Vol. 11, No. 3, October 1993

IEA Heat Pump Centre

NEWSLETTER

Heat Pumps and the Environment

IEA
OECD
heat pump
centre

Contents

Front Cover: *Installing a water-to-water electric heat pump in this recently restored 19th century building, at Lugano Lake, Switzerland, benefitted the environment by avoiding an annual emission of 4.8 tonnes CO_2.*

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Cooperation and Development (OECD) to implement an International Energy Programme.

A basic aim of the IEA is to foster cooperation among the 23 IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology, and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration currently within the framework of 35 Implementing Agreements, containing a total of more than 60 separate collaboration projects. This publication forms one element of this programme.

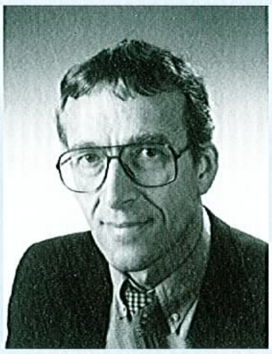
IEA Heat Pump Centre, 1993.

The nine member countries of the IEA Heat Pump Centre (HPC) form a network for exchanging information on heat pump technology. By increasing awareness and understanding worldwide, the HPC aims to accelerate the implementation of heat pump technology as a means to reduce energy consumption and thereby to limit harmful environmental effects. This publication is one element of the HPC activities.

Editing/Production:
Lucinda Maclagan / Roswitha Muyres / Heleen Smeets.
Technical Editing:
Jos Bouma / Bert Stuij / Mike Steadman.
Illustrations:
Offermans EPS, Maastricht.
Printers:
Huntjens Drukkerij, Stein.

ISSN 0724-7028

Time to Implement



Heat pumps are closely linked to two of the most pressing environmental problems perceived today: ozone depletion and the greenhouse effect.

The ability of heat pumps to save energy and thus mitigate the greenhouse effect is generally recognized. However, the matter has long been complicated by the environmental flaws of heat pump working fluids. The phase out of CFCs (and HCFCs in due course) is virtually eliminating their ozone depletion potential, but the impact of alternative working fluids on global warming remains an issue. It is interesting to observe in which directions solutions are sought. In Europe, some countries are opting for natural refrigerants such as ammonia, hydrocarbons and CO_2. In North America, the emphasis is on mixtures and blends based on HFCs.

With the environmental drawbacks of working fluids rapidly diminishing, it is appropriate to concentrate on the environmental strength of the heat pump: its ability to save energy. The containment of the environmental impact of energy use is a growing challenge. The IEA predicts that current policies in OECD countries will not reduce CO_2 emissions in the foreseeable future. At the same time the economic and population growth in developing countries can result in a large increase in greenhouse gas emissions. It is clear that these concerns require a truly global strategy with energy policies at its heart. And heat pumps can and should be part of energy policies in many countries.

In recent years, many heat pump research programmes have led to improved performance, higher efficiencies and wider applicability. While further worthwhile development continues, the emphasis should now shift to the implementation of available technology, both in buildings and in industry. It is encouraging to see that a number of governments are becoming more aware of the potential benefits of heat pumps and are actively promoting implementation. The IEA Heat Pump Programme has also taken a lead, with the implementation of a worldwide promotion campaign under the slogan 'better by nature'.

The time is now right for widespread implementation of heat pumps.

Jos W.J. Bouma
General Manager, IEA Heat Pump Centre.

News & Views

"Risks from propane and ammonia are grossly exaggerated"

Annex 20 completes study on working fluid safety

IEA - With much discussion on the merits or otherwise of using natural refrigerants such as propane and ammonia in heat pumps and refrigeration equipment, Annex 20 of the IEA Heat Pump Programme - 'Working Fluid Safety', which began 2 1/2 years ago, addresses one of the 'hottest' issues of today's HVAC&R industry. With the Annex nearing termination, Prof. Jan Berghmans of the Catholic University of Leuven in Belgium - the Operating Agent, reports on the results.

Concern for the risks involved in the use of alternative working fluids (such as propane) or in the expanded use of conventional working fluids (such as ammonia) led five countries (Belgium, Japan, The Netherlands, Norway and Switzerland) to collaborate on Annex 20. The work encompassed not only working fluids in heat pumps but also those used in refrigeration machines.

The first task was to conduct a literature survey on accidents related to these systems. The limited amount of data on non-domestic ammonia systems revealed that fatal accident rates related to ammonia systems are low when compared to industry in general. Very little data was available on other working fluids. However, statistics related to the use of natural gas revealed that the risk of fatal accidents from the use of flammable working fluids in domestic refrigerators is negligible.

In the second part of the study, refrigeration standards were analyzed for a number of countries. This revealed a large diversity in the evaluation of risks from working fluids.

