology matches seasonal heat and cold demand and supply of commercial/institutional buildings and housing clusters. Energy savings of 50-80% have been achieved with aquifer systems in the building sector. These systems store winter cold for space cooling in summer, thereby reducing annual cooling cost substantially. Waste heat rejected in summer is stored in the aquifer for space heating in winter. Heat pumps can be part of such systems.

Best practice guidelines for designing and installing aquifer storage systems have been developed and issued for developers and designers. The guidelines apply to simple energy storage systems with a standard design and a capacity under 80 m^3/h. These guidelines deal with the heat exchanger as well as controls and safety devices but not with the building installations.

The guidelines have been issued in Dutch jointly by Novem and NVOE, the Dutch Association for Ground-coupled Energy Storage Systems.

Source: IEA Heat Pump Centre

Rock to market heat pump

USA – Manufacturers do different things to promote their products and make them "easier on the eyes". A residential heat pump produced by Water Furnace International Inc., also known as the Rock, is housed in a decorative rock structure, which is available in five colours (**Figure 1)** to blend in with different terrains and environments. The unit can be completely concealed in the rock because it is a water-source unit without outdoor fan. The fact that the unit is therefore quieter than an air-source unit is now being used to promote it in the US market. The manufacturer claims a heating COP of up to 4.5.

Figure 1: Rock housing for a US heat Pump

Source: The NEWS, October 14, 2002

Certification of ground-coupled energy storage systems

Netherlands – Deteriorating performance of aquifer systems caused by extraction wells slowly silting up can be a major problem. TNO in the Netherlands has announced that they plan to set up a certification scheme for installers and suppliers of ground-coupled heat and cold storage systems. This will guarantee the purchaser of a system that it has been built according to specifications. Such a scheme would remove a major technical obstacle to further market development of these systems.

Source: Duurzaam Nieuws, TNO-MEP Nieuwsbrief 3/2002

Enhanced capital allowances

UK – On 5 August 2002, heat pumps became one of five eligible technologies added to the revised Energy Technology Criteria List of the government's Enhanced Capital Allowances scheme. No manufacturers have yet had specific models accredited.

Source: UK Heat Pump Network, Sept. 2002

Quality system for heat pump installers

Netherlands – In the Netherlands DWA, TNO-MEP and PRC Bouwcentrum are developing a quality control system for installers of residential heat pumps. Uneto-VNI (the Netherlands Association of Installers and Electricians) has commissioned this task. In the first phase of the project, a handbook will be produced on the installation of exhaust air/heat pump water heaters. In the second phase, heat pumps for space heating and passive-cooling will be dealt with. The handbooks will contain checklists and decision schemes for installers to help them select the right heat pump system and install it properly. The handbook should allow contractors (including those without heat pump experience) to sell and install properly functioning and satisfactory heat pump systems. The handbook for the installation of residential heat pump water heaters will be available at the end of 2002, while the handbook for heat pump systems for space heating will be ready at the end of 2003.

Source: R. Traversari, TNO Environment, Energy and Process Innovation
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Energy labelling for AC units

After January 2003 all room air conditioner products of less than 12 kW cooling capacity offered for sale in EU countries will need an energy efficiency label. The label shows the performance of the unit in relation to seven colour-coded efficiency bands showing how the unit relates to others. Also included will be noise level and annual energy consumption based on a nominal 1,000 kWh.

Source: JARN August 25, 2002

IIR input to Johannesburg WSSD

By preparing the report *Refrigeration Sector Achievements and Challenges* as input to the World Summit on Sustainable Development, the objective of the International Institute of Refrigeration was to highlight the key role of refrigeration, air conditioning and heat pumps in sustainable development.
This 80-page report was prepared thanks to the co-operation of 32 experts from 15 countries from all 5 continents. These experts are part of the IIR's network of specialists but also of organizations such as AREA, ASHRAE, IEA/HPC and UNEP.
A summary of the key conclusions of this report was distributed to the delegations of the countries represented. *Tomorrow*, distributed to 20 000 WSSD attendees, rated the IIR's report as the best among the 22 such sector reports and described it as follows: "The report presents a balanced view of the sustainable-development contributions and challenges for the sector. It sets several ambitious and measurable targets for improved performance over the next 20 years that focus on the entire life cycle".
The IIR also published an editorial in the booklet *Responding To Climate Change*; this editorial focused on high-priority actions to be implemented in the refrigeration field with a view to mitigating climate change, and in a broader sense, to promote sustainable development. This booklet was widely distributed in Johannesburg and in New Delhi during the Conference of the Parties to the UN Framework Convention on Climate Change (COP-8) in October 2002.

A summary of this report and the editorial are available on the IIR Web site (*www.iifiir.org*), in the column "Thematic files". The whole report is now on sale and can be ordered from the IIR at: *iifiir@iifiir.org*

Source: IIR

IIR and DKV sign agreement

On 16 October during the IKK exhibition in Nuremberg, Germany, IIR and the German Association of Refrigeration signed an agreement for collaboration. The agreement enables extension and intensification of current co-operation.

Source: CCI Print, November 2002-12-04

Programme for heat pump water heaters

USA – The New York State Energy R&D Authority (NYSERDA) has announced a new programme designed to promote installation of heat pump water heaters. The programme is intended to encourage customers to replace their old electric water heaters with heat pump water heaters, which have a much higher energy efficiency compared to even new electric units. Consumers in the state of New York could save up to 60% on their monthly water-heating bill. A second objective is to develop a reservoir of contractors trained to properly install and service heat pump water heaters. The incentive structure associated with the pilot programme includes USD 300 for consumers and USD 100 for contractors for each qualified unit installed.

Source: ASHRAE eNewsletter, Sept. 2002

Ground-coupled system for US President

USA – Two of the USA's past presidents used ground heat and today, President Bush is using ground-coupled heating and cooling at his Texas ranch. The first US citizen credited for developing and using a ground-source heat pump for his house was Prof. Carl Nielsen of Ohio State University in 1948.

The President's buildings at his ranch not only have ground-coupled heating and cooling, they also have ground-coupled domestic water heating. Each of the two heat pumps has its own vertical ground loop with boreholes drilled down to a depth of 90 meters. The ground loops use pure water to transfer the heat. The systems have been in operation for about 1.5 years now and use about 25% of the electricity of a conventional US heating and cooling system.

Source: The NEWS August 26, 2002

Support for renewable energy

Japan – In an increasing number of OECD countries power generation by renewable energy sources such as wind, solar and biomass is stimulated. Earlier this year, the House of Councillors in Japan voted into law a bill to this end. The new legislation obliges power utilities to generate a certain proportion of their electricity output through renewable energy, based on quadrennial targets imposed by METI, the Ministry of Economy, Trade and Industry. The Upper House also enacted a revision to the law on energy conservation. Under the new law, large office buildings, department stores and government agencies have to compile energy saving plans.

Source: Asian Energy News, May-June 2002

Energy sector to pay environment tax

Japan – Energy companies in Japan may soon pay more taxes as METI is considering to impose new tax on petroleum, natural gas and coal based on the amount of carbon dioxide emitted during their production. This new tax measure is expected to be implemented in 2003 after the Government's Council on Economic and Fiscal Policy approves the proposal. Nuclear plants will be excluded. It is expected that the new tax measure will be able to generate funds to be used to combat global warming and promote energy conservation and the use of renewable energy sources.

Source: Asian Energy News, October 2002

Energy conservation act

India – The Indian government implemented the Energy Conservation Act to tap the vast energy saving potential of 25 GW and the equivalent in fossil fuel through voluntary measures and self-regulations. Energy consumption standards have been set for the industrial, agricultural and the building sector. Equipment identified for setting electricity consumption standards includes refrigerators, air conditioners, storage water heaters, blowers, compressors etc. The initiative includes a labelling scheme.

Source: Asian Energy News, July-August 2002

Earth energy systems promising

Ottawa – Earth energy systems displace the emission of at least 200,000 tonnes of CO_2 each year, according to an analysis to be released by the Earth Energy Society of Canada. The current installed capacity of 33,000 units reduce electricity demand by 577 million kWh for space conditioning and water heating applications, and environmental benefits are higher if SO_2 and NO_x emissions are included.

Souce: Canadian Association for Renewable Energies, December 2002
More information: www.renewables.ca

Ontario rebates for heat pumps

Toronto – Provincial legislation to provide tax incentives for new power generation facilities in Ontario, Canada also contains proposed rebates for water-source heat pumps used in eligible deep lake water cooling facilities.

Source: www.renewables.com

Boost for heat pumps in Norway

Norway – The last quarter of 2002 and the first week of 2003 saw electricity retail prices never before experienced in Norway. The peak was reached on January 6, when the cost per kWh (VAT included) levelled at Euro 0.21 (NOK 1.5). This does perhaps not sound frightening for consumers in many other countries, but it certainly does for Norwegians, who are used to a relatively stable electricity price level around Euro 0.07-0.084 (NOK 0.5-0.6) per kWh, and who heat their homes directly with electricity.

There are very likely several reasons for the unprecedented increase in electricity cost in Norway over the last months, but the foremost explanation is that prices are now set by the market. This was also the intention with the New Energy Act, introduced in 1990. As almost 100 percent of Norwegian power is generated by hydroelectric power stations, the system is obviously sensitive to the amount of precipitation. The autumn of last year was extremely dry, and the consequence is now that the water reservoirs are far lower than usual. These facts coupled with an extremely cold period between 25 December and January 6, resulted in the high prices.

A consequence of the high prices is that energy conservation measures in general and heat pumps in particular have gained in popularity. While total heat pump sales in 2001 reached a record 6,500 units (see also Market section), the figure for 2002 is likely to surpass 10,000 units by good margin. Most Norwegian consumers have not yet received their electricity bill for the last quarter of 2002. When they do, it is expected that heat pumps, as well as other energy conservation measures, will be even more in demand. Already, some suppliers and installers have had a hard time meeting the demand for heat pumps.

The prevailing market situation represents opportunities in Norway. However, threats are also looming, notably unqualified companies entering the market for a quick profit. The Norwegian Certification Scheme should be able to prevent these problems.

Source: Norwegian National Team, January 2003

Technology & applications

Flowers conditioned with a 800 kW heat pump

Netherlands – For many years, around two-thirds of the global floriculture trade has taken place via the Netherlands. In 2001 Dutch exporters sent flowers and plants with a total value of more than four billion Euro all over the world. The company Hilverda De Boer is one of the five largest flower exporters. Two hundred fifty employees, including 25 specialised purchasers, ensure that customers of Hilverda De Boer are presented with a wide range of fresh products each day. Customers are located in Europe, North America, Asia and the Middle East.
For its new building, Hilverda De Boer ordered an 800 kW heat pump, to be supplied by GEA Grenco. At night, in the morning and in the winter, the heat pump will heat the production and office rooms. In the afternoon, the heat pump operates as a refrigeration system. During summer, it can be used as an air conditioning system. To minimise environmental impact, ammonia is used as refrigerant, of which the total charge is less than 200 kg. The heat pump system will start operation in spring 2003.

Source: w.nicolai@grenco.nl

Innovative air conditioner

Israel – An Israeli company is developing a so-called Green Air Conditioner (GAC), based on a low-pressure water vapour compressor and hygroscopic brine heat exchangers. Advantages over conventional air conditioners include the high efficiency (more than 50% energy savings at 25 °C and 50% relative humidity), operation in extreme temperatures (cooling and heating) and cost-effectiveness. The GAC uses a high-volume/low-pressure water vapour compressor. The hygroscopic brine direct contact heat exchangers are required because otherwise condenser pressure would be too high for air conditioning in summer. With this new concept, the brine is used for vapour condensation to minimise the pressure gradients on the compressor and reduce energy consumption. The expected cooling COP in summer varies between 5.5 and 7.5. Major applications are in medium to large air conditioning. It is claimed that the system performs well in extreme climatic conditions, such as cooling at high temperatures and humidities and heating at temperatures below 0 °C

The company is looking for a strategic partner and financial resources to complete development and start marketing.

Source: Cordis focus, August 2002
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Markets

Heat Pump Association in France

France – The heat pump market in France is developing rapidly. Only a few years ago, French manufacturers of heat pumps were hard to find. Today, activities have increased tremendously, not in the least as a result of Electricite de France's heat pump programme. Earlier this year, the French Heat Pump Association AFPAC (Association Française pour les Pompes A Chaleur) was founded. AFPAC's main objectives are to promote and develop heat pump technology, to co-ordinate the exchange of information between members, facilitate relations and monitor certification and standards work. Specific commissions are working in the following fields:

- Floor radiant heating and cooling;
- Combined space and water heating;
- Design and installation of ground coils;
- Regulations and heat pumps;
- Training and quality;
- Commercial/institutional sector.

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Norwegian heat pump market flourishes

Norway - Norwegian heat pump sales reached almost 6,400 units in 2001. Of these, about 6,000, or 94%, were installed in residential units.

More than 90% of the units have an installed heating capacity of less than 10 kW, and 1% have an installed capacity of more than 100 kW. Of these 6,400 units, 73% are small air-to-air systems and 17% are water-to-water, with sizes ranging from 5 kW to several MW. The remaining 10% are exhaust air and air-to-water units.

The reason for the lead position of small air-to-air split units is that electricity (from hydropower) is the main source of power for space heating in residential units and in the commercial/institutional building sector. In the residential sector almost 70% of space heating is powered by direct electricity and in the tertiary sector more than 65%. As a result, a limited number of houses have hydronic heat distribution systems. This limits the possibilities for the extensive use of water-to-water heat pump systems. However, it should be mentioned that in the past year 30% of new residential units have been equipped with hydronic central heating systems, mostly radiant floor heating.

At the end of 2001, a total of 37,000 heat pumps were installed in Norway. The residential sector took up 90-95%. A growing number of heat pump based small district heating systems are being used in various parts of Norway. In 2001, a decision was made to build 23 such plants. These plants are realised with subsidies from the energy authorities.

Source: European Heat Pump News, Dec. 2002

Spanish heat pump market observations

Spain – The Spanish heat pump market is evolving in a positive way, both in terms of sales numbers and value. Compared to 1990, when 100,000 heat pumps were sold, the market really took off in the second half of the 1990s, with more than 400,000 heat pump systems sold in 1999 and almost 500,000 in 2001. More than 400,000 of the systems sold in 2001 were reversible ductless units. More than 60% of the total air conditioning market sales (volume) in 2001 were heat pumps. They represented more than 65% of the total market in terms of sales value.

Source: IEA Heat Pump Centre

Joys of air conditioning

India – The Indian air conditioning market is experiencing rapid growth in 2002 and companies expect sales to get even better. The air conditioning boom in this country is driven by rising disposable incomes among the 40-70 million members of the Indian middle class, lower air conditioner prices and a low market saturation. Temperatures regularly reach 45 °C.

Source: The HVAC&R Industry, 7 November, 2002

Swiss market upswing

Switzerland – Switzerland claims position number two in the European heat pump market, after Sweden. With 40% of new single-family homes equipped with a heat pump system, the market continues to grow.

Fifty percent of the heat pump systems extract heat from the air, 39% from the ground, using deep boreholes (300 metre), and 11% from ground and surface water.

The goal of the Swiss is to ensure that in ten years more than 50% of new homes and 10% of existing homes use a heat pump. Training of installers and designers is a key element of the Swiss strategy.

Source: Vision nr.3/2002, September
www.waermepumpe.ch

Russian market awakes

Russia – The air conditioning market in Russia has returned to a steady growth pattern since 1997. Most global brands are represented in this market, where room air conditioners are the main stream. Heat pump units constitute 90% of total sales volume; cooling-only models may be in more demand in southern parts of Russia. Recent market size figures are not available.

Source: JARN, July 25, 2002

Irish heat pump market

Ireland – Compared to a number of other countries, Ireland is a relative newcomer to the European heat pump market. With just over 1,000 ground or water-source heat pumps installed, Ireland has been slow to embrace the proven technology of heat pumps.

That is about to change. The Irish heat pump market benefits from excellent conditions, perfect for the development of a heat pump market and industry. The climate is mild and Ireland has good heat sources to tap into (for example, the average temperatures in Dublin during the heating season are: ground at 1 m depth 6.3ºC, outdoor air 6.6ºC). Heating requirements and heat loads are also quite low and can be met by smaller heat pumps. Electricity is relatively cheap (night rate Euro 0.04/kWh; day rate Euro 0.095/kWh).