The study continued by examining techniques for determining the effect of fires, explosions and emissions on people. Calculation techniques were developed in order to predict the following effects:

- pressure waves due to explosion of a pressure vessel;
- pressure waves generated during the explosion of a flammable cloud of working fluid;
- thermal radiation from a jet or pool fire;
- exposure to toxic clouds.

Emission calculation procedures were developed in order to determine the size and characteristics of a cloud of working fluid. The software developed has been made available to all Annex participants so they can quantify the effects of potential accidents with heat pumps and refrigeration equipment. In addition, a database was set up to provide safety data (toxicity and flammability) on more than 160 working fluids.

From these studies, the risks from various working fluids were compared. It can be concluded that the risks assigned (subjectively) to working fluids such as ammonia and propane are, in general, grossly exaggerated.

(Source: Prof. Jan Berghmans, Catholic University of Leuven, Celestijnenlaan 300A, 3030 Heverlee, Belgium. Tel. +33-16-28661 Ext. 2541; Fax +33-16-293674.)

Cold-climate heat pumps receive warm reception

Canada - The 2nd International Conference on Heat Pumps in Cold Climates aroused considerable interest at Moncton this August. Sitting, somewhat ironically, in space-cooled rooms, the participants heard presentations on the theme 'Unique Performance Requirements and Application Challenges Facing Heat Pumps in Cold Climates.' Topics included environmental benefits, Demand Side Management (DSM) programmes, new refrigerants, advanced ground heat-exchangers, compressor developments, advanced cycles, and systems analysis. Much attention was focused on direct-expansion ground-coupled systems. The conference was held on 16 and 17 August, and the proceedings will be available at the end of the year.

(Source: IEA Heat Pump Centre.)

Faultless operation can be achieved with standard products

Heat pumps form happy partnership with cogeneration

Switzerland - Through its Energy 2000 programme, the government is encouraging the use of small cogeneration plants for heat supply with the important proviso that 33% of the electricity generated is used to power heat pumps. The combination of heat pumps and cogeneration has been tried out in Switzerland over the past five years and the results have been very positive.

A typical system will supply about twenty homes or an office block via a heat distribution network. The cogeneration units use natural gas or biogas and supply electricity and heat at an efficiency of 88-95%. In combination with heat pumps, the efficiency of the system rises to 140-160% and CO_2 emissions are reduced by 30-50% in comparison with a conventional gas-fired heating system.

While a similar performance may be achieved with a gas-driven heat pump, the combination of two machine types (the heat pump and cogeneration unit) offers considerable flexibility:

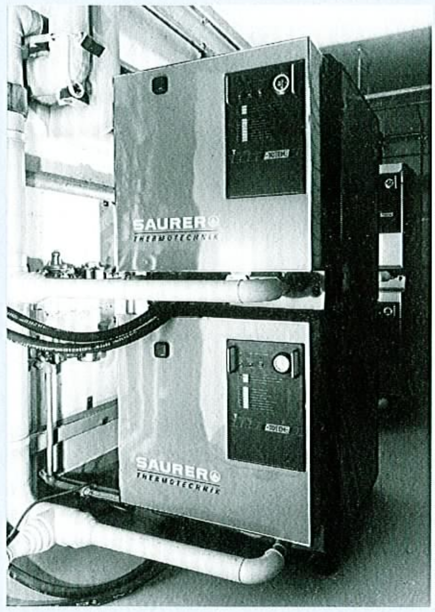
According to demand, either one or both of the units may be operated;

The public network can be used as buffer for excess power generated by the cogeneration unit;

The cogeneration unit can help limit peak loads on power utilities;

The cogeneration and heat pump units need not be installed in the same location since connection via the public network is not limited by distance.

Experiences so far show that faultless operation can be achieved with standard products. The transfer of knowledge on these systems is being enabled by courses run by the Swiss programme on the rational use of Energy (RAVEL).



These cogeneration units work together with heat pumps to supply a heating network.

(Source: Dr Hansueli Bruderer, Saurer Thermotechnik AG, P.O. Box 196, CH-9320, Arbon, Switzerland.)

Alternatives conference addresses hot issues

USA - According to one participant at the R22/R502 alternative refrigerants conference, "the hottest issue is time". This reflected the urgency surrounding the replacements issue, while concerns over the choice of second generation alternatives also helped to raise the temperature of the discussions in Gaithersburg MD. The presentations highlighted the difference between European and North American attitudes to natural and hydrocarbon type refrigerants. In the USA, attention is focused on synthetic refrigerants including mixtures. Key aspects of research are flammability, performance, capacity and thermophysical properties. Evidently there is still disagreement on the test procedures to determine flammability and flame propagation. Mr Mark Menzer of ARI (The Air-Conditioning and Refrigeration Institute) presented results from calorimetry tests for HCFC-22 alternatives under the Alternative Refrigerants Evaluation Program (AREP). Reports on compressor and system drop-in tests are now available from ARI.

In Norway and Germany, decisive steps have been made towards the use of ammonia and hydrocarbons. Prof. Kruse of the University of Hannover, Germany presented an overview of alternatives developments in Europe. In Germany, much discussion centres around the global warming potential of refrigerants.

Ammonia is still used in the USA for air conditioning equipment but is recommended only for commercial and industrial applications. Considerable barriers must be overcome before propane can become an acceptable refrigerant

(continued on page 6)

(continued from page 5)

here, although a proposal for a standard to enable the safe use of propane is currently being prepared for submission to US standards organizations.

The conference was organized by ASHRAE and the National Institute of Standards and Technology (NIST) and held on August 19 and 20 1993. The proceedings will be published at the end of the year.

(Source: IEA Heat Pump Centre.)

Utility promotes better systems

USA - Duke Power of North Carolinais offering advertising support to authorized dealers who have been certified in the design, installation, and service of heat pump equipment. Authorized dealers can participate in an advertising plan funded jointly by Duke Power, the distributer and the dealer. Alternatively, they can receive cash for advertising, training or service equipment. Customers benefit directly by receiving financing and rebates from Duke Power.

The utility is also encouraging improvements of existing systems by paying half of the costs (US$ 50) of ductwork leakage testing, and 95% of any subsequent repair costs. This should have significant benefit since duct leakage can account for 20 - 25% of space conditioning energy use.

(Source: EPRI Heat Pump News Exchange, Summer 1993)

ARI holds novel cycles competition

USA - The Air-Conditioning and Refrigeration Institute (ARI) is sponsoring a competition to promote consideration of novel cycle technologies for application in the space conditioning or refrigeration industry. Novel cycles are defined as refrigerant cycles not in common use, but need not be original.

Papers should define and analyze the theoretical cycle, paying particular attention to non-idealities. Possible applications for the cycle must also be considered. All papers submitted for this contest must reach ARI by February 28, 1994. Full details are available from ARI's Research and Technology Department at 4301, N. Fairfax Drive, Suite 425, Arlington, Va. 22203, USA, (Tel.:+1-703-524-8800; Fax: +1-703-528-3816). ARI will award cash prizes for well-written papers judged to be of value to the air-conditioning industry.

(Source: Koldfax from the Air-Conditioning and Refrigeration Institute, June 1993.)

Europe sets air cycle project in motion

The Netherlands - A multi-national research project on air cycle heat pumping systems is to be carried out under the European Community's technical development programme on non-nuclear energy - JOULE II. With an estimated budget of 1 million ECU (European currency units - 1 ECU = US$ 1.1) the proposed project will develop systems for space conditioning and refrigeration applications.

Research will cover closed-cycle systems as well as open-cycle systems where the refrigerant air is used to heat or cool a space directly. The project will take approximately three years and will involve research institutes and industries in Germany, Ireland, the Netherlands and the United Kingdom. Project coordination will be provided by the Netherlands Organization for Applied Scientific Research - TNO.

(Source: Mr René van Gerwen, IMET-TNO, the Netherlands, Tel.: +31-55-493172; Fax: +31-55-493493.)

Dutch Seek Programme Partners

The Netherlands - As reported in the previous Newsletter issue (page 5), a programme on heat pumps is now underway in the Netherlands. The programme is managed by TNO (The Netherlands Organization for Applied Scientific Research), and is in tune with the heat pump related activities of Novem (The Netherlands Agency for Energy and the Environment). For the execution of this new venture, help is sought from contractors within the Netherlands. In addition, the programme would welcome the cooperation and advise of heat pump experts from all parts of the world. Further information is available at the address below.

(Source: Mr Peter Oostendorp, IMET-TNO, P.O. Box 342, 7300 AH Apeldoorn, the Netherlands, Tel.: +31-55-493-771; Fax: +31-55-419-837.)