Ireland has a growing population of almost 4 million. The housing market continues to boom. For the next five years 50,000 new houses will be built every year. This drives rapid expansion of the heat pump market in Ireland.

This positive framework has already resulted in a rapid increase in sales, with an annual growth superior to 130% during the last three years. The Irish heat pump industry is also expanding, with the number of companies involved in the installation of heat pumps tripling during the last three years.

The Renewable Energy Information Office, a service of the Sustainable Energy Authority of Ireland, has estimated that a total of 80,000 units could be installed by 2012, providing the right measures are put into place. Sustainable Energy Ireland (SEI) is currently working on a four-year action plan for the development of heat pumps, which will include a training and certification programme, a marketing and promotion campaign, a quality charter scheme for the industry and an installation labelling project. Funding is also available via SEI's Research Development and Demonstration Programme for Renewable Energy. A subsidy of up to 25% for medium to large-scale demonstration projects should boost the use of heat pumps in commercial/ institutional buildings as well as in the industrial sector.

Source: European Heat Pump News, Dec. 2002
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New Japanese heat pump models

Japan – The new Japanese room air conditioner models are on the market and manufacturers are making large efforts in promoting their newest ultra-energy efficient products. As the New Energy Saving Law will be implemented in refrigeration year 2004, it will soon become difficult to sell low-end models with a low COP. This means that manufacturers must attain the weighted-average high efficiency rates. A summary of new model features and trends:

- ventilation function for improved indoor air quality;
- ultrasonic air purifying using dust filters with 90% efficiency;
- UV degerming cleaning using bacteriolytic enzyme filters;
- aerotherapy using ultrasonic technology;
- temperature/humidity control adapted to biorhythm during sleep;
- quick floor heating, etc.

The new heat pump models are so efficient that the heating costs have become lower than the heating costs of a kerosene heater in Japan.

Source: JARN, Oct. 25, 2002

Working fluids

CO_2 technology for cars

Japan – DENSO International presented CO_2 heat pump technology on its FCHV-4 fuel cell hybrid car at the Earth Technologies Forum in Washington DC. Although the company has successfully applied CO_2 in heat pump water heaters, there are still several remaining challenges to their development and application in cars, including high cost, additional weight, reliability and maintenance.

Source: OzonAction Newsletter, August 2002

Germany/Japan/Denmark –Much of this research concerning CO_2 technology for cars focuses on CO_2 compressors. Researchers in Germany are studying reciprocal and swash-plate compressors. Prototypes have been tested showing good efficiencies.

In Japan the focus is on hermetic swing compressors that can maintain high efficiency and reliability under all conditions. Leakage was discovered to have a major influence on capacity, and the volumetric efficiency was found to be rather low. Optimized designs for minimum leakage, based on the designs used in heat pump water heaters, are now being considered.

Danfoss in Denmark is testing low-capacity hermetic compressors. Tests ran for more than 1,300 hours with individual compressors without detecting critical wear.

Source: Ozone Layer Protection, Sept-Oct 2002

New HFC refrigerant

USA – The HFC refrigerant RS-24 has been approved by the US Environmental Protection Agency EPA (under the Significant New Alternatives Program) for retrofitting systems originally designed for use with R-12. The refrigerant works with mineral oil. Its makeup includes a small amount of a specially formulated hydrocarbon component that provides enhanced oil return capabilities. The refrigerant is still awaiting ASHRAE designation.

Source: The NEWS, October 14, 2002

CO_2 Hot Water Heat Pump "Eco-Cute" Promotional Programme started in Japan

Japan – As of September 20, 2002, a new programme for the promotion of the use of residential hot water heat pumps has been put in place in Japan with robust government support. The programme aims at accelerating the use of energy efficient hot water heat pumps using CO_2 as refrigerant. This new development in Japan is nicknamed "Eco-Cute" (or Kyuto), and refers to an environmentally friendly tap water heater ("Kyuto" means hot water supply in Japanese). The motivation for this new programme is that this new heat pump technology is highly rated as one of the key technologies that are effective in reducing fossil fuel consumption. It is therefore expected to help realize compliance with the Kyoto Protocol targets for reducing greenhouse gas emission by 2010.

In addition to the high seasonal COP of more than 3.0 for hot water production, another feature of the "Eco-Cute" heat pump is that – by storing high temperature water of up to 90 °C at night – it mainly uses cheap off-peak electricity. This makes it a cost-attractive option for end-users. About 50% of the incremental equipment cost compared with conventional water heaters, mostly gas heaters, will also be paid to end-users as a subsidy. The plan is to realise 30,000 heat pump units in fiscal year 2002.

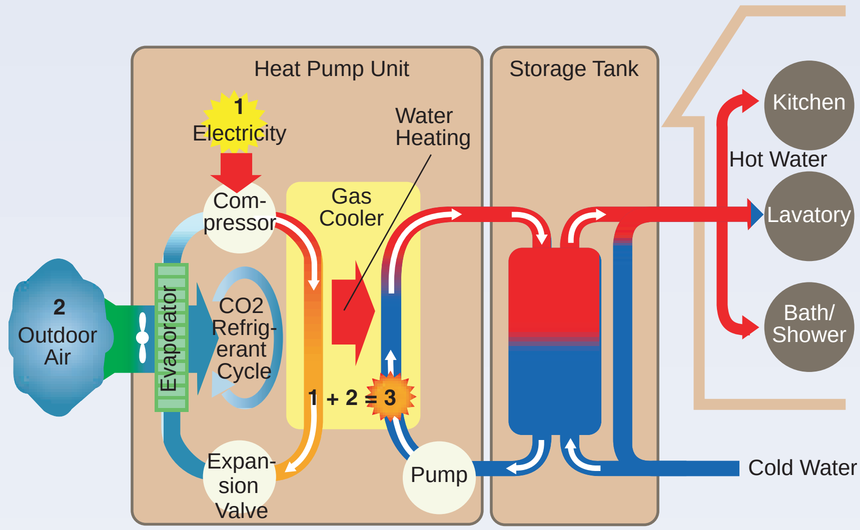

Figure 2: Schematic diagram of "Eco-Cute"

A total budget of about USD 44 million (YEN 5.3 billion) has been allocated to fund the promotional programme for fiscal year 2002 - 2003. The Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ), which is the key organisation responsible for carrying out the "Eco-Cute" promotional programme under METI (Ministry of Economy, Trade and Industry) and NEDO (New Energy and Industrial Technology Development Organization), has already started promotional activities.

A schematic diagram of the heat pump system is presented in **Figure 2** .

Source: Heat Pump Technology & Thermal Storage Technology Center of Japan

Germany discusses HFC ban

Germany – The German refrigeration and air conditioning industry faces another major change in the use of refrigerants. The Federal Ministry of the Environment has published a position paper on the reduction in use of fluorinated gases, and has invited industry, the states and other market players to respond on short notice (31 October 2002). Existing installations using HFCs would only be allowed for a limited period still to be determined. A ban of HFCs for application in refrigeration, air conditioning and heat pump equipment could be the result.

The availability of alternative refrigerants and technologies for the refrigeration and space conditioning sectors is the main argument being used by the Ministry.

Natural working fluids could benefit from this development. The German Eurammon group, an initiative of companies, institutions and individuals, has promoted the use of natural working fluids in Germany.

The total stock of refrigeration systems is estimated at 100 million units. Two-thirds of the refrigeration capacity is installed for industrial applications at only 26,000 plants. Natural working fluids are traditionally used in this sector. Natural working fluids have also gained wide use in domestic refrigerators, and German car manufacturers are investigating the use of carbon dioxide in car air conditioning.

Source: CCI Print November, 2002

HFC ban

Denmark/Luxembourg/Sweden – Denmark has already decided to phase out HFC refrigerants. This means that the entire refrigeration stock will have to be converted (to natural working fluids) by 2006. Some think that this could put Denmark in a leading position worldwide in the area of adapting current compressor designs.

In Sweden, an upper limit of 200 kg of HFCs has now been prescribed for any given installation. In Luxembourg all large installations must now be based on ammonia.

Source: JARN, Nov. 25, 2002

Collaboration sought

In recent years, prototype CO_2 heat pumps have been developed, built and analysed under the so-called COHEPS Project (EU JOULE Programme). They included residential heat pump water heaters, integrated heat pumps for commercial buildings, residential retrofit heat pumps and dehumidification heat pumps. The project partners have developed design guidelines for these applications. They concluded that the risks of using CO_2 in heat pumps are low and acceptable as long as the charge is limited so as to ensure that the concentration in rooms after release is less than 5%.

Collaborative support is now being sought for further research and development, information exchange and training.

Source: Cordis focus, Sept. 2002
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CO_2 studies for home heating and cooling

Researchers at Modine Manufacturing Co. in the USA are making progress with CO_2 in automotive and portable heating and cooling systems. They also are interested in using CO_2 in heat pumps for water heaters and buildings. CO_2 could replace the conventional refrigerant R-134a.

Growing interest in the USA is being triggered by developments elsewhere in Europe and Japan. Toyota is expected to introduce a CO_2 heating and cooling system on a fuel cell hybrid vehicle as early as next year. German carmakers are geared up to introduce CO_2 systems in the 2006 model year. However, there is still some doubt as to whether CO_2 heat pumps will become a success in the market for residential heating and cooling. Europe and Asia will lead the way in commercialization of CO_2 systems, in part because energy costs are high in these regions.

Source: ASHRAE e-Newsletter, December 5, 2002

International ozone network anniversary

Sweden – The pioneering network of government officers responsible for phasing out ozone depleting substances, initiated with the proactive support of the Swedish government, has celebrated its 10th anniversary in Stockholm, Sweden on 7-11 October. This network functions as a model for more than 110 developing countries around the world, who formed a network of officers in charge of implementing the Montreal Protocol under the UNEP in their countries. Regular meetings and interactions are organised to design and implement phase-out policies, strategies and programmes that are appropriate to the conditions in the various countries. Sharing information, experiences and approaches are key factors in their success. At the celebration in Stockholm, a new publication was launched: “Networking counts – Building bridges for a better environment”.

Source: UNEP TIE
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IEA Heat Pump Programme

IEA starts new heat pump Annex

At the 2002 fall meeting, the Executive Committee of the IEA Heat Pump Programme agreed to start a new Annex proposed and headed by Switzerland. The topic of the Annex is: Test procedures and seasonal performance calculations for residential heat pumps with combined space and water heating.

Existing test procedures are restricted to the separate testing of space heating (or cooling) and the heating of tap water. The Annex will investigate the testing of the most common integrated heat pump system designs with heating of tap water by:

- de-superheating;
- sub-cooling of condensed refrigerant;
- cascade hot water heat pump;
- tapping heat from the supply line of the heating system.

The aim of the testing is to generate the data needed for calculating the overall Seasonal Performance Factor of these heat pump systems. The system to be investigated includes the heat pump, the hot water storage (or a once-through water heater) and a supplemental backup heating (optional).

The Annex will produce a set of comprehensive test procedures as a recommendation for national and international standards organisations. In addition, easy-to-use calculation methods will be developed for the design of the systems.

Participants in the Annex are Switzerland, USA, Austria, France, Norway and Canada. Potential other participants are Sweden and Japan, who showed strong interest. The Annex, which has been given the number 28, will begin in January 2003 and is scheduled for completion in May 2005.

Source: IEA Heat Pump Centre

Single-room heat pumps study completed

The application of air-to-air single-room heat pumps in cold climates is often characterised by low performance and reduced heating capacity of the heat pump. Efficient defrosting is required for air-source heat pump systems that operate in these cold climates, as defrosting reduces the overall performance. In recent years, the industry has claimed improvements of single-room heat pumps for cold climates. This Heat Pump Centre study focussed on two questions:

- what are the real improvements and their consequences in practice?
- what other improvements of single-room heat pump have been achieved?

The aim of the study was to provide an overview of small, energy efficient air-to-air and other single-room heat pump units for cold climates that are available, and assess the impact of recent improvements. Specific aspects studied included seasonal performance and partial load performance. The study also covered design and installation aspects and presented a brief market projection. The focus of the study is on single-room reversible heat pumps for space heating (and cooling) in residential and small commercial applications, and on opportunities and problems with these heat pumps in cold climates. Ground- and water source units are also covered.

The study concludes that the COP of modern split-type air-to-air single-room heat pump units that use R-410A refrigerant can be higher than 5 at an outdoor temperature of 7°C. Another important finding is that the sound level of indoor coils of air-to-air single-room heat pump units needs to be reduced.

The report provides useful information for designers, specifiers, installers and purchasers of single-room heat pump products. It is available from the Heat Pump Centre (order HPC-AR14 via the website).

Source: IEA Heat Pump Centre

IEA Information Centres brochure

The IEA has opened a web page with brochures on the IEA Information Centres, including the Heat Pump Centre. Brochure can be downloaded from http://www.iea.org/tech/infocentres, or visit www.heatpumpcentre/links (Related IEA programmes/implementing agreements).

Source: IEA Heat Pump Centre

Ongoing Annexes

Red text indicates Operating Agent.

Annex	No.	Participants
Annex 25 Year-round Residential Space Conditioning and Comfort Control Using Heat Pumps	25	FR, NL, UK SE, US
Annex 26 Advanced Supermarket Refrigeration/Heat Recovery Systems	26	CA, DK, SE, UK, US, UK
Annex 27 Selected Issues on CO_2 as a Working Fluid in Compression Systems	27	CH, JP, NO, SE, UK, US
Annex 28 Test Procedure and Seasonal Performance Calculation for Residential Heat Pumps with Combined Space Heating and Domestic Water Heating	28	AT, CA, CH, FR, JP, NO SE, US, UK

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 countries are member of the IEA Heat Pump Centre (HPC). The Netherlands is Operating Agent of the HPC.

The Building Co-ordination Group

An effort to improve co-ordination and achieve synergies between the building related programmes of the International Energy Agency.

Several of the Implementing Agreements (IA), or programmes, under the IEA umbrella deal with building related issues and activities. Traditionally, there has been neither much communication nor co-ordination between these programmes. The idea behind the Buildings Coordination Group (BCG) initiative is to foster co-ordination between the building related Implementing Agreements (BRIAs), in order to achieve synergy effects in terms of joint activities, organisational learning and a more efficient use of resources.

The BCG is made up of representatives from the BRIAs, the associate chair of the IEA End-Use Working Party and a representative from the IEA Secretariat. This reflects the desire to coordinate activities horizontally as well as vertically within the IEA organization. Seven participating implementing agreements are represented in the BCG:

- energy conservation in buildings and community systems
- demand-side management
- district heating and cooling;
- energy storage
- heat pumping technologies
- photo-voltaic power systems
- solar heating and cooling

A representative from energy efficient lighting, an implementing agreement under preparation, also participated in the meetings.

The primary stakeholders for the BCG initiative are the representatives from the different Executive Committees and market representatives from the countries involved in the IAs as well as the entire IEA organization.

It should be emphasized that participation in the BCG is strictly voluntary and that it will operate in an informal and non-bureaucratic manner. The BCG will meet once or twice a year, preferably back-to-back in conjunction with other major events. So far, two BCG meetings have been organized, the first in Rome, Italy, in January 2002, and the second in Oslo, Norway, in October 2002. Both meetings were of an exploratory nature; an important activity was the development of a mission statement.

After being in operation for nine months, it is still early to say exactly what the specific activities and outcome of the BCG initiative will be. It seems clear, however, that the following general activity areas will draw much attention:

- Information exchange and dissemination (what goes on in the different implementing agreements?)
- Organisational development and learning (how to conduct business within the implementing agreements)
- Issues of technology development (coordinated efforts)
- Development and expansion of the membership base (how to attract new member countries to the IAs)

More specifically, it was decided that in 2002 the BCG would launch a web portal with links to all the BCG IAs and related IEA information centres, such as the Heat Pump Centre. It has also been suggested that the BCG should become the frame for the Future Buildings Forum.

The BCG initiative was enthusiastically initiated and organised by the Swede Mr. Hans Nilsson. Since Mr. Nilsson has now left the IEA, the new Chair for the BCG will be Mr. Egil Öfverholm, also a Swede, who is the new vice-Chairman for the End-Use Working Party.