Technology & Applications

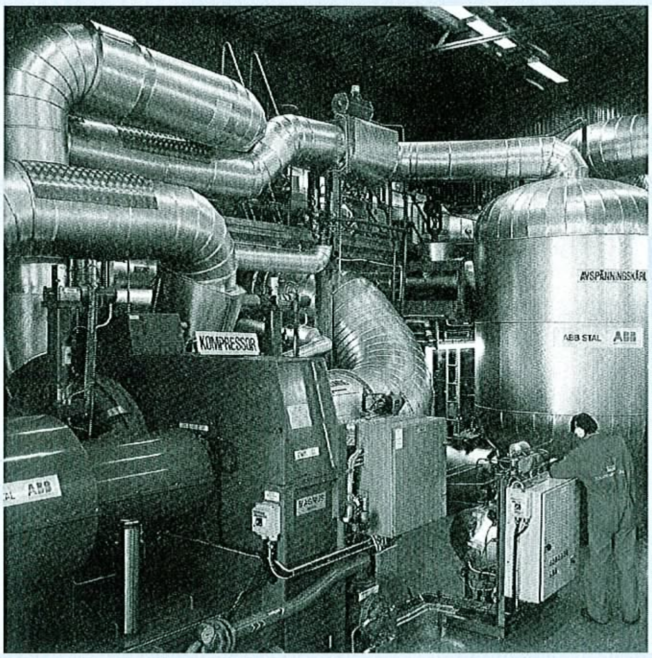
More favourable results for propane heat pumps

Germany - Following hard on the heels of RWE (see HPC Newsletter Vol. 11, No.2, p.8), electric utility VEW is also trying out hydrocarbons as alternatives to HCFCs and HFCs in heat pumps. In a test run, two heat pumps using CFC-12 and HCFC-22 respectively, were converted to run on a propane/butane mixture. The investigation showed that propane-based heat pumps can operate effectively in low-energy houses where heat is recovered from exhaust air. The tests measured an improvement in COP of 3% to 4% and demonstrated that propane performs favourably at high supply (output) temperatures. With these positive experiences, VEW now plans further work on the development of propane-filled heat pumps including equipment optimization and practical realization. The safety issues concerning the use of propane will also be addressed.

(Source: Wärmepumpe from IZW, Germany, June 1993.)

District heating heat pump converted to HFC-134a

Sweden - While heat pumps continue to play an important role in the production of district heating in the 1990s, the potential environmental benefits of these systems is reduced through the use of CFCs and HCFCs. At the Hammarby district heating plant, one of five electric heat pumps has been successfully converted from CFC-500 to HFC-134a refrigerant. The heat pump, rated at about 25 MW, is equipped with a two-stage turbo compressor and uses treated sewage effluent as heat source.



This 25 MW district heating heat pump now uses HFC-134a.

The conversion required a complete overhaul of the unit, including oil change and the replacement of shaft seals. The same type of synthetic oil was used, as well as the same shaft seal design. New impellers were fitted and gaskets, O-rings and some safety valves, instrumentation and pressure gauges were replaced. The process software was modified and safety functions were adjusted. A new type of drying agent was used. The rotational speed of the compressor remained unchanged. Approximately 21 tonnes of the original refrigerant was replaced by HFC 134a.

The heat pump was converted in six weeks and was then operated continuously for a twelve month trial. The project was carried out by ABB STAL AB in cooperation with Stockholm Energi AB and technical help from ICI. The total cost of the project was 12 million Swedish Krona (US$ 1.5 million).

Higher Temperature

The converted heat pump was able to supply 90 °C heat to the district heating network instead of 85 °C reached previously. The heat pump functioned in most other respects in the same way as with the original refrigerant although anomalies were noted in the separation of oil and refrigerant. Performance tests showed the coefficient of performance (COP) to have remained unchanged and that the compressor could operate at even lower partial loads than before.

Oil samples taken throughout the trial period showed no notable abnormalities. After twelve months, the trial period concluded with the

(continued on page 8)

(continued from page 7)

disassembly of several components for closer analysis. There was no evidence that either the teflon seals or O-rings had been affected. However, the O-rings of the shaft seal for the service-fluid pump had significant wear. This shaft seal has now been replaced with an alternative version, which uses an expander seal instead of an O-ring. No significant leaks were discovered in the gaskets.

Refrigerant loss of approximately 3% during the twelve month trial period may be attributed largely to leakage from the compressor's shaft seals. However, there is no evidence to suggest that the new refrigerant has increased the amount of leakage.

Satisfactory Trial

While the performance of this particular heat pump cannot be assumed to apply to all similar heat pumps, the trial has proved that it is possible to convert to HFC-134a, while retaining the same functional characteristics and satisfying performance specifications.

(Source: Swedish National Team.)

Linear compressor offers high efficiency gain

USA - A linear compressor, currently in development by Sunpower Inc., has received lavish praise for its energy saving potential by the Environmental Protection Agency (EPA). "We believe this invention will do for the refrigeration and air conditioning industry what the microchip did for the computer" pronounced EPA administrator Carol Browner.