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Heat Pump Programme short course at IIR Congress

The IEA Heat Pump Programme is organising a short course at the IIR Congress in Washington in August 2003. The topic of the course is: “Advances in supermarket refrigeration - improved refrigeration/heat recovery systems, analytic methods, refrigerant management, and secondary fluid in international context”.

The short course has several objectives:

- Sharing results from IEA Annex 26 “Advanced supermarket refrigeration/ heat recovery systems”
- Stimulating application of modern heat recovery in supermarket refrigeration systems with minimal environmental impact through the use of design aids
- Sharing international experiences and results from refrigerant conservation and disposal programs

Proposed speakers are to come from research institutions, universities, manufacturing industry and the Heat Pump Centre.

Source: IEA Heat Pump Centre

Workshop on heat pumps in Madrid

On 23 October 2002, the Spanish National Team (ENEBC) organised an international workshop with the title: “The Heat Pump – Present and Future”. The programme included presentations and discussions on the following topics:

- Domotic controlled buildings
- Life cycle and environmental cost analysis of a heat pump
- Spanish heat pump market
- Spanish market development
- Heat pumps and renewable energy
- Propane heat pump
- National heat pump research
- IEA Heat Pump Programme
- Annexes of the IEA Heat Pump Programme

The main conclusions were that the Spanish heat pump market is developing well and that more active involvement in international R&D programmes should be considered. Spanish market players and researchers were encouraged by the Ministry of Science and Technology and the Ministry of Economy to formulate new collaborative research activities.

Source: IEA Heat Pump Centre

HPC up for tendering

In the period 1 January – 15 March 2003, the IEA Heat Pump Centre (HPC) is up for tendering. Proposals for operating the HPC must be sent to the Executive Committee chairman Dr Rune Aarlien at SINTEF Energy Research in Trondheim, Norway (address, see backcover). For information about tendering, ask your country contact person (see backcover).

25 Years with IEAs Heat Pump Programme

Rune Aarlien, Norway

The IEA *Implementing Agreement for a Programme of Research and Development on Advanced Heat Pumps* was established in July 1978. With 14 member countries, the 25 year-old is currently one of 42 active Implementing Agreements under the IEA. This article looks at some of the achievements and developments through the years.

The Programme

The vision is that the Heat Pump Programme (HPP) should be the foremost worldwide source of independent information and 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 should be highly valued by stakeholders.
The Programme serves the needs of policy makers, national and international energy and environmental agencies, utilities, manufacturers, designers, and 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, and air conditioning technologies.

A link between R&D and the market

Since its inception, the primary purpose of the HPP has been to foster continued and increased deployment of the heat pump technology to achieve improved energy efficiency and environmental benefits. Consequently, the Programme is established and designed to be a link between the R&D community and the market, a body that should facilitate a higher degree of market penetration for heat pumps. The basic idea behind the HPP is that different countries face many common challenges, and that these challenges are most effectively solved through international collaboration and pooling of resources.

Expanded focus

When the HPP was established 25 years ago, the focus on the Programme and its activities were explicitly on heat pumps as such. However, heat pumps face many of the same challenges as the technologies of refrigeration and air conditioning. Working fluids, heat exchangers, energy efficiency, operation and controls are but a few of the common issues shared between the technologies. Furthermore, all three technologies are often found intertwined in the same energy system. It was, therefore, natural to expand the focus of the Programme to also include the disciplines of refrigeration and air conditioning. This was done in the mid-1990s and the Programme now changed its name to the *Implementing Agreement on Heat Pumping Technologies*. Annex 26 (see below) was the first project to investigate combined systems including all technologies.

International coordination

During later years, the HPP has come to emphasize cooperation and coordination with related programmes and entities. During the Executive Committee (ExCo) meeting held in Oxford, UK, 2000 a framework agreement for cooperation between the IIR and the HPP was signed. This formal agreement is intended to enhance the existing collaboration in a variety of areas, such as representation, congresses and conferences, scientific cooperation, publications, and the Internet. As a direct result of the agreement delegates of the HPP ExCo have been appointed to serve as liaison for IIR Commissions E1/E2 (Air Conditioning, Heat Pumps and Energy Recovery) and B1/B2 (Thermodynamics, Equipment and Systems). IIR/HPP contacts have also been assigned for ongoing Annexes 25, 26, and 27, and an important result is that the IIR will carry out peer reviews of Programme reports, as already is the situation with HPC reports.

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has co-sponsored HPP heat pump conferences. ASHRAE is an international organization that enables members to share a wide variety of information and knowledge regarding heat pumping technologies and their applications. The HPC, through its Director, has also been actively involved in ASHRAE Technical Committees on heat pumps and the International Committee.

The HPP has developed a partnership with the European Heat Pump Association (EHPA), which is an interest group with members from heat pump industry associations, installers, promotion organisations, organisations (BRE and BSRIA) from the UK, the French energy and environment agency ADEME, and the French utility EdF. The EHPA aims to stimulate the proper use of heat pumps and the heat pump market in Europe.

The HPP also seeks to stay abreast with developments and work undertaken in related IEA Implementing Agreements. The ExCo is therefore involved in the so-called Building Coordination Group (BCG), which seeks to coordinate efforts and interests among the building-related implementing agreements.

Achievements

Even though it can be difficult to measure the exact and direct effect of international cooperation, one way to measure the achievements and success of the HPP is by the number of accomplished activities.

Annexes

One of the most commonly used vehicles for collaboration under the Programme is an *Annex*, or collaborative project, typically lasting over a three-year period. The following is a short description of all Annexes, completed and on-going under the Implementing Agreement.

Annex 1: Common Study of Advanced Heat Pumps

The objectives of this Annex were to collect and evaluate data obtained by international experience with advanced heat pump systems, derive relevant proposals for expected and desired developments in this field, and recommend future research and development programmes. Sorption heat pumps as well as compression heat pumps intended for space heating application in the domestic sector were considered. The scope of the work included the following elements: technology survey, market survey and identification of new R&D projects.

Annex 2: Vertical Earth Heat Pump Systems

The subject investigated in this Annex was the heat pump extracting heat from the soil by means of a vertical heat exchanger. The soil is recharged by means of heat from solar collectors, ambient air collectors, or by means of waste heat from air conditioning systems. Electrically driven heat pumps, as well as combustion engine-driven heat pumps were considered in the study. The objectives of the Annex were to collect performance and cost data regarding these systems in order to assess the conceivable market potential, outline a programme for hardware developments and experimental plants, and develop specifications for components of the storage and heat recharging systems.

Annex 3: Heat Pump Systems Applied in Industry

This third Annex concentrated on industrial heat pumps (compression as well as absorption heat pumps, and open cycle as well as closed cycle heat pumps). Ten countries participated. Reports concerning existing industrial heat pumps were prepared by each participating country. These reports were incorporated in a final report, which in addition to these reports contained the following information: state-of-the-art description of all the types of industrial heat pumps in current use, analysis of the performance of industrial heat pumps, investigation of cost and competitiveness of the industrial heat pumps, and research and development recommendations.

Annex 4: IEA Heat Pump Centre

Established in 1982, this was the first Heat Pump Centre Annex. The objective at that time was to promote commercialisation of advanced heat pumps, which, from a technical, economical, and environmental point of view, were able to compete with conventional heating systems and other energy conservation equipment. In particular, the HPC was to foster international cooperation on all aspects related to research, development, and demonstration of advanced heat pump systems and components. The Fachinformationszentrum Energie, Physic, Matematik GmbH, Karlsruhe, Germany, was the operating agent and 11 member countries participated. This HPC was much similar to the current one and performed many of the same tasks.

Annex 5: Integration of Large Heat Pumps into District Heating and Large Housing Blocks

The main objective of this Task was to assess the technical and economical performance of large heat pumps in district heating and large housing block applications. In particular, heat pumps with a thermal output between 1 and 10 MW and which made use of a compressor or absorption cycle were considered. Electric motors or internal combustion engines were assumed to drive the compressors. The work programme consisted of the following elements: case studies, assessment of the market potential, and identification of new research and development projects.

Annex 6: Study of Working Fluid Mixtures and High Temperature Working Fluids for Compressor Driven Systems

The objective of this Annex was to gather information on heat pump systems utilizing new working fluids or mixtures and to evaluate their potential compared to other heat pump systems. Closed cycle systems were investigated with working fluids of either pure fluids capable of condensing at temperatures above 100 °C or non-azeotropic mixtures. The work was carried out in two steps: a state-of-the-art report and a report on a hardware project involving a heat pump design or experimental activity related to state or transport properties of working fluids.

Annex 7: New Development of the Evaporator Part of HP Systems

The objective of Annex 7 was to collect and evaluate existing theoretical and experimental information for the evaporator part of heat pump systems. Types of evaporators included were equipment for both liquid and gaseous heat sources used in direct as well as indirect systems. The final report has the following main chapters: heat pump evaporator types, heat transfer and pressure drop (refrigerant side and heat source side), and optimisation of heat pump evaporators. In addition, R&D trends in the participating countries were investigated.

Annex 8: Advanced in-ground Heat Exchanger Technology for HP Systems

Annex 8 was proposed and established as a natural continuation of Annex 2, which dealt with system design and performance of ground-source heat pumps employing vertical heat exchangers. The principle scope of Annex 8 was a combination of experiments and mathematical modeling. The work focused in particular on: developing a better understanding of heat transfer processes between the circulating fluid and the surrounding ground using various operational strategies, and developing better and more efficient ground-source heat exchanging systems. Field experiments and monitoring projects were carried out.

Annex 9: High Temperature Industrial Heat Pumps
This Annex was established on the background that there seemed to be a large potential for energy conservation in industry, and that the possibilities looked very bright for heat pump systems operating at temperatures between 100 and 300 °C. The objective of this Annex was to provide a detailed state-of-the-art analysis on high temperature heat pumps and the potential for energy conservation through application of these heat pumps in industry at temperatures above 100 °C. The work programme included the production of country reports on the subject and an analysis of the energetic and economic performance of the heat pumps. All types of heat pumps, including mechanical vapor recompression systems and heat transformers, were investigated.

Annex 10: Technical and Market Analysis of Advanced Heat Pumps
Annex 10 concentrated on defining the general market, economic, institutional, and technical status of heat pumps. The objective of this work was to provide a better foundation for carrying out the Executive Committees work, and in this sense, the Annex continued the work from Annex 1. One of the desired outputs was the creation of new Annexes. Other results were: an analysis of the economic and non-economic factors explaining the fluctuations in the European heat pump market, and an analysis of the government roles in R.D&D programmes.

Annex 11: Stirling Engine Technology for Application in Buildings
The objective of this Annex was to provide a strategic assessment of the technology of Stirling engine-driven heat pumps than could be obtained through current national and individual programmes. Also, topics for further research that could improve the technology were investigated. The Annex was operated as a series of three workshops, which focused on: key technology issues of common interest, issues pertaining to system reliability and performance, and economic, cost and commercialisation issues.

Annex 12: Modeling Techniques for Simulation and Design of Compression Heat Pumps
Annex 12 had two primary objectives, namely: to assess the adequacy of existing techniques for modeling seasonal performance of compression heat pumps, and to define the needs for additional fundamental information and research within the field. Participants contributed computer programs, experimental field measurements of weather conditions and building energy use, and papers for evaluating the adequacy of current modeling techniques. The Annex revealed the lack of models that could simulate variable-speed heat pumps, and found little information on part load and dynamic data on component performance for use in computer models.

Annex 13: State and Transport Properties of High Temperature Working Fluids and Non-Azeotropic Mixtures
The objective of this Annex, which was a continuation of Annex 6, was to increase the knowledge of state and transport properties of high temperature working fluids and non-azeotropic mixtures. The work was divided in the following three parts: identification of important data, assessment of the data, and measurement of data. In light of the CFC problem, the work of the Annex was extended into new pure fluids and mixtures.

Annex 14: Working Fluids and Transport Phenomena in Advanced Absorption Heat Pumps
This Annex focused on the following three main issues: (1) the collection and evaluation of data on working fluids and transport phenomena in components for advanced absorption heat pump systems, (2) appropriate proposals for future developments in this field, and (3) recommendations for future research and development programmes. The study was primarily occupied with systems using air as the heat source, but also systems based on water were investigated. Working fluids investigated included: water-lithium/bromide, ammonia, halogenated hydrocarbons, and alcohol.

Annex 15: Heat Pump Systems with Direct Expansion Ground Coils
The aims included assessing problems of oil return from ground coil back to the compressor, determining and solving the problem of refrigerant flow in vapor and liquid stages, and developing a new high performance direct expansion (DX) ground-source heat pump. Four different ground heat exchange (GHE) and DX systems were developed and tested. Products resulting from the work of this Annex included: computer programs, general design guidelines and new technology (DX copper spiral GHEs), which have since been successfully demonstrated in various field installations.

Annex 16: IEA Heat Pump Centre
The objective of the Centre is to promote the use of heat pumps and foster international cooperation on all aspects relating to research, development and demonstration of heat pumping and related technologies. Collection, analysis and dissemination of information constitute the bulk of its work. Products include reports, proceedings, brochures, a quarterly newsletter and the website. Its message reaches an international audience through co-sponsorship of workshops and meetings, and with the organisation of "National Teams" of heat pump experts in participating countries.

Annex 17: Experiences with New Refrigerants in Evaporators
The heat transfer and pressure drop behavior in the evaporator of heat pump installations was studied in this effort to increase knowledge of the performance of new refrigerants. This Annex enabled the revision of existing correlations, and suggested new correlations.

Annex 18: Thermophysical Properties of Environmentally Acceptable Refrigerants
Annex 18, which began in 1990, was initially a two-phase project, but in 1996, upon approval by the ExCo, was extended to a three-phase project. Following on from the successful Phase 1 equation-of-state comparisons, which led to the declaration of international standards for the properties of R-134a and R-123 – a sanction endorsed by the IIR – the Annex completed a similar process for R-32 and R-125. In an analogous task for mixtures, the Annex compared six models (representing three distinct approaches) to an extensive database of experimental mixture property data. Phase 3 concentrated on HFC mixtures, ammonia, and hydrocarbons. Annex 18 continued to cooperate with Annex 22 in the area of thermophysical properties of natural refrigerants.

Annex 20: Working Fluid Safety
Investigating the safety of refrigerating machines and heat pumps involved looking at accident statistics, safety norms and regulations, and safety evaluations (hazard identification, effects, evaluation techniques, and accident and risk evaluation). Results include the development of calculation techniques, which can be used to assess, in a quantitative way, the risks involved in the use of conventional and alternative working fluids.

Annex 21: Global Environmental Benefits of Industrial Heat Pumps
Industrial heat pumps (IHPs) offer the potential to conserve energy, improve plant productivity and process capacity, but can also reduce air and water pollution by decreasing the consumption of fuels. In this study of IHP, applications and evaluation of market development and environmental impact were investigated. Products from the Annex included a detailed IHP manual, guidelines for IHP applications, an expert computer program to assist in IHP implementation, and a comprehensive report and brochure on the global environmental benefits of IHPs.

Annex 22: Compression Systems with Natural Working Fluids
The main result from this Annex is a set of guidelines for effective and efficient design and safe operation of heat pumping systems operation using natural working fluids.
Annex 22 focused mainly on residential and commercial heat pumping systems using the natural working fluids ammonia, hydrocarbons, carbon dioxide, water, and air. The main objective of the Annex was to evaluate and promote the use of natural working fluids; identify technical key problems/challenges, carry out research and development projects, gather relevant existing information and make it readily available by means of status reports, an Internet homepage, and acknowledged guidelines. Core work has been information dissemination, organisation of workshops, R&D projects, and preparation of reports and proceedings.

Annex 23: Heat Pump Systems for Single-Room Applications
This Annex was completed in 1998 after two years of operation. The objective was to develop and promote heat pumps for single-room applications, and to benefit heat pump users, power utilities and the environment. Each participating country collected market information on a number of dwellings using single-room heating devices, such as hydronic radiators, direct electric resistance room heaters, electric storage heaters, room-sized heat pumps, etc. A main objective of the Annex was to identify systems that retain heat pump benefits and avoid the peak-load problem for conventional room heating and cooling systems.