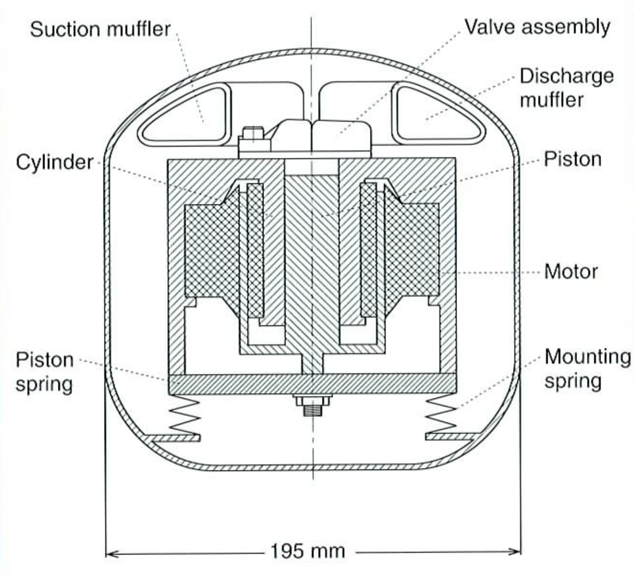


Figure 1: Linear Compressor under development by Sunpower Inc.

Like a conventional compressor, the linear model (see Figure 1) uses the up-and-down motion of a piston to pump gas. But a linear motor drives the piston directly without the need for a crank mechanism. The piston oscillates rapidly back and forth in its cylinder, floating contact-free on a gas film. The use of gas bearings means that the refrigerant vapour can serve as its own lubricant thus eliminating the difficulties associated with refrigerant oil.

The compressor has been demonstrated in Stirling cycles where air, helium or hydrogen is used as working fluid. Commercialization of this technology is being considered for domestic refrigerators for which energy savings of 15% are promised. The development work has been supported financially by EPA and by Americold, a unit of White Consolidated Industries.

(Source: Air Conditioning and Refrigeration News, 14 June 1993.)

Markets

Survey shows decline in world air conditioner market

Japan - The Japan Refrigeration and Air Conditioning Industry Association (JRAIA) has recently disclosed the results of a survey of global supply and demand for air conditioners (A/C). The survey covers two categories of A/C: room A/Cs for the residential market and packaged A/Cs for shops, restaurants and offices. Room A/Cs generally refer to window type, but for Japan and some other countries, small split systems are also included.

(continued on page 9)

Type	Oct '92 to June '93 No. of units	% change from '92
Domestic		
Room A/C	4,514,137	-15.1
Cooling-only	895,796	-25.5
Heat Pump	3,618,341	-12.1
Packaged A/C	589,289	-14.9
Cooling-only	102,175	-22.1
Heat Pump	487,114	-13.2
Export		
Room A/C	1,124,215	-25.3
Packaged A/C	234,198	-13.9

Table 1: Air conditioning shipments in Japan.

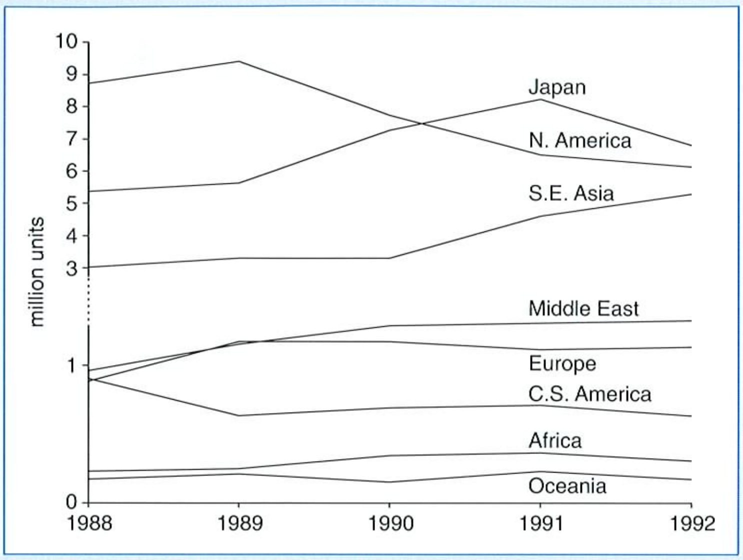


Figure 2: World demand for air-conditioners.

(continued from page 8)

The survey shows that in 1992, world demand declined by 5% to an estimated 21.8 million units. As indicated in Figure 2, this downturn contrasts with a continued rise in A/C demand in previous years in some regions. Only South East Asia shows continued growth, most notably in China (see page 10).

In Japan, the latest statistics from JRAIA show a continued fall in A/C demand, although the fall in heat pump demand is less severe than for cooling-only units (see Table 1). Exports are also falling.

(Sources: JARN, July and August 1993, and the Japanese National Team.)