Annex 24: Ab-Sorption Machines for Heating and Cooling in Future Energy Systems
This Annex aimed to further increase and promote the use of thermally driven systems, i.e. absorption systems, adsorption systems, and compression/absorption systems, for heating and cooling in a future efficient and environmentally acceptable energy system. The Annex work focused on gaining a better understanding of the market opportunities for thermally driven systems in a global perspective, and to examine how different factors, such as economic, political, environmental, and knowledge, will affect the promotion and application of such systems in residential, commercial, and industrial sectors.

Annex 25: Year-round Residential Space Conditioning and Comfort Control Using Heat Pumps
The objectives of Annex 25 were to define and show the technical feasibility of new packaged systems for year-round residential space conditioning using heat pumps.These systems target mainly new residences and use either water or air as energy distribution medium. Work carried out covers low initial and operating costs, comfort provided, suitability to customer demands, design/installation requirements, performances, integration in buildings and aesthetics.

Annex 26: Advanced Supermarket Refrigeration/Heat Recovery Systems
Annex 26 intended to demonstrate and document the benefits of advanced system design for food refrigeration and space heating and cooling for retail supermarkets. A specific goal was to identify advanced system design options to reduce the total equivalent warming impact (TEWI) of supermarkets. A spreadsheet-based analysis model of supermarket refrigeration systems was developed. This model is now being validated against field data from the Annex field demonstrations and conducting analytical comparisons of advanced system approaches.

Annex 27: Selected Issues on CO_2 as Working Fluid in Compression Systems
The main objective of Annex 27 was to bring the carbon dioxide heat pumping technology closer to commercialisation, by addressing critical issues of both basic and applied character. Emphasis was put on involving industry, especially manufacturers, as well as research organisations. Each participating country undertook one or more projects, and the intention is to synthesise the findings in a final report.

Annex 28: Test Procedures and Seasonal Performance Calculations for Residential Heat Pumps with Combined Space and Domestic Hot Water Heating
Approved by the ExCo at its fall meeting in 2002, work under this Annex will be started in January 2003. The Annex applies to heat pumps with hydronic heat distribution systems and alternative or domestic hot water production. The first objective is to establish a test procedure, which yields the necessary data in order to calculate the overall Seasonal Performance Factor of such heat pump systems with a minimum requirement for testing equipment and testing time. The second objective is to work out an easy method to calculate the Seasonal Performance Factor for the heat pump systems.

Workshops
Workshops have been another popular vehicle for cooperation under the umbrella of the HPP. Workshops are usually an integral part of Annexes, but also the Heat Pump Centre has taken an active part in staging such events. Usually two to four workshops are organised each year, and participation has varied between 25 and 130 people.

IEA Heat Pump Conferences
Every three years the HPP stages an international heat pump conference. Altogether seven IEA heat pump conferences have been organised under the HPP:

- 1984 Graz, Austria;
- 1987 Orlando, Florida, USA;
- 1990 Tokyo, Japan;
- 1993 Maastricht, Netherlands;
- 1996 Toronto, Canada;
- 1999 Berlin, Germany;
- 2002 Beijing, China.

The Heat Pump Centre
The Heat Pump Centre (HPC) is the hub of the HPP, and its primary objective is to gather, process, and disseminate information. The activities and achievements of the HPC are elaborately described in another article in this newsletter.

Organisational development

One of the central activities of the HPP is the development and dissemination of information, an activity that to an increasing extent has been undertaken by the HPC. For the first 20 years or so of the HPP's existence, the HPC was organised as an Annex like all other Annexes (with the possible exception that the HPC was operated on a tri-annual basis). Participation was voluntary, and members could come and go as they pleased. During the last half of the 1990s it became evident that several of the HPP member countries perceived HPC membership increasingly expensive. The sense of an expensive HPC membership was reinforced by the fact that the number of members also had declined. This forced the HPC to reduce its activities. Another feeling that developed was that the services of the HPC were available to the non-HPC members almost to the same extent as to the members. A free-rider problem had developed. On this background, the HPP was in 2001 restructured in such a way that HPC membership has now become mandatory for all HPP participants. Consequently, all HPP countries are now sharing and taking an active part in the HPC.

The future

Any programme that has been in existence for some time, sooner or later, face more or less serious challenges. At the outset, members form a common platform that they agree to and adhere to because the ultimate goal is clearly understood. As time goes by, delegates are replaced and ramifications are changed, and suddenly the goal is not so visible anymore. The HPP has not been an exception. However, through deep and thorough strategic processes we have managed to "gather the forces" again. Still, occasionally the question is raised: Why bother? Why become, or continue as a member? In trying to answer such questions, at least a couple of important factors come to mind.

Benefits
First, any country can only undertake a limited amount of activities within a certain discipline. Funding for research and technology development has always been and will continue to be limited. Why then, not get together with other countries and organisations by pooling resources? Obviously, this must be the most cost-effective way.

Second, and perhaps the most obvious point, working together across geographical borders creates valuable networks. In networks, information flows, new ideas are generated, and cooperative projects are established. Researchers can stay abreast of developments and "bring home" ideas and inspiration, and they have a large market to test their own ideas. Decision makers can learn from programmes and policies carried out in other countries, and perhaps most importantly, avoid mistakes already made by others.

Success factors
The continued success of a strong HPP in the future is dependent on several factors. Some of the more important are:

- strong National Teams that are acting as effective links between the HPP and their home markets. Success requires that information is fed into the programme from the different countries, and that the outcome and results of the HPP is effectively disseminated in the member countries;

- increased industry involvement. The involvement of industry has become increasingly important in order to release public funding in most countries. Industry participation also proves that there is a market for the products of the HPP;
- wider dissemination of results and information developed. Even though results are already disseminated widely, there is a large potential for increased dissemination of the results from the Programme. Increased dissemination will increase the attention and recognition of heat pumps;
- coordination with related organisations and bodies. Energy systems are increasingly seen as a black box by building owners, who are only interested in heat and cold whenever required. The heat pump or air conditioner must therefore work properly together with the rest of the energy system. Increased understanding of systems integration and related disciplines will therefore be more important. This situation can be improved by cooperation and coordination with related organisations and entities.
- expanding the membership base of the Programme. Even though many of the large heat pump countries are already members of the HPP, there is a large potential for an increased membership base. More countries would mean more information to process and share, as well as more cooperation.

If countries continue to see the benefits and the Programme will continue to develop by fulfilling the success factors, the future should be bright for the IEA Heat Pump Programme.

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The Heat Pump Centre – a decade in review

Jos W.J. Bouma IEA HPC

A summary of the achievements of the Heat Pump Centre (HPC) since it began operating from Sittard in the Netherlands in 1990

Markets in motion

During the past decade, the world market for heat pumps and air conditioners has seen rapid growth. Since 1992, the global heat pump stock has increased by 60%. In Europe, growth was 53%. Although Japan and the US still dominate the world heat pump market, new markets are developing very rapidly, notably in China. These new markets are characterised by a combined demand for space cooling and heating. But heat pumps are also seeing increasing use in countries where climate dictates that heat pumps are used mainly for heating purposes – in residential buildings and even more so in commercial/ institutional buildings. Increased human comfort, new building codes and heightened environmental concerns are the main reasons behind this trend. Sweden and Greece are two of the few European countries with an autonomous heat pump market. Upcoming markets in Europe are France, Switzerland, Austria and Germany.

Energy efficiency and, more recently, the environmental impact of energy use have become important drivers of national energy and environment policies. Gradually, an integrated approach is being adopted aimed at sustainable development, in which environmental aspects play an increasingly important role. The TEWI (total equivalent warming impact) analysis for working fluids and the life cycle climate analysis for equipment are just two examples of this. The effect of international agreements (Montreal protocol/ozone depletion; Kyoto protocol/global warming) on national energy and environmental policies is also becoming increasingly noticeable.

Inseparable from the trend towards sustainable development is the need for an increased use of renewable energy sources, both directly and through energy conversion. This creates great opportunities for heat pumps in the building, agriculture and process industry sectors. New opportunities may also arise in the area of car space conditioning. The position of electric heat pumps will become very strong once they are powered by renewable energy, notably solar, wind and biomass. Even when using present-day electricity from combined-cycle power technology, heat pumps are very energy efficient and environmentally friendly. However, there are other factors, such as equipment and installation cost reduction, training and certification, which are key elements for a market breakthrough of heat pumps. In the final analysis, a market breakthrough will happen only if manufacturing industries see the market potential and governments implement support and regulations.

Effective global information exchange on heat pumps, air conditioning and refrigeration is, and will remain, an important driver of the above trends and developments. It is also a very cost-effective tool for countries wishing to improve their own energy situation as well as contribute to the global environment. Modern communication tools, such as e-mail and the Internet, have opened up new and faster methods for exchanging information. This provides a tremendous opportunity for leveraging the effect of global information exchange on the development of the heat pump market. At the same time, information service providers such as the HPC must remain alert and focused on providing the right type of information to its target groups and on using the most appropriate vehicles.

Programme strategy

In October 1992, the Executive Committee of the IEA Heat Pump Programme confirmed the central goals of the Programme:

- accelerating market penetration of heat pumps;
- further developing heat pump technology;
- increasing the environmental benefits of heat pumps and communicating these benefits.

To achieve these goals, seven strategic areas were defined:

- information dissemination;
- market contacts;
- networking;
- systems;
- standards;
- working fluids and cycles;
- environmental benefits.

The HPC was given two special assignments consistent with the above:

- conducting an analysis of the environmental benefits of heat pumps;
- organising a workshop on Energy Efficiency Standards.

Both the study and the workshop were completed successfully and the results made available in the form of two publications.

After thorough evaluation, a new Programme strategy was adopted in 2000: The IEA Heat Pump Programme Strategy Plan 2001-2005 – International Collaboration for Energy Efficient Heating, Refrigeration and Air Conditioning. It has four main objectives and strategic areas:

- *Environment*: to quantify and publicise the benefits of heat pumps in the areas of environment and energy efficiency.
- *Market and deployment:* to develop appropriate technologies and deliver information to support deployment of these technologies.
- *Technology*: to develop and maintain international technical R&D collaboration in support of the environmental and market related objectives.
- *Information management*: to stimulate collaboration and provide an effective flow of information to, from, and between stakeholders and other bodies.

Programme actions

The new Strategy Plan has served to guide the HPC in its efforts to help realize the stated goals. In doing so, the HPC has focused on the following core activities:

- producing quarterly heat pump newsletters;
- conducting analytical studies and surveys;
- organising workshops and experts meetings;
- promoting heat pump technology;
- answering enquiries;
- managing the HPC website;
- providing support to the IEA Heat Pump Programme.

Energy efficiency and the environmental benefits of heat pumps are at the core of HPC's activities. The activities are also based on, and consistent with, the consolidated needs of the member countries. As different countries have different climatic conditions, domestic energy resources/demands, and energy policies as well as varying degrees of market maturity, a broad range of information is needed on matters relating to technology, the market and regulatory issues.

Newsletter

The key product of the HPC, the newsletter, has evolved into a magazine that provides up-to-date information for a wide audience, with readership in both member and non-member countries. Its news section serves the needs of all those concerned with heat pumps, air conditioning and refrigeration. In each issue, an international overview article provides comprehensive coverage of key topics based on information obtained via HPC's international network and in-house expertise. Nature and style of the newsletter have evolved from a research-oriented periodical to a magazine covering a broad range of technology- and market-related topics, each consistent with the overall Strategy Plan. Summaries of the newsletter have been translated into German, French and Japanese.

Readership development from 1990 to 2001 is shown in **Figure1**.
Declining readership during the last 3 years mirrors fluctuating membership of the HPC.

Newsletter topics include technology developments, trends, market developments, Heat Pump Programme issues etc. A regularly reappearing subject has been working fluids, reflecting the rapid changes in this area. For a list of newsletter topics covered over the years, the reader is referred to the HPC website: www.heatpumpcentre.org.

Starting in 2002, the newsletter has been available at the HPC website in PDF-format.

Workshops

Bringing together experts from various countries to participate in workshops and experts meetings serves the dual purpose of exchanging knowledge and helping to build contacts. Over the past decade, the HPC has organised 18 workshops on various key issues such as *Consequences of (H)CFC replacement in HVAC applications, Systems and Controls for Energy Efficiency, Building HVAC Equipment Regulations and Standards, CO2 Technologies in Heat Pumps, Refrigeration and Air Conditioning Systems, Natural Working Fluids, and Hands-on Experiences with Heat Pumps in Buildings*. The HPC website provides a list of workshops and proceedings.

Analyses

The emphasis has been on meeting the needs of the key actors in the heat pump market. Heat pump manufacturers and suppliers need reliable data on the current state and potential of local, regional and world markets as well as the factors that influence these markets. Heat pump experts need information on state-of-the-art technology and related issues around the world. Policy makers within governments and utilities need to learn from programmes and past experiences in other countries relating

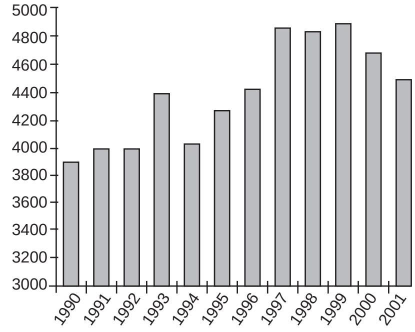

Figure 1: Newsletter readership development.

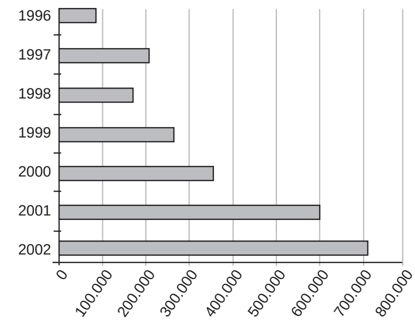

Figure 2: History of website page requests.

to the development of heat pumps and associated markets. They should also be advised on the environmental benefits of heat pumps.

Analytical studies, such as the *International Heat Pump Status and Policy Review (1992 and 1999)* and the *Environmental Benefits of Heat Pumps (1999)*, have provided many answers by drawing on the wealth of information available from many OECD countries on matters related to market, technology, policy and environment. In the study, *The Role of Heat Pumps in a Deregulated Energy Market (1998)*, the effects on heat pumps of deregulation of the energy sector have been analysed. The study, *Heat Pump Energy Efficiency Regulations and Labelling Requirements (1996)*, provided broad insight into relevant government and utility regulations and policies. For a list of analytical studies and reports, the reader is referred to the HPC website.

From 2000 onwards, so-called tailored collaborative projects have been carried out. Most of these studies involved international surveys of selected topics, providing state-of-the-art overviews of these topics. Topics covered include:

- reducing carbon emissions with heat pumps (UK study);
- single-room heat pumps for cold climates;
- refrigerant recovery, recycling and reclamation – an international assessment;
- ground-source heat pump systems;
- retrofitting with heat pumps in buildings;
- domestic heating and cooling distribution and ventilation systems and their use with residential heat pumps.

Most studies have been completed, and reports are available from the HPC.

Promotion

Promoting heat pump technology has been an important element of the Programme Strategy Plan. The widespread use of heat pump technology will not be realised unless there is awareness of the potential benefits, especially outside the 'heat pump community'. The HPC has worked to meet this challenge by producing and distributing thematic brochures, in which the benefits of heat pumps are clearly presented in a form that is accessible to a non-technical audience. Examples are the so-called Informatory Fact Sheets on *Ground-source heat pump systems and Hydrocarbons for residential heat pumps and air conditioners*. A special brochure was also produced for policy makers at the Global Climate Change Conference in Kyoto, in December 1997, explaining the environmental benefits and potential of heat pumps. Similar information was also made available to participants of the COP-6 meeting in The Hague in the Netherlands in 1999.

Another way of reaching a wider audience is by raising the profile of the HPC as a pre-eminent source of information on heat pumps. Various tools have been used to provide information on HPC activities, products and services. The HPC website has evolved into a major vehicle for promotional information and for positioning the HPC. The Heat Pump Programme has also been promoted via workshops and conferences. The growth in sales of HPC publications as well as the increasing number of visitors to the website shows that these efforts have been successful.

Enquiry service

The enquiry service has been a well-used service for several years. The number of enquiries has increased substantially in recent years, notably because of the website. A new audience, consisting of individual homeowners, end-users and potential buyers of equipment, has been contacting the HPC with specific questions. In 1997, the number of enquiries reached 300. In 1999, this service was continued via the website in a 'Frequently-Asked-Questions' section.