Heat pumps serve nearly 7 million homes

USA *- The Energy Information Agency (EIA) has completed a "Housing Characteristics" survey of U.S. homes in 1990. This finds that 6.4 million homes use heat pumps as the primary heat source out of a total of 94 million housing units, a saturation of 6.9%. A further 400,000 heat pumps are used as `secondary' heating equipment.*

Heat pump use has more than doubled in the ten years from 1980 when the Decennial Census of Population and Housing counted 3.1 million homes using heat pumps. As is well known, the greatest penetration for heat pumps is in the Southern States where 4.8 million homes (15%) have a heat pump. The survey also considers the influence of climate on heat pump use, showing that almost no heat pumps are used in regions with more than 7,000 heating degree days (HDDs) (measured in Fahrenheit relative to 65°F: equivalent to about 3,800 HDDs measured in Celsius relative to 18°C).

Further information on the study is available from EIA's National Energy Center, E1-231, Forrestal Building, Room 1F-048, Washington D.C., USA. Tel: +1-202-586-8800.

Loan

The influence of utility run incentive schemes on heat pump growth is illustrated by the low-interest loan programme run by Tennessee Valley Authority (TVA). Since 1979 when the programme begun, heat pump saturation in the seven states served by TVA has risen from 9% to nearly 23% with nearly 120,000 heat pumps installed under the scheme. Participating power distributers can offer incentives such as cash payments, electric bill credits or low-interest loans of up to US$ 7,500. Customers may take up to ten years to repay the loan without having to make a down payment. The programme applies to both new and old housing and includes an on-site inspection to ensure that equipment is properly installed. The programme has made significant energy savings by replacing the traditional resistance heating systems.

Demonstration

Further north, the merits of the ground-source heat pump are being promoted in an energy-efficient home currently under construction in Vermillion, South Dakota. Known as E-2000, the home will demonstrate the energy saving benefits of advanced building techniques and materials, insulation and energy-efficient appliances. It will be heated and cooled by a ground-source heat pump and passive solar energy. The project is sponsored by a local utility as well as a bank and local government.

(continued on page 10)

(continued from page 9)

Gas Furnaces

But not all developments in the U.S. are good for heat pumps. In Falls Church, Virginia, the Washington Gas Light Company is reaping the benefits of a lucrative market for the replacement of residential heat pumps by gas furnaces. Working with HVAC contractors, the utility expects to replace 3000 heat pumps in 1993, adding to the 1000 replaced last year.

(Source: Air Conditioning and Refrigeration News, 21 June and 2 August 1993.)

World's fastest growing market

China - According to an industry source, the demand for room A/Cs appears to have jumped from 800,000 in 1991 to 2 million in 1992. A further rise to 2.5 million is expected for this year and 5 million units is predicted for 1997. With these figures, the Chinese market stands out from the rest of the world in terms of growth rate. Most of this rise is due to demand from the southern districts centering around Kwangshow. Sanyo is already producing room A/Cs in China and will soon be joined by Sharp and other Japanese manufacturers. The current demand is characterized by an increasing share of split systems for room A/C which rose to 45% in 1992 as against a 55% share for window type equipment.

(Source: JARN March, 1993.)

IEA Heat Pump Programme

HPC Workshop reviews heat pump water heaters

Deep in the Rocky Mountains near Denver, USA, surrounded by snow-capped giants, experts attended an HPC Workshop on "Domestic Hot Water Heat Pumps". The framework for the two-day programme of presentations and discussions was the HPC's analysis on this topic, published in April of this year. Presentations from North America, Japan and Europe addressed issues such as developments in performance and features, actual field performance in buildings, and factors which have successfully encouraged markets. These presentations initiated lively discussions channelled through three discussion groups dealing separately with technology, markets and applications. One interesting conclusion was that heat pump water heater technology is mature, products are available, and applications have been realized - putting this technology to more widespread use is purely a question of marketing. The participants also discussed how the technology could benefit from further activities within the IEA Heat Pump Programme.

The Workshop took place on the 1st and 2nd of July and was organized jointly by the HPC and the U.S. National Team, and co-sponsored by EPRI (Electric Power Research Institute) and the U.S. Department of Energy. The proceedings will be available from the HPC in November this year.

(Source: IEA Heat Pump Centre.)

France signs up

The IEA Heat Pump Programme welcomes France as its newest member and a participant of Annex 21. With the departure of Finland, there are now fifteen countries active in the Programme.

Programme activities are summarized in Table 2. As shown, the work of Annexes 17 and 20, including the production of Final Reports, is nearing completion. Annex 18 will be publishing several important equations-of-state for alternative working fluids in internationally renowned scientific journals.

Maastricht, in the Netherlands, will host two Heat Pump Programme meetings this Autumn: Annex 21 holds its third Expert's Meeting there and the HPC (Annex 16) holds its National Teams Working Meeting where strategies for the promotion of heat pumps, and the ongoing Analysis: 'International Heat Pump Status and Policy Review' will be discussed.

The Executive Committee, representing Programme member countries, will consider proposals for new Annexes at their October meeting in Rome, Italy. Proposals include:

- 'Chemical Process for Ecological Thermal Energy Systems' and
- 'Heat Pump Systems in Low-Energy Buildings'

More information on the IEA Heat Pump Programme is provided in two recently released brochures - one a general description of the IEA Heat Pump Programme, and the other a summary of its 'Strategy Plan to the year 2000'; both are available from the HPC (see back inside cover).

(Source: Technical Services Support Unit at the IEA Heat Pump Centre.)

No.	Annex Agent	Operating	Participants	Start Date	Completion
15	HP systems with direct expansion ground coils	CA	AT, CA, JP, US	1989	Apr. 1993
16	Heat Pump Centre	NL	AT, CA, IT, JP, NL, NO, SE, CH, US	Jan. 1990	
17	Experiences with new refrigerants in evaporators	SE	CA, NL, NO, SE, CH	Nov. 1990	Oct. 1993
18	Thermophysical properties of environmentally acceptable refrigerants	US	AT, CA, DE, JP, NO, SE, UK, US	Dec. 1989 Jan. 1993 [1]	Dec. 1992 Dec. 1996 [1]
20	Working fluid safety	BE	BE, JP, NL, NO, CH	Apr. 1991	Oct. 1993
21	Global environmental benefits of industrial HPs	US	CA, FR, JP, NL, NO, SE, UK, US	Jan. 1992	Apr. 1994

Participating countries: Austria (AT), Belgium (BE), Canada (CA), Denmark (DK), France (FR), Germany (DE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), Spain (SP), Sweden (SE), Switzerland (CH), United Kingdom (UK), United States (US).

[1] Phase two

Table 2: Summary of the Annexes.

Annex 21 examines industrial heat pump potential

Industrial heat pumps (IHPs) have generally been viewed as a means to conserve energy; however they can also improve plant productivity and expand process heating capacity at low costs compared to boilers. Because of their energy savings potential, IHPs should also be viewed for their potential to reduce pollution (both air and water) by decreasing the combustion of fuels. To assess the potential environmental benefits of IHPs, eight countries (see table) are currently participating in Annex 21 - 'Global environmental benefits of industrial heat pumps'. Mr Steven Williams, of RCG/Hagler, Bailly, Inc. - a contractor for this Annex - reviews the work programme.

The objectives of the Annex are to provide potential IHP users with a tool to screen potential opportunities at their plants, and to provide policy makers with information on the benefits of IHPs. Annex activities are focused on the development of a personal-computer program and a market-potential study.

Program

The computer program will identify applications where IHPs can be used economically. It will contain data on the performance and cost characteristics of some 20 IHPs, including electric-, primary energy- and waste-heat driven technologies divided into four categories, namely: closed-cycle, thermal vapour recompression (TVR), mechanical vapour recompression (MVR), and absorption. The user will be able to determine the technical and economic feasibility of different heat pumps in various industrial processes. This will allow industrial firms to screen their process operations for IHP opportunities.

Data on more than 100 industrial processes and unit operations will be included in the program, while site-specific data may also be analyzed. The program will identify suitable heat pumps for operation at the sink and source temperatures specified by the user and outline possible heat pump configurations. It will inform the user on the heat pump lifetime costs and calculate the payback time based on user information on fuel prices.

The program will be available to interested parties in countries participating in the Annex.

Market Potential

Annex participants are now in the process of analyzing the environmental benefits of IHPs by conducting a market-potential study. The focus will be on five main industries - chemicals, food, petroleum refining, pulp and paper, and textiles, although the major industries in each country will also be covered. The study will examine the future potential for IHPs and the associated energy savings. The potential reductions in SO_X, NO_X, CH_4, and N_2O emissions will be determined from the estimated energy savings.

Annex 21 will be finalized in the Spring of 1994 when both a detailed and a summary report will be published. A workshop to discuss the findings of the Annex is also planned for this time.

(Source: Mr Steven Williams, RCG Hagler, Bailly, Inc., 1530 Wilson Boulevard, Suite 900, Arlington, VA 22209-2406, USA. Tel.: +1-703-351-0300 Fax: +1-703-351-0342.)

Heat Pumps and the Environment - an International Overview

Mike Steadman, IEA Heat Pump Centre

Since the 1992 United Nations Conference on the Environment and Development (UNCED) in Rio de Janeiro, many countries are now committed to limiting the emissions of greenhouse gases. The HPC's analysis 'The Impact of Heat Pumps on the Greenhouse Effect' has suggested that heat pumps can make a major contribution towards meeting this commitment, especially with regard to the reduction of CO_2 emissions. This article summarizes the growing evidence on the emissions reduction potential of heat pumps, and highlights some of the measures now being taken to help realize this potential.