Internet

The Internet is being increasingly used to provide information and promote heat pumps. The HPC website was launched in September 1995. The number of visitors per month initially varied from 12,000 to 15,000 in 1998, with the HPP library attracting the most visitors **Figure 2**. In the late 90s, the website was improved for easier navigation, which resulted in a further increase in the number of visitors. The annual number of visits has now reached a level of 700,000.

The site provides news, information on the HPC and heat pumps, publications, answers to frequently asked questions and links to National Teams, Annexes and related organisations. It also provides access to information developed and collected by the Programme and the HPC for non-HPC members as well.

Heat Pump Programme

The past decade has seen the position of the HPC confirmed as the leading international information centre on heat pumps. Within the Heat Pump Programme, the HPC has been the designated distribution channel for all information generated by Annexes. It has published all Annex reports since 1992 (see HPC website). Publications have been advertised in the newsletter and promoted via press releases and the website in order to reach a wide audience.

In 1997, for the first time, the 5^{th} IEA Heat Pump Conference Proceedings and the International Absorption Heat Pump Conference Proceedings 96 (a publication not produced under the HPP) were published by the HPC. Recently, the proceedings of the 7^{th} IEA Heat Pump Conference were published in CD ROM and book format. As a result, the HPC has evolved into one of the world's largest publishers of heat pump literature.

The bibliographic database of Program

me publications has been made widely available via the Internet. This is one of the most frequently visited pages on the website. It contains many (more than 1,300) records with abstracts of reports, papers and articles generated under the Programme and continues to grow with every HPC publication.

Related organisations

In the 90s, links with international organisations operating in the same field, such as the IIR, UNEP and ASHRAE, were strengthened. The IIR's global network of scientists and experts adds a powerful extension to the HPC network. It has provided the HPC with access to information from countries otherwise not easily obtained. Some studies and workshops have been conducted jointly with the IIR. The IIR also plays a specific role by providing scientific reviews of HPC publications, particularly analytical reports. The HPC reviews the Informatory Notes of the IIR, and strong links exist with Commission E2 (Heat Pumps and Heat Recovery). In 2000, the links between the Programme and the IIR were formalised by signing an agreement for collaboration.

The HPC has contributed input to the UNEP 1998 and 2002 Reassessment reports of the Technical Options Committee on Refrigeration, Air Conditioning and Heat Pumps for the Montreal Protocol.

Links with the EU were initiated in various areas including the organisation of a joint workshop on Natural Working Fluids, the newsletter, participation in an EU Save project (Transforming the Market for Electric Heating of Domestic Dwellings) and information exchange with the European Union Heat Pump Network. Links with other heat pump associations were also strengthened, notably via the European Heat Pump Association (EHPA), to which the HPC is a partner.

Links with utilities were maintained through the International Power Utility Heat Pump Group (IPUHPC), a group of large power utilities around the world. An initial joint workshop was organised in Baden, Switzerland in 1994 under the title 'Utilities Perspectives on Heat Pumps for Retrofit and New Applications in Buildings'. A well-attended two-day workshop was jointly organised in 2001 in Arnhem, Netherlands with the title 'Hands-on Experience with Heat Pumps in Buildings'.

ASHRAE's extensive R&D programme and information potential in the area of heat pump technologies, working fluids and standards is an important element for keeping up to date with relevant developments in North America. The work of the Society's Technical Committee offers insight and first-hand information (new R&D, standards) in topical areas such as unitary heat pumps, absorption heat pumps, engine-driven heat pumps, ground-coupled heat pumps, applied heat pump systems and working fluids. ASHRAE is also an important co-sponsor of IEA Heat Pump Conferences.

Accomplishments

It's only fair to ask, "What has the HPC accomplished in member countries?" It is not possible to provide tangible proof of exactly what the HPC has accomplished with its efforts at providing relevant information to its target audiences. But it is clear that the HPC has contributed indirectly to improving heat pump technology and encouraging related market developments. The nature of these effects is different from country to country and ranges from risk and cost reductions to the adoption of innovative ideas and creating a market leadership position. An example of the latter is the residential diffusion absorption heat pump, which is based on a Swiss concept and has been developed commercially in the Netherlands by Nefit-Buderus **Figure 3**. Other examples are the users group of large absorption heat pump systems, which contributed to realising a MW-size absorption heat pump in Uppsala, Sweden and a heat transformer in the Netherlands, as well as the development of a mobile in-situ test installation for ground-coupled heat pump systems. Finally, the HPC also provides a level playing field for manufacturers and suppliers of equipment that want to introduce new products and applications to an international audience.

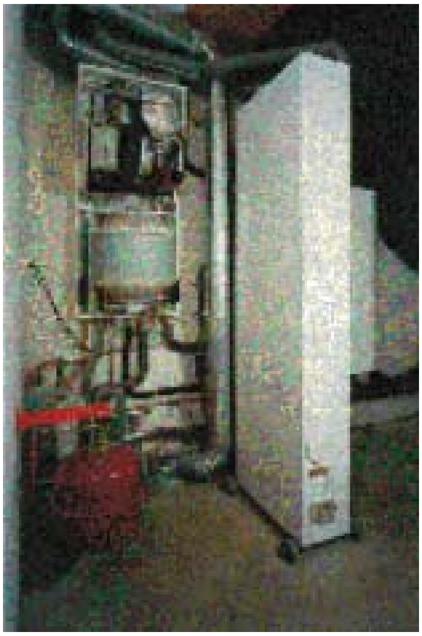

Figure 3: Prototype diffusion absorption heat pump Nefit-Buderus.

Extending the network

For gathering and disseminating information, the HPC relies heavily on the network of National Teams in its member countries. To a large extent, they have determined the success of the activities.

Of the eight member countries that joined the HPC in 1990, Sweden (1993), Italy (1995) and Canada (1996) ended their participation in different years. An important reason for withdrawal has been declining government support. Austria, Japan, the Netherlands, Norway and the US have been members since 1990. The markets in these countries differ and range from mature (Japan) to early stage (Netherlands).

One obstacle to joining is that governments increasingly required industry to share in the cost. The issue of ‘free riders’ also continued to be a major drawback and obstacle for (new) members. Nevertheless, Switzerland joined the HPC in 1992, and Spain joined in 1996. In 1999, seven countries were members of the HPC (USA, Norway, Netherlands, Switzerland, Austria, Japan and the UK). Spain left the HPC after three years in 1998.

As the narrow membership base was an obstacle to providing good information service and wide information coverage, efforts were made to attract new members and reduce membership fees.

A new HPC

With HPC membership fluctuating and declining in the late 90s, a restructured programme was implemented in 1999. It included a Base Part and a Tailored Collaborative Part. This provided increased flexibility and control of the programme by the member countries. The National Teams in the member countries determined the HPC activities and had to make sure that the HPC programme was consistent with their national programme for maximum benefit.

From January 2002 on, each Programme country joined the HPC. This solved the problem of free riders and fluctuating membership. At the same time, the annual contribution fees as well as the base tasks of the HPC were reduced. It is still too early to conclude what the effects of the new structure will be, but one thing is certain: the information base and network have become much stronger. Hopefully, this will attract several new members from various parts of the world.

Conclusions

One of our main conclusions in overviewing the last ten years activities is of a rather abstract, organisational kind: Pooling of resources contributes to a more efficient use of funds and more effective information management.

The main accomplishment of the HPC during the past decade has been the contributions it has made to generating improved insights into the markets and their constraints, to stimulating technological development and application of heat pumps, and to collecting and providing information on heat pump policies and regulations. The various publications and tools used to collect and disseminate relevant information from and to the various target groups have played a key role in this regard.

The position of the HPC as the leading international information centre and publisher of heat pump literature has been confirmed and strengthened. Information is being drawn from an increasingly wide base, including international organisations such as the IIR, EHPA, EU and UNEP. The HPC also plays a central role in the Heat Pump Programme by supporting the Programme with a comprehensive information service.

There has been a notable increase in interest in heat pumps. Several governments now consider heat pumps to be an important option for tackling energy and environment issues. The market has developed positively in many countries, including those with cooler climates. The services provided by the HPC and the activities of the member countries have contributed significantly to these developments.

Years with a purpose

In the next five years, the HPC aims to maintain and further strengthen its position as the leading international information centre on heat pumps. It will seek to further improve the effectiveness of its activities, both by serving the needs of the so-called ‘heat pump community’ and by reaching out to people beyond the Programme’s traditional audience, such as policy makers in governments and utilities. Consistent with the goals of the Heat Pump Programme, the HPC will continue to offer information services with the right message for the right audience.

Jos Bouma
IEA Heat Pump Centre

IEA Annex 26: Advanced supermarket refrigeration systems

D. Baxter, USA

Present supermarket refrigeration systems require very large refrigerant charges and are heavy consumers of electricity. IEA Annex 26 was formed to investigate and help promote the use of energy efficient, low-charge refrigeration system designs. Analyses show that advanced systems can reduce energy consumption by over 10% and total equivalent warming impact (TEWI) by as much as 60%. Integrating refrigeration and HVAC functions can potentially reduce combined operating costs by over 10%.

Introduction

Supermarkets belong to the most energy-intensive types of commercial buildings with consumption ranging from about 400 to 1000 kWh/m^2/year worldwide. About half of this consumption – from 1 to 1.5 million kWh annually in North American stores alone – is used to refrigerate products in display cases and storae refrigerators and freezers.

Figure 1 shows the layout of a typical large modern supermarket. Today's most common supermarket refrigeration system is the multiplex direct expansion (DX) system. In large (3700 - 5600 m^2) stores, several compressors are arranged in parallel on two or more racks. Individual compressors cycle on and off automatically so that compressor capacity closely matches the refrigeration load. Compressors are connected to DX evaporators in each display case and cold storage room via long pipe runs requiring thousands of meters of pipe and many individual unit connections.

Heat rejection is usually done using air-cooled condensers due to low cost and easy maintenance. Evaporative condensers would reduce condensing temperature and system energy consumption, but they would also increase maintenance costs. System controls are usually set to allow the condensing temperature to float with the outdoor ambient temperature to a minimum level of around 21°C. The refrigerant charge for this type of system is very large – 1300 to 2500 kg. The large amount of piping and number of connections required can result in large refrigerant losses – 30% or more of the total charge in older stores. New systems designed to reduce leakage can achieve loss rates of 15% or lower [1]. The relatively large charge and high loss rates result in high values of TEWI, with direct refrigerant loss accounting for about half of that number (see **Figure 2**).

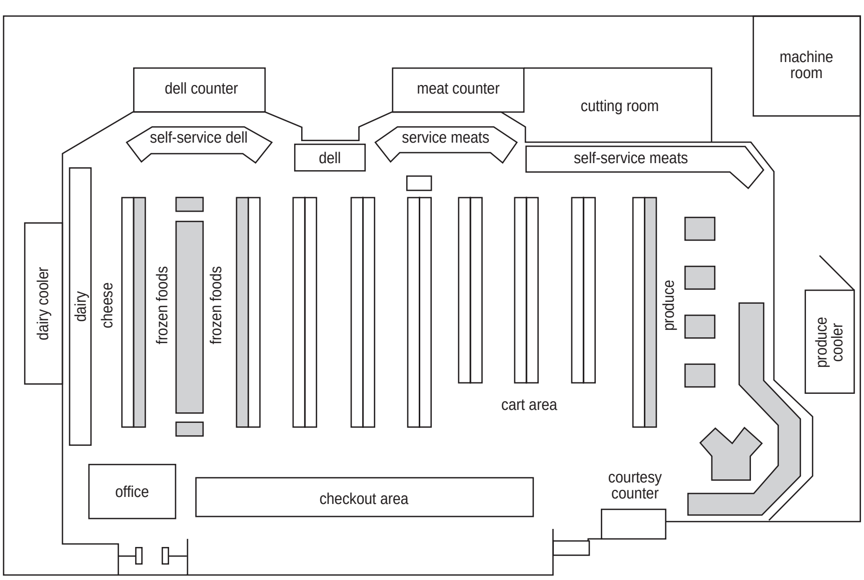

Figure 1: Layout of a typical modern supermarket.

IEA Annex 26

The International Energy Agency (IEA) established IEA Annex 26 (Advanced Supermarket Refrigeration/Heat Recovery Systems) to help promote the development and use of advanced, low-TEWI systems. Annex 26 focuses on demonstrating and documenting the energy saving and environmental benefits of advanced systems for food refrigeration and space heating and cooling for supermarkets. In this context, 'advanced' refers to systems that are more efficient and produce lower refrigerant emissions. Heat recovery methods investigated for integrating store HVAC and refrigeration systems include the use of heat pumps.

Advanced systems under investigation are:

- Distributed compressor systems: small multiplex compressor racks located in close proximity to the food display cases they serve,

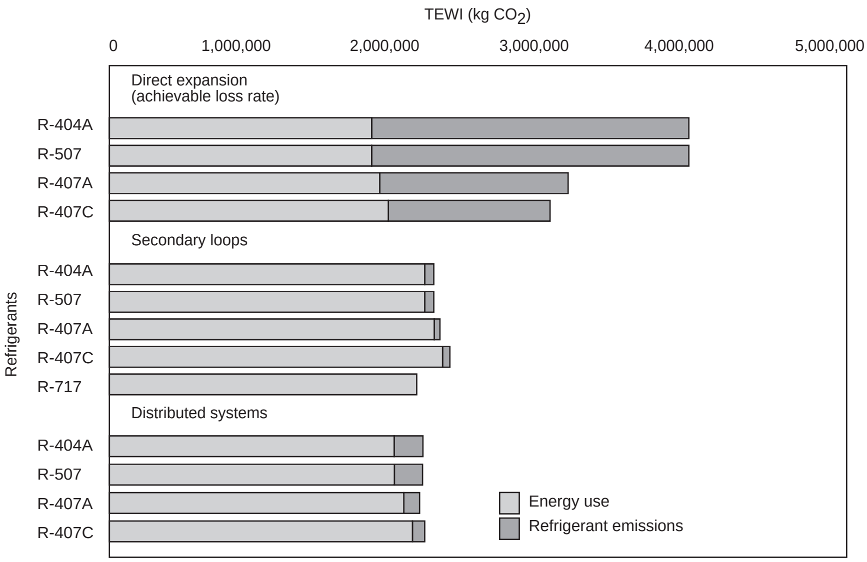

Figure 2: Total equivalent warming impact (TEWI) of various low-temperature supermarket refrigeration systems in North America.

significantly shortening connecting refrigerant line lengths. Rooftop air-cooled condensers may be used for each rack or all may use fluid-cooled condensers connected to a common secondary loop with remote cooling tower.

- Secondary loop systems: a central chiller is used to refrigerate a secondary coolant that is pumped to the food display cases. In large stores, two or more secondary loops (each with its own chiller and controls) may be used to meet refrigeration loads at different temperature levels.
- Self-contained display cases: each food display case has an integral refrigeration unit. Fluid-cooled condensers would typically be used with secondary loop and remote cooling tower to remove heat from sales area.
- Low-charge DX: similar to conventional supermarket systems but with improved controls to reduce charge.

A workshop on advanced supermarket refrigeration was held October 2-4, 2000 in Stockholm. The workshop proceedings are available from the IEA Heat Pump Centre [2].

The Annex has five participants: Canada, Denmark, Sweden, the United Kingdom, and the United States.

Annex participant activities

***Canada*:**
Two advanced systems and a baseline multiplex DX system are being tested. One approach uses multiplex DX systems with heat recovery for space and water heating and ground water use to supplement heat rejection. The second approach has heat pumps integrated into the system to provide space heating for the store and sub-cooling for the refrigeration system.

Figures 3 and **4** illustrate the second approach. In winter, the discharge gas from the refrigeration compressors first goes through three plate heat exchangers that serve to de-superheat and pre-condense the gas. The three heat exchangers also serve as evaporators for rooftop heat pumps that supply space heating to the store. Using heat pumps for heat recovery places no minimum limit on refrigeration system condensing pressure, as is the case for traditional heat recovery approaches. A fourth rooftop heat pump is integrated with the liquid line exiting the air-cooled condenser via a fourth plate heat

Figure 3: Rooftop heat pump unit at Canadian test store.

exchanger. This heat pump sub-cools the refrigerant leaving the condenser and uses the recovered heat for store space heating.

Initial baseline tests in 1999-2000 showed that both advanced systems achieved about 6% lower specific energy consumption (kWh/m^2/yr) compared to the baseline system. A technology showcase is planned for installation in a Montreal area supermarket in 2002.

***Denmark*:**
A propane/CO_2 cascade plant is being tested in a small store. Propane is used as the high-temperature refrigerant (-14/+30°C) while carbon dioxide is used at the low-temperature level (-32/-11°C). Data indicate that the energy consumption of the test plant is comparable to that of R-404A DX plants in other stores of the same chain. The additional cost for a propane/carbon dioxide cascade plant for a

Figure 4: Plate heat exchangers (HX) for heat pump evaporators and refrigeration de-superheaters and sub-cooler at Canadian test store.

medium sized Danish supermarket (30 kW freezing load and 60 kW cooling load) is estimated to be about 15% of the total installation cost.

***Sweden*:**
Sweden's work for the Annex is part of their national Eff-Sys program within the project 'Energy Efficient Solutions for Supermarkets in Theory and Practice'. They have developed a computer model (Cybermart) for system pre-design and have carried out field measurements in four supermarkets to validate the model. Sweden's analyses indicate that well designed advanced secondary loop systems do not compromise energy efficiency compared to conventional DX systems. The analyses also show that two-loop secondary systems with sub-cooling of the low temperature loop are more efficient than cascade systems.

***United Kingdom*:**
Four research activities have been completed in the UK:
- evaluation of combined heat/power schemes and combined cooling/heating/power schemes for supermarkets;
- comparison of various alternative systems with standard DX systems;
- investigation of the effect of various store conditions on case performance;
- analytical and experimental investigation of three defrost methods and alternative control strategies.

***United States*:**
A 3720 m^2 supermarket based on the layout in **Figure 1** was simulated, and TEWI and energy consumption estimates were made for a baseline air-cooled multiplex refrigeration system and for advanced systems; see **Table 1**. Total refrigeration load was 328 kW with a refrigerant charge of 4.15 kg/kW load. The distributed compressor-, low-charge multiplex-, and secondary loop systems (with four independent secondary loops) each achieved estimated annual energy savings of about 11%. Use of evaporative heat rejection was the principal driver for these energy savings; baseline system energy consumption was 8.2% lower with an evaporative condenser. The lowest TEWIs were achieved by the secondary loop refrigerationdistributed system and the secondary loop systems, with CO_2 emission reductions of about 813 to 14.6 million kg, or 43.457 to 60%. The low-charge multiplex system achieved estimated TEWI reductions of about 24% or 43% depending upon the refrigerant loss assumption made.

An analysis of a distributed compressor refrigeration system with an integrated water source heat pump showed that about 13% operating cost savings could be achieved compared to a baseline air-cooled multiplex refrigeration system and with conventional rooftop HVAC units.
Two systems are being field tested – a distributed compressor system with water source heat pumps and a low-charge multiplex DX system.

Table 1: Total Equivalent Warming Impact (TEWI) for various supermarket refrigeration systems

System	Condensing	Charge, kg/kW	Primary Refrigerant	Leak (%)	Annual kg/kW	TEWI (million kg of CO_2) Direct	Indirect[a]	Total
Multiplex	Air-cooled (baseline)	4.15	R-404A /R-22[b]	30 (15)	976,800	13.62 (6.81)	9.52 (9.52)	23.14 (16.33)
	Evaporative	4.15		30	896,400	13.62	8.74	22.36
Low-Charge Multiplex	Evaporative	2.77	R-404A /R-22[b]	30	863,600	9.08	8.42	17.50
				15	863,600	4.54	8.42	12.96
Distributed Compressors	Water-cooled, Evap. tower	1.24	R-404A	5	866,100	1.00	8.44	9.44
Secondary Loop	Evaporative	0.69	R-507[c]	10	875,200	1.13	8.54	9.67
				5	875,200	0.56	8.54	9.10
	Water-cooled, Evap. tower	0.27	R-507[c]	5	959,700	0.23	9.36	9.59
				2	959,700	0.09	9.36	9.45

Results for Washington DC location – assuming a 15 year service life

[a] Conversion factor = 0.65 kg CO_2/kWh
[b] 1/3 R-404A (low temp.), GWP = 3260; 2/3 R-22 (medium temp.), GWP = 1700
[c] R-507, GWP = 3300

Conclusions

Analyses carried out under Annex 26 have shown that both energy savings (over 10%) and TEWI reductions (up to 60%) can be realised using low-charge refrigeration systems instead of conventional multiplex DX systems. Use of evaporative heat rejection technology (condensers or cooling towers) to reduce condensing temperature is a key factor in obtaining maximum energy savings. Integration of heat pumps into the refrigeration system to recover heat, rejected by the refrigeration system, for space heating can yield overall cost savings of 10% compared to conventional approaches.

In general, further efforts to reduce TEWI of advanced low-charge systems would benefit more from reduction in energy consumption (through efficiency increases or load reductions) than from further reduction in refrigerant charge and losses.

The total value of the Annex research work is about 5 million USD. This represents a leveraging of each participant's funds of up to 10:1.

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Acknowledgments

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Direct evaporation ground-coupled heat pumps in Austria

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In Austria, direct evaporation ground-coupled systems with horizontally installed ground coils dominate the heat pump market. This is due to their lower cost and higher efficiency, compared to secondary loop systems, which is achieved by omitting the circulation pump and avoiding heat transfer loss in the evaporator of a secondary loop system. The SPF of the direct systems is in the range of 4 to 5.

Introduction

Vertical systems are a good alternative to horizontal coil systems if limited ground area is available, or when installation of horizontal coils would mean destroying the garden. Direct evaporation systems have also been developed that can be installed vertically. These developments have been strongly influenced by the results of the IEA Heat Pump Programme Annex 15, Heat Pump Systems with Direct Expansion Ground Coils.

One of the first people to suggest using the ground as a heat source was Zölly from Switzerland in 1912. In the 1940s, investigations into ground-source heat pumps were resumed in the US. These systems, partly direct evaporation systems, worked very reliably. Similar work was carried out in Germany. The commercial use of the ground as a heat source for heat pumps began in the 1970s after the first oil price shock. The systems installed at that time were mainly secondary loop systems. Later, direct expansion systems, especially in combination with horizontally installed ground coils, were introduced (Sanner 1992).

For the utilisation of the ground as a heat source for heating-only operation, various system designs have been developed (**Figure 1**). The differences are caused mainly by the capacity of the system and the area available (see VDI Handbook 1998):

- Horizontal ground coils are most commonly installed about 0.3 m below the frost line, this is at a depth of about 0.8 to 1.2 m. At the beginning of the heating season, the ground temperature is higher than the undisturbed (natural) ground temperature. During the heating season it can drop below 0°C, as a result of heat extraction. But moisture migration to, and frost formation around the coil increases heat conductivity, and this plus the latent heat stabilises the temperature.

- Vertical wells are used if the surface area available is insufficient for horizontal systems. Two designs are possible: shallow wells down to a depth of 20 m, or deep wells down to 100 m or even deeper (250 m). The depth depends on the ground conditions and on the drilling equipment available. The heat exchangers can be of the coaxial type, the U-tube or double U-tube type.

- Another type of ground heat exchanger is the spiral heat exchanger (**Figure 2**) as developed by O. Svec, Canada.

Direct expansion/evaporation systems

Globally speaking, the systems most commonly installed are secondary loop systems. However, in Austria more than 60% of the heating-only heat pumps installed are direct expansion systems with refrigerant evaporation in the ground coil. These systems have several advantages compared to secondary loop systems:

- The evaporator of the heat pump unit is installed directly in the ground, so that the heat transfer from the ground to the refrigerant occurs directly, thereby avoiding heat transfer loss.

- The drive energy for the circulation of the refrigerant in the evaporator comes from the compressor and from the throttling. This means that no additional power input is needed.

- Heat transfer properties of the copper tubes (coated with a thin plastic film to avoid corrosion) used in direct expansion coils are better than those of the plastic tubes used in secondary loop systems.

If designed properly, direct expansion/evaporation systems therefore are more efficient than secondary loop systems. The Seasonal Performance Factors (SPFs) of direct expansion/evaporation systems in new, well insulated buildings with specific heat loads below 60 W/m^2 and equipped with (low-temperature) floor heating systems are in the range of 4 to 5 and even higher. To achieve such high SPFs, the design of the heat pump unit and the construction of the system have to be carried out very carefully, taking into account the following points:

- The refrigerant velocity in the evaporator has to be kept as low as possible for a small pressure drop (which also means a drop in the evaporation temperature), but it has to be high enough to ensure oil return to the compressor. To realise this right velocity and to make a sufficient mass of ground accessible, the diameter of the evaporator tube has to be smaller than that of

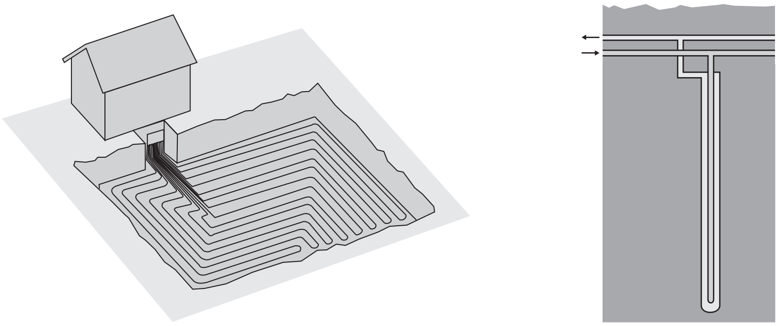

Figure 1: Ground heat exchangers – horizontal and vertical.

secondary loop systems. This means that the temperature drop from the ground to the tube surface either becomes larger or the heat transfer area has to be increased.

- The refrigerant cycle control cannot be carried out using a conventional thermostatic expansion valve because of the length of the tubes used (60 m and 75 m), and the run-through time is mostly around, or more than 30 seconds. Possible solutions are capillary tubes or thermostatic expansion valves designed for liquid sub-cooling in the condenser. The latter technology has been developed in Austria by A. Bangheri and seems to be the best solution.

- The coils of vertical systems have to be designed very carefully. K. Steinkellner realised that for depths from 50 m to 60 m, evaporation in the down-comer has to be used to compensate for pressure wins caused by gravity. The riser has to be sized to guarantee oil return to the compressor. Within the framework of Annex 15, a computer model for calculating direct expansion/ evaporation systems was developed, which demonstrated that it is possible to size a vertical coil in such a way that externally no pressure loss exists. The model also showed that the use of natural circulation systems is restricted due to the high density of (H)CFC refrigerants.

- In the case of partial load operation using two-speed compressors, variable-speed compressors or two compressors in parallel (which is an efficient way of increasing the SPF), the refrigerant velocity drops. To ensure oil return, maximum capacity operation at the beginning of a cycle, or after a defined time interval has to be implemented.

If the above points are taken into account, direct expansion/evaporation systems can operate efficiently and reliably. However, such systems also have a few disadvantages:

- In-situ brazing to connect the coil and the heat pump unit is necessary, which introduces a potential risk of refrigerant loss and groundwater pollution;

- The ground coil evaporator is much larger than the evaporator of a compact heat pump unit, thereby increasing the refrigerant charge.

Manufacturers and installers of direct expansion/evaporation systems (Halozan 1997) have succeeded in resolving these potential problems. In Austria direct expansion/evaporation systems are so successful because this country has skilled designers and constructors of these systems.

Recent developments

Progress in heat pump technology has continued in several areas. It has been strongly influenced by advances in refrigeration technology and by various regulations. Some of the main developments are explained here.

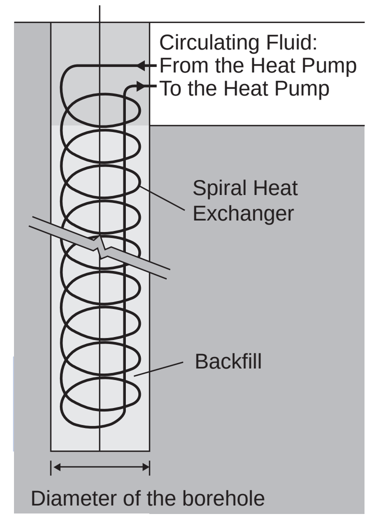

Figure 2: Spiral heat exchanger.

Refrigerants

The (H)CFC phase-out, resulting from the 1987 Montreal protocol on substances that deplete the ozone layer, created various challenges that had to be dealt with by the refrigeration and heat pump community. The synthetic, chlorine-free compounds developed by the chemical industry as alternatives to CFCs and HCFCs are the hydrofluorocarbons (HFCs). But of these, only R-134a can be used as a pure fluid to replace R-12. R-32 and R-143a are both excellent, but flammable refrigerants. However, to replace R-502, they can only be used in blends such as R-404A and R-507. R-407C is an alternative for R-22, and R-410A is now also available as an alternative. However, R-410A, a very efficient working fluid, requires high-pressure (40 bar) design. The problem is that all of these fluids have a high global warming potential and are therefore part of the Kyoto basket of greenhouse gases. Next to ozone depletion, this is another major topic of discussion with regard to the global impact of heat pumping technologies.

Another option is switching back to 'old' refrigerants such as ammonia, hydrocarbons, water, and CO_2 (Halozan 1995). Ammonia and hydrocarbons do not meet the requirements of a safe refrigerant, due to toxicity and/or flammability. Water and CO_2 are safe refrigerants. Among the hydrocarbons, propane is an excellent substitute for R-22, practically a drop-in, and using an internal heat exchanger it becomes even more efficient than R-22 with about the same cooling capacity. In addition, the use of propane allows the refrigerant charge to be reduced by about 50% compared to R-22. But the use of propane as a refrigerant is restricted due to existing regulations and the restrictions introduced by compressor manufacturers. It seems that at least one large compressor manufacturer wants to prevent the use of hydrocarbons in heat pumps in Europe. Nevertheless, some manufacturers continue to use hydrocarbons, for instance propane, as a refrigerant.

Packaged direct evaporation heat pump with propane as working fluid

J. Neudorfer, a heat pump manufacturer in Austria, has developed a packaged direct expansion/evaporation residential heat pump. The propane heat pump unit is designed for outdoor installation in compliance with Austrian regulations and has an integrated ground coil evaporator. It is prefabricated, filled with the refrigerant charge required, and tested in the factory. The complete system is transported to the site, where the heat pump unit is installed on a small foundation. The evaporator coil is rolled out into the excavated ground space and covered with a layer of sand and a layer of soil. The heating system in the building is connected to the outdoor unit via the supply and return pipes and cables for power supply and control. The controls and the heating water circulation pump are installed in the building.

CO_2 heat pipe based ground probe

A relatively new concept is the heat pipe used as a ground heat exchanger. Because the heat pipe contains only CO_2 working fluid without any lubricant, and is self-circulating, environmental risks are minimised. Such systems can achieve a SPF similar to that of direct expansion/evaporation systems.

K. Mittermayr developed an interesting heat pipe based ground probe with CO_2 as working fluid for vertical applications down to a depth of 75 m (Rieberer and Mittermayr 2001). No circulation pump is required. The heat pipe works as follows (see left schematic in **Figure 3**):

- Due to gravity, the liquid working fluid (CO_2) flows along the tube wall to the heated section of the probe, where it evaporates;
- The liquid film becomes thinner and thinner while the vapour rises to the top because of its buoyancy;
- In the cooled section – at the top of the heat pipe – the vapour condenses and the cycle starts again.

The system design consists of a heat pump cycle that is physically de-coupled from the CO_2 heat source cycle (see layout in **Figure 3**). The refrigeration cascade consists of the ground probe in which CO_2 evaporates in the bottom part and the probe-head, which functions as the CO_2-condenser and the refrigerant evaporator of the heat pump. Experimental analysis has confirmed that the proposed CO_2 ground heat pipe is a reliable, highly efficient and environmentally friendly alternative to the more common ground-coupled systems. Using a prototype heat pump system, a SPF of higher than 5 has been measured.

Highly insulated new buildings

The new building sector is characterised by two related aspects: improved thermal insulation, and significantly reduced heat loads. This means that even in cold climates (design temperatures -12°C; 3,500 heating degree days; heating period 200 days) buildings with specific heat loads of 60 W/m^2 can be heated by ground-coupled heat pump systems with SPFs of 4 to 5.

A further step has already been realised in so-called passive houses. The transmission losses through the building envelope are in the range of 15 W/m^2. The next step has been the introduction of controlled ventilation combined with exhaust air heat recovery. Using heat recovery heat exchangers, ventilation losses can be reduced by 50 to 90%, depending on the type of heat exchanger used. However, heat exchangers can only reduce the ventilation heat load. With heat pumps, ventilation losses can also be reduced. Heat pumps can increase the fresh ambient air temperature to a level higher than the indoor air temperature. Of course this requires energy input, in contrast to heat exchangers alone.

The best solution is a combination of both: a heat exchanger and a heat pump.

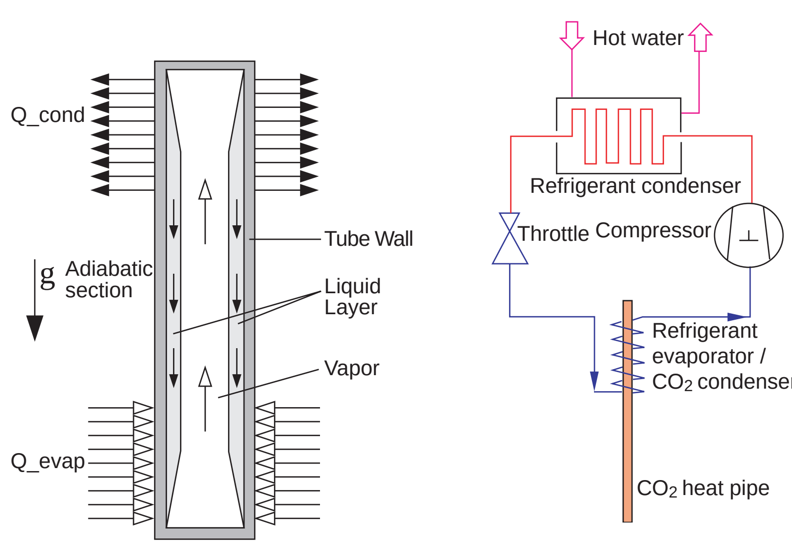

Figure 3: System layout and working principle of a heat pipe (two-phase thermosyphon).

The exhaust air is first cooled down in the heat exchanger and than used as a heat source for the heat pump. The fresh air is preheated in the heat exchanger and then heated further by the heat pump. Such a system can work effectively even at relatively low outside temperatures. Any remaining heating demand can be covered by electric resistance heating, or by further reducing the heat load.

One variation of the above involves preheating the fresh air in the ground (**Figure 4**). For a typical single-family house, a suitable air/ground collector consists of about 60 m of pipe with a diameter of 0.25 m buried in the ground at a depth of about 1.5 m. With such a collector, the air temperature will always be higher than -5∞ C, even when the outdoor temperature drops below -20°C. This preheating makes it possible to heat the building using only the heat recovery system. However, the SPFs achievable with such systems applying a heat pump with CO_2 as working fluid are 6 for the system and 4 for the heat pump. A further improvement can be achieved by using a ground coil to avoid frosting/ defrosting losses (**Figure 5**). The SPFs are then about 10% higher.

These systems seem to offer a feasible future solution for low-energy buildings. Due to the high thermal insulation standard and the controlled ventilation, such systems also provide excellent hygienic conditions and high comfort for the consumer, combined with a low energy bill (Rieberer and Halozan 1997).

Retrofitting existing buildings

The retrofit sector for existing buildings is a more problematic market due to the higher supply temperatures required. The heat consumption for existing buildings is about 250 kWh/m^2, which is about 5 times higher than for new low-energy houses and over 15 times higher than for so-called passive houses. But heat pumps with maximum water supply temperatures of 65 °C are already feasible using present technology with propane as refrigerant. In particular, a system that is comprised of the economiser flow scheme in combination with a scroll compressor and that uses the ground as heat source, offers high SPFs that compete favourably with conventional heating systems. Retrofitting, which was common at the beginning of the heat pump market in the 1980s, could expand the heat pump market significantly.

In this context, absorption heat pumps could also become interesting. Such systems are more expensive than electrically driven heat pumps, but as they permit the use of smaller ground coils, the investment costs for the entire system can be comparable.

Summary

Direct expansion/evaporation ground-coupled heat pumps can achieve SPFs between 4 and 5, assuming that building standards are complied with and the overall system has been designed

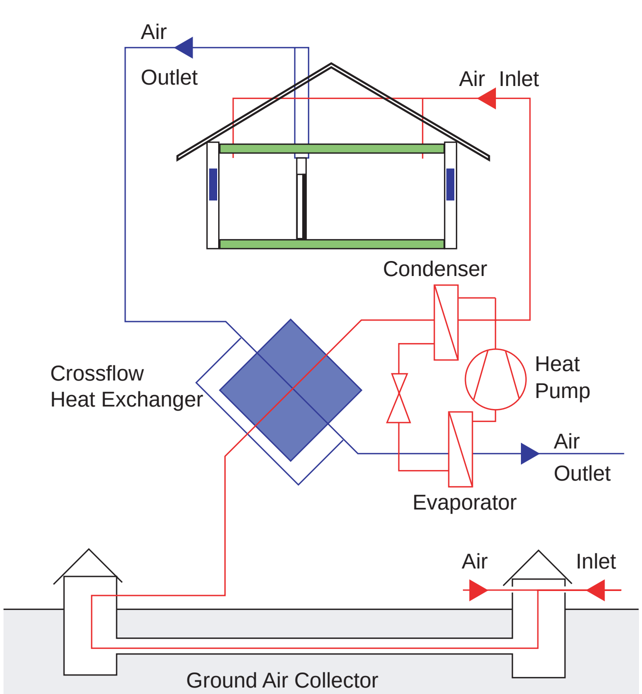

Figure 4: System with air/ground collector, heat exchanger and air-to-air heat pump.

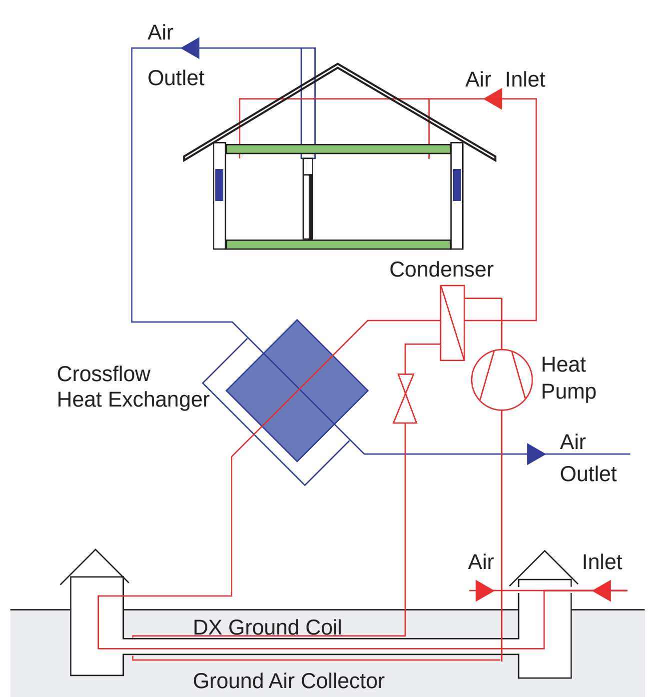

Figure 5: System with air/ground collector, heat exchanger and direct expansion-to-air heat pump.

properly. Such high SPFs can only be realised with the help of highly skilled system designers. Such designers do not design and sell heat pump units. They rather design and sell systems. The sales of direct expansion/evaporation systems, either with horizontally installed collectors or with vertical probes down to 60 m, are increasing, and they already dominate the Austrian market. IEA Annex 15 has been a major factor in these developments.

New developments such as improved heat pump units, advanced direct expansion/evaporation heat pumps and heat pipe-type vertical probes demonstrate that there is still room for new ideas and improvements. These remain necessary to ensure success in the future.

Apart from new buildings, it also remains important to focus on the stock of existing buildings. Retrofitting these buildings will be the heat pump market of the future.

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Enova – spearheading environmentally-friendly restructuring of the energy policy area in Norway

Roar Fjeld and Anita Eide, Norway

Enova, a new, flexible and market oriented national agency, is responsible for promoting energy conservation and the use of renewable energy and environmentally friendly natural gas applications in Norway - a new approach and a new organisation.

Introduction

On March 27, 2001 the Norwegian Parliament approved the establishment of a new agency for promoting energy savings, renewable energy and environmentally friendly natural gas solutions. The name of the new agency is Enova. Located in the city of Trondheim, it is owned by the Government of Norway and represented by the Ministry of Petroleum and Energy. Enova has been operational since January 1, 2002 and is headed by Eli Arnstad.

The establishment of Enova signals a shift in Norway's organisation of its energy efficiency and renewable energy policy. By gathering strategic policy responsibilities in a small, flexible and market oriented organisation, Norway aims to create a pro-active agency that can stimulate energy efficiency by supporting cost-effective and environmentally sound investment decisions. By developing key energy and energy efficiency indicators and evaluation guidelines, Enova aims to achieve more cost-effective use of public funds in the energy area.

The reorganisation is the result of a desire to achieve greater consistency in the incentive structure. The same organisations charged with implementing energy efficiency policy measures also had strong motives to increase their volume sales of energy. Furthermore, Norway had been experiencing growing national use of energy over the past few years. Coupled with the belief that a more market oriented approach was necessary to achieve lasting results, a more dynamic organisation was created. Enova was given improved financial resources with a longer term perspective, which puts it in a position to plan strategically and develop successful policy initiatives that can take into account changes in economic, political, legal and environmental conditions, both national and international.

Objectives and main tasks

Enova's main task is to achieve the objectives adopted by the Norwegian Parliament in the spring of 2000:

- limit energy use considerably more than if developments were allowed to continue unchecked;
- decrease dependence on electricity for heating purposes and increase annual use of water-based central heating systems based on renewable energy sources, heat pumps and waste heat by 4 TWh by the year 2010;
- to install wind power capacity of 3 TWh by the year 2010;
- to increase environmentally sound use of stationary, land-based use of natural gas.

The consolidation of policy and strategic planning responsibilities into *one* national agency seeks to improve energy efficiency, to increase flexibility in the energy supply and to decrease dependence on direct electricity for heating, and increase the share of renewable energy sources, other than large hydropower, in the energy supply mix.

Freedom of management and responsibility

To achieve these objectives, the Norwegian Parliament has indicated that it is prepared to provide grants up to NOK 5 billion (ca. 650 million Euros) over a ten-year period, providing a more predictable and stable funding situation. The funding will come from a levy on the electricity distribution tariffs and regular funding from the national budget. Enova will *manage* the Energy Fund and finance programmes and initiatives that support and underpin its objectives. Enova will be given the *freedom* to choose its policy measures and the *responsibility* to establish incentives and financial funding schemes that will result in cost effective and environmentally sound investments. Enova is expected to develop knowledge of and nearness to the market, be pro-active and engage market participants to stimulate energy efficiency and renewable energy initiatives. Enova's efforts will be scrutinised and expectations are high. Evaluation and reporting of activities and achievements will be done on an annual basis. After a four-year period, the Ministry of Petroleum and Energy will conduct a thorough evaluation of the various activities and results of Enova and make future

recommendations on funding levels and revisions of goals.
The above objectives mean that Enova will focus its efforts on both the energy supply and the energy demand side, and that high priority will be given to the development and adoption of reliable methodologies for performance measurement and results verification. Enova will participate in international activities and advise the Ministry in questions related to energy efficiency and new sources of renewable energy. The Norwegian Water Resources and Energy Administration is the regulatory body for the electric utility sector, and as such will remain responsible for various electricity demand and supply side issues.

Why restructure?

The time for large scale hydropower developments in Norway is over. Society is increasingly unwilling to accept the irreversible environmental impacts associated with large hydropower developments. A higher value is now being put on unspoiled wilderness than before. However, energy use in Norway continues to rise. Thus, even if Norway achieves its ambitious goals of improving energy efficiency and reducing its heavy reliance on electricity for heating, there will still be a need for additional energy supply in the future. Future generation of additional energy should preferably come from renewable energy sources, other than large hydro power developments.

In recent years Norway has experienced peak demand on cold winter days, which has brought the energy system closer to black-outs than ever before. Heating in residential, commercial and public sector buildings is heavily based on electricity, a situation that Enova's programmes very much aim to change. Incentives are being put in place to stimulate increased use of heating technologies other than direct electric heating.

The old and new organisation models

The old model under NVE

The old model for public energy efficiency was two-tiered. Government funds were spent on national efforts to reduce the growth in energy use and encourage the introduction of renewable energy. Funds from an end-use transmission charge (levy) were used on a local and regional level to provide information and advice to customers on efficient use of energy.

While the Norwegian Water Resources and Energy Directorate (NVE), a government body, was responsible for national efforts, the utilities were responsible for local and regional efforts. NVE subcontracted out most of the national work to four operating agents, working within separate segments of the market. The utilities subcontracted out most of the regional and local work to twenty Regional Energy Efficiency Centres (REECs).

NVE received instructions from the Ministry of Petroleum and Energy on the main policy issues to be addressed and goals to be achieved. During the last few years, policy focus has become more ambitious. From an earlier focus on improving end-user knowledge of efficient energy use, the focus has shifted to encouraging actual change in energy efficient behaviour and the increased introduction of renewable energy.

The new model

The new organisation model has at its core a national Energy Fund. The contributions to the Energy Fund stem from a levy on the electricity transmission charge and regular funding from the national budget. Enova manages the national fund and is free to choose which policy measures to implement to achieve its overall goals. However, Enova is also charged with providing a nation-wide information and advisory service on energy efficiency, non electrical heating alternatives, and renewable energy. Enova is market oriented and will buy capacity to implement and execute its programmes on a competitive basis from subcontractors.

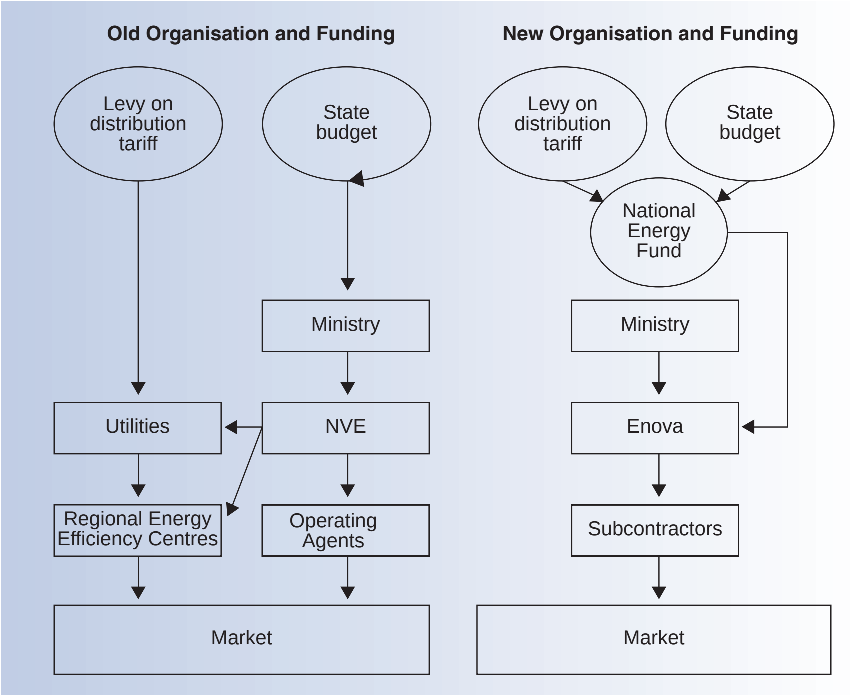

Figure 1: Old and new organisation models

A comparison between the old and the new model

Organisational matters

NVE, as the regulatory body for the utility sector, is subordinate to the Ministry of Petroleum and Energy. In the 1992-93 White Paper on Energy Efficiency and Renewable Energy, the Ministry signalled a change in the implementation of national programmes. As of 1995, NVE began implementing most of its work at the operational level through subcontractors. Subcontractors were granted contracts as operating agents. As the regulatory body, NVE also oversees the utility sector. The responsibilities of the utilities, as mandated by the provisions of the Energy Act of 1990, were vague and allowed utilities considerable freedom in how they chose to conduct matters at the operational level, weakening NVE's authority as controller and its ability to follow up the public sector energy efficiency efforts at the local and regional levels in an effective manner.

Furthermore, NVE had entered into agreements with each REEC. The agreement contained few specific obligations. It merely represented an "official" assignment of status as REEC. Utilities both owned and appointed management of the REECs. The overall coordination of public sector energy efficiency was dependent in large part on voluntary cooperation between the utilities, REEC's and NVE with its operating agents. Roles, authority and responsibility were unclear, making it difficult both to achieve overall goals and to offer a comprehensive service to the public.

Enova, organised as a public enterprise and reporting to its Board of Directors, has a clear role and clear objectives. It subcontracts programme coordination and project implementation to market actors on a competitive basis, thereby also stimulating the delivery of cost-effective energy solutions.

Financing

NVE received funds from the national budget on an annual basis. However, many projects are long term, making the national budget financing procedure unsuitable for this purpose. In contrast, utilities financed the local and regional work via a wire charge on the low-voltage grid levels. Utilities were not allowed to accumulate large deficits or surpluses on the balance of these funds from one year to another. The new energy fund, which is based on a combination of national budget funds and a fixed levy on the transmission charge, is allowed to accumulate and can be transferred from one year to the next. **Figure 1** illustrates the old and new situation.

Conclusion

The new organisational model is much more transparent and focused than the old one, with respect to structure, responsibilities and funding. It should provide a much better basis for realising Norway's national policy goals in the area of energy efficiency and renewable energy.

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Pulse Width Modulation control for small heat pump installations

Tests in a residential dwelling – Phase 2

Dr. Martin Zogg, Switzerland

The rationale behind Pulse Width Modulation heat pump control basically is to make full use of the thermal inertia of the building and its heat distribution system and to optimize heat consumption over the day, by making use of low-tariff electricity. This can be achieved by careful adjustment of the heat pump operating periods.

Testing

In Phase 2 of this project, two different heat pump controls supplied by two industrial partners were programmed with the new control strategies developed in Phase 1 (see p.22 of newsletter Vol. 20, Nr. 2). The controllers were tested in combination with an air-to-water heat pump installed in a private house, a typical building in need of renovation (**Figure 1**). The hydronic heat distribution system included a storage tank installed in series. Heat was distributed by means of floor heating (FLH) and radiators (RAD). Their relative contribution could be switched from 33% FLH / 67% RAD to 33% RAD / 67% FLH.)

Results

No problems were encountered in programming the controllers with the new control strategies. Using ambient temperature and water return temperature as input parameters, this control system achieved the same level of comfort in the living space as a conventional controller (CC), while providing the following additional benefits:

- the share of low-tariff electricity was between 60% and 70% in comparison to 43% for CC;
- longer heat pump running times of 0.5-1.5 hours were achieved at partial load;
- when the heat pump was switched off, the circulation pump could also be switched off, resulting in reduced auxiliary energy consumption;
- simplicity of regulation: there is no heating characteristic curve required, and it is not necessary to match the heating characteristic curve with the time or with the domestic hot water system;
- optimum use of low-tariff electricity without the need to oversize the heat pump.

Three control concepts

Three pulse width modulation concepts were tested. These concepts differ in the methods they use to determine the quantity of heat required ánd the optimum heat distribution during the day.

The first two concepts are fairly simple. In the first concept, the heat demand is determined from the energy characteristic as a function of ambient temperature. In the second, this demand is determined from the run time characteristic (heat demand determined by the energy characteristic divided by the heating capacity, which follows from the heat pump specifications). The first method does not take the thermal inertia of the building into account. The second does take this factor partly into account.

The third concept, called Model Predictive control, is considerably more complex and takes into account the thermal inertia of the building and the heat distribution system by means of a physical model. This method estimates the ambient temperature in the hours to come, based on the temperature measured during the previous 24 hours. In optimizing the heat supply, the

Figure 1: Building used to test the three control concepts based on pulse width modulation.

Coefficient Of Performance (COP) of the heat pump and the tariff structure and cut-off times of the electricity utility are also taken into account. Room temperature is indirectly taken into account via the return water temperature. The controller may be operated in one of two modes:

- minimum energy consumption;
- minimum electricity costs.

The control algorithms of the three Pulse Width Modulation concepts are described in the final report (see box at the end). The report provides detailed results for each test period.

Figure 2 gives an example of the room temperature distribution achieved using Model Predictive control. Despite the fact that the controller did not include a room temperature sensor, the standard deviation of the living room temperature remained below 0.5 °K.

Follow-up

The tests performed in the private house in Phase 2 also served to provide a realistic set of heat demand data for use in the ETH-Zürich dynamic heat pump test rig. In Phase 3 of the project, the ETHZ test laboratory plans to carry out a comparative study of the above control concepts under identical operating conditions. Later phases of the project will be concerned with:

- restricting the condenser outlet temperature in installations with high water flow reductions due to thermostatic valves;
- defrost control;
- and domestic hot water production.

Possible advantages to be gained from measuring room temperature and insulation will also be investigated.

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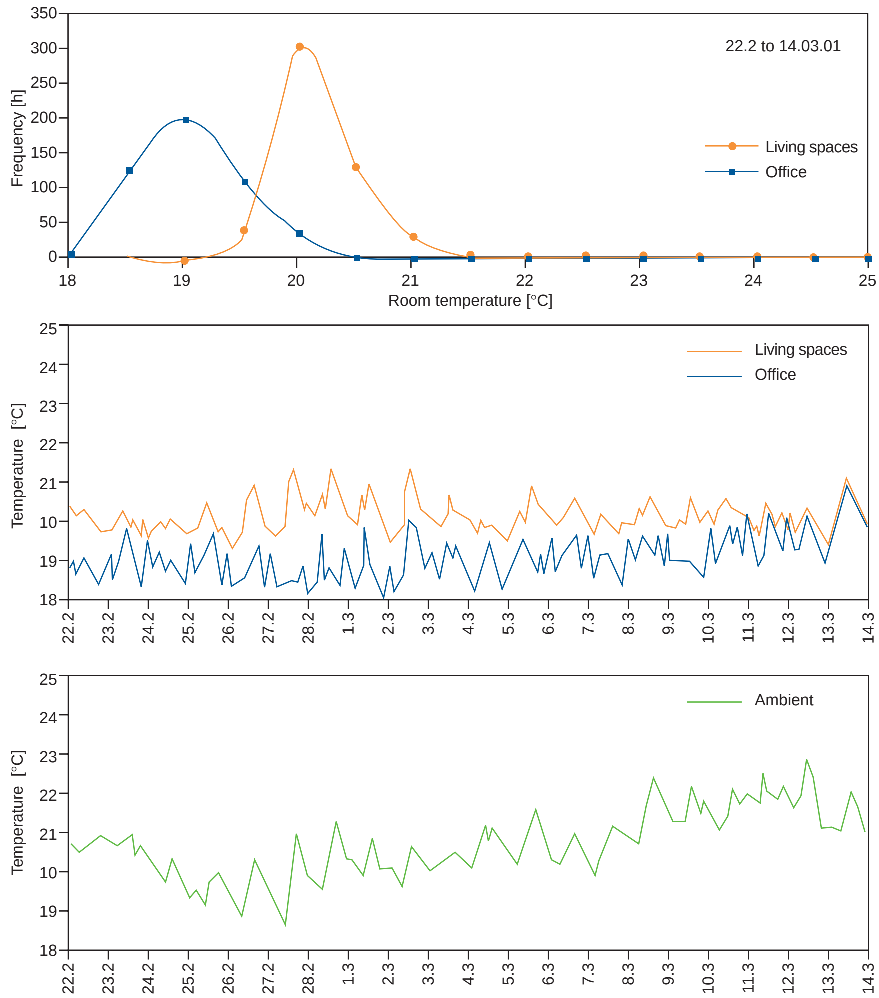

Figure 2: Room temperature variation in the living room and in the office compared with ambient temperature using Pulse Width Modulation control (Model Predictive control)

Detailed final report on the SFOE research project (in German!):
H.R. Gabathuler, H. Mayer, E.Shafai, R.Wimmer, Pulse Width Modulation for Small Heat Pump Installations, Phase 2, Final Report, Swiss Federal Office of Energy, 2002.

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The S.E. Asian air conditioning markets
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BSRIA has recently released a new research study into the air conditioning markets in Southeast Asia. Markets reviewed include Malaysia, Singapore, Thailand, the Philippines, and China. The Australian market was reviewed earlier this year. New findings are presented regarding the packaged air conditioning and close control market as well as the central plant market.

Air-to-air heat pump use in cold climates
IIR International Journal of Refrigeration
Vol. 26, nr. 1, January 2003, p.12-18

This article proposes a new sub-cooling system employing a scroll compressor with a supplementary inlet. It can effectively solve the shortcomings typical for operation in cold climates. A prototype air-source unit was validated and operated in winter in Beijing, China. Relevant dynamic performance functions were tested, and the results showed that the system could work very well at ambient temperatures as low as –15 °C. The application of air-source heat pumps could be extended substantially using this technique.

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Standard Reference Data Program, NIST
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Tel: +1 301 975 2008
Fax: +1 301 926 0416
E-mail: srdata@nist.gov
www.nist.gov/srd/nist23.htm
Price: USD 200.-. Owners of previous versions may upgrade for USD 100.-.

Version 7.0 of REFPROP, a PC based database of refrigerant thermodynamic and transport properties, includes 39 pure fluids and is capable of calculating properties for refrigerant blends with up to 20 component refrigerants. Features include:

- Additional fluids and mixtures;
- Updated and improved models for many fluids and mixtures;
- A graphical user interface that incorporates enhanced usability, new features and options;
- Increased calculation speed;
- More options for plots of thermophysical surfaces;
- More calculation options;
- Support for Excel spreadsheets and other applications.

Protecting the Ozone Layer, the UN History
Earthprint Ltd.
PO Box 119
Stevenage, Herfortdshire SG1 4TP
England
Tel: +44 1438 748111
Fax: +44 1438 748844
E-mail: orders@earthprint.com
www.earthprint.com
Price: USD 6.-, plus delivery costs.

The book tells the story of the Montreal Protocol, now recognised as a unique example of international co-operation on environmental issues. An insider perspective is given on the history of science, diplomacy, technology, implementation and compliance, and on the involvement of NGOs and media in the making of this historic agreement.

Standardschaltungen für Kleinwärmepumpenanlagen – 2 Volumes (in German)
FHBB
Institut für Energie
Fichtenhagstrasse 4
CH-4132 Muttenz
Tel: +41 61 467 4349
Fax: +41 61 467 4543
www.fhbb.ch/energie

In Part 1 of the study Standard Schemes for Small Heat Pump Systems, a step-by-step method for the design and layout of small heat pump systems was developed. The methods utilise simple rules and formulas based on empirical values and simulation results. Part 1 includes seven standard system arrangements with and without water heating. Part 2, Fundamentals and Computer Simulations, contains theoretical considerations and detailed simulation results. One conclusion drawn from the simulations is that heat pump systems without thermal storage and without thermostatic valves are the most cost-effective ones in Switzerland. The conclusions drawn from the simulations can be incorporated in installer design tools to size heat pump systems without the use of a computer. The project was sponsored by the Swiss Federal Office of Energy.

New MarkVI DOE/ORNL heat pump design model available

The new Mark VI DOE/ORNL design model is now available for online web use. The web model can be accessed at: http://www.ornl.gov/~wlj/hpdm/MarkVI.html. The Mark VI home page includes links to a description of the new features and to a companion Powerpoint presentation that shows more details of the engine and interface improvements. The previous Mark V model will remain available for the foreseeable future. HFC properties and correlations have been improved and merging options for heat exchanger surface, airflow and condenser circuit are available.

2003

Erdgekoppelte Wärmepumpen und unterirdische thermische Speicher Forum
18-19 February, 2003 / München, Germany
Contact: Anna Fuchssteiner
Otti Energie-Kolleg
Wernerwerkstrasze 4
93049 Regensburg, Germany
E-mail: anna.fuchssteiner@otti.de
www.otti.de

IIAR ammonia refrigeration conference
16-19 March / Albuquerque, New Mexico, USA
Contact: IIAR
Tel: +1 703 312 4200
E-mail: iiar@iiar.org
www.iiar.org

ISH 2003
25-29 March / Frankfurt, Germany
Contact: Messe Frankfurt GmbH at
Tel: 49 69 7575 6477
Fax: +49 69 7575 6758
E-mail: iris.jeglitza-moshage@messefrankfurt.com
www.ish.messefrankfurt.com

Thermodynamics Heat and Mass Transfer of Refrigeration Machines and Heat Pumps Seminar
31 March – 2 April 2003 / Valencia, Spain
Contact: Prof Rafael Royo
IMST Group, IIE
Departemento de Termodinámica Aplicada
Tel.: +34-9638-77325
Fax: +34-9638-77329
Email: rroyo@ter.upv.es
Internet: http://www.imst.upv.es/eu_seminar.htm

Earth Technologies Forum
22-24 April / Washington DC, USA
Tel: +1 703 807 4052
E-mail: earthforum@alcalde-fay.com

2003 IGSHPA Technical Conference and Exhibit
28-30 April / Stillwater, OK, USA
Contact: International Ground Source Heat Pump Association
Tel: +1 800 626 4747 or 405 744 5175
Fax: +1 405 744 5283

Cold Climate HVAC 2003, The 4th international Conference on Cold Climate Heating, Ventilation and Air Conditioning
15-18 June 2003 / Trondheim, Norway
Eurotherm Seminar
Contact: Conference Secretariat
SINTEF Energy Research Refrigeration and Air Conditioning
N-7465 Trondheim, Norway
Tel.: +47-73592511
Fax: +47-73593186
E-mail: elisabeth.sognen@energy.sintef.no

ASHRAE annual meeting 2003
28 June-1 July / Kansas City, USA
Contact : ASHRAE meetings section
Tel : +1 404 636 8400
E-mail : jyoung@ashrae.org
www.ashrae.org

21st IIR International Congress of Refrigeration
17-22 August 2003 / Washington DC, US
Contact: ICR 2003 Conference Manager, Nadine George
Hachero Hill, 6220 Montrose Road
Rockville, MD 20852
Tel.: +1-301-984-9450 x11
Fax: +1-301-984-9441
Internet: http://www.icr2003.org

3rd International conference on energy efficiency in domestic appliances and lighting (EEDAL '03)
1-3 October 2003 / Turin, Italy
Abstracts due: 31 January 2003
Tel: +39 0332 78 9299
Fax: +39 0332 78 9992
E-mail: jrc-eedal03@cec.eu.int
www.energyefficiency.jrc.cec.eu.int/events

4th International Symposium on Heating, Ventilation and Air Conditioning
9-11 October, 2003 / Beijing, China
Contact:
Tel: +86 10 6278 1339
E-mail: ishvac@tsighua.edu.cn
www.ishvac2003.org

2004

ASHRAE winter meeting and AHR Expo
24-28 January, 2004 / Anaheim, California, USA
Contact: ASHRAE meetings section
Tel: +1 404 636 8400
E-mail: jyoung@ashrae.org
www.ashrae.org

Interclima
3-6 February / Paris, France
Contact: Philippe Brocart
Tel: +33 1 4756 5088
E-mail: philippe_brocart@reedexpo.fr
www.interclima.com

Mostra Convegno Expocomfort
2-6 March / Milan, Italy
Contact:
Tel: +39 02 48555 01
Fax: +39 02 4800 5450
E-mail: mce@planet.it

Natural Working Fluids - 6th IIR Gustav Lorenzen Conference
29 August-1 September, 2004 / Glasgow, UK
Contact: Miriam Rodway
E-mail: oir@ior.org.uk
www.ior.org.uk/gl2004

5th International conference on compressors and coolants – Compressors 2004
29 September-1 October, 2004 / Nitra, Slovak Republic
Contact: Peter Tomlein
SZ CHKT, Hlavnà 325
900 41 Rovinka, Slovak Republic
Tel: +421 2 4564 6971
Fax: +421 2 4564 6971
www.isternet.sk/szchkt

Next Issue

Test procedures and efficiency labels

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International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster 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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6130 AA Sittard, The Netherlands
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Fax: +31-46-4510389
E-mail: hpc@heatpumpcentre.org
Internet: http://www.heatpumpcentre.org

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