* * *

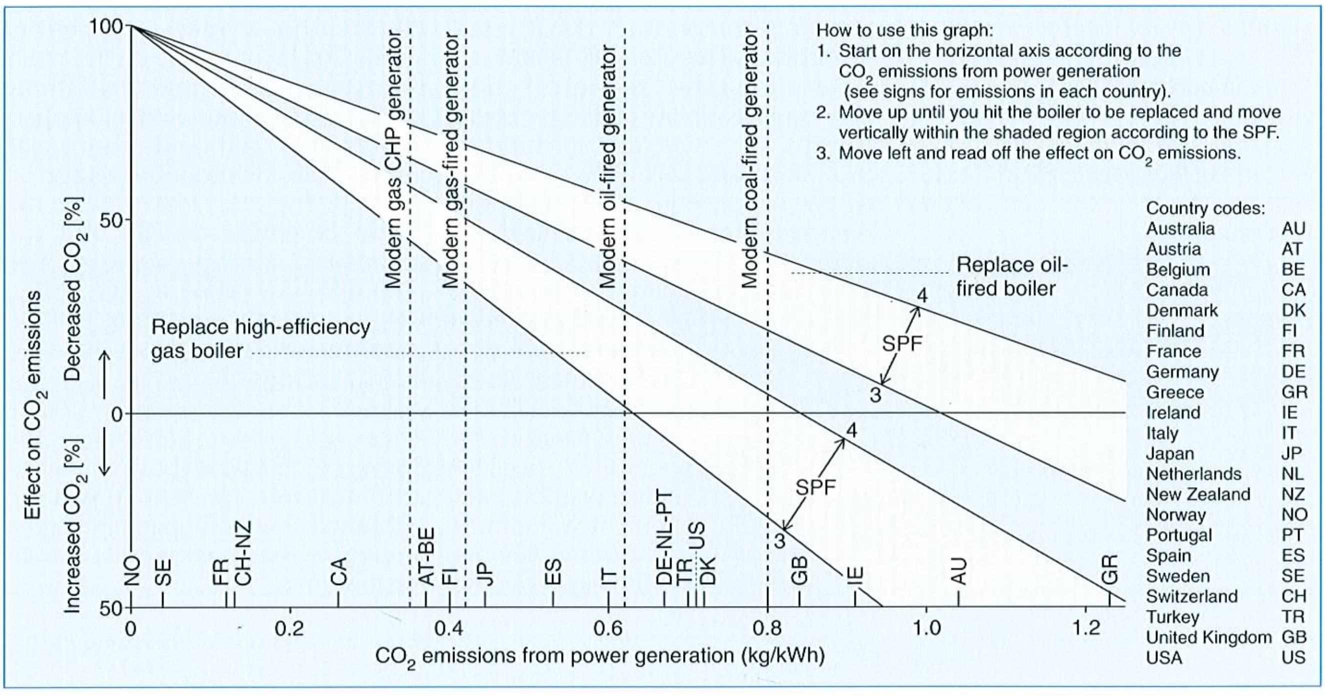
While the energy-saving benefits of heat pumps are clear, their environmental impact is complex to assess, as it depends on the technology, the drive energy and the working fluids. With the move away from CFCs, the environmental drawbacks from working fluids are rapidly diminishing. A closer look at progress in this field will be given in the March 1994 issue of this Newsletter.

The potential of electric heat pumps to reduce CO_2 emissions is to some extent open to interpretation - should the CO_2 emission rate from the total electricity network be considered, or just the marginal power used to drive newly installed heat pumps? And what type of conventional heating system should be used for comparison? This can depend on how the availability of gas is interpreted.

A Simple Comparison

Figure 1 provides a simple method for comparing the CO_2 emissions from space heating with an electric heat pump to those from a gas or oil-fired boiler. As shown, electric heat pumps driven by modern power generators, offer substantial CO_2 reductions over

Figure 1: Percentage reduction in CO_2 emissions when using an electric heat pump in place of a conventional boiler. CO_2 emissions from national power generation is calculated using IEA data on fuel supplied to power utilities, on electricity consumption, and on trade in electricity in 1990. Emissions: gas boiler 0.21 kg CO_2/kWh; oil boiler 0.34 kg CO_2/kWh. CHP: avoided CO_2 emissions allocated equally to heat and power.



Assessing the environmental impact

Austria Heat pumps have been estimated as having the potential to reduce CO_2 emissions by 4% by meeting 15-20% of the heat demand. In 1992, 111,500 heat pumps were in use, avoiding an estimated 730,000 tonnes of CO_2 emissions. This is equivalent to about 1.3% of the total energy-related CO_2 emissions in 1990 in Austria estimated by the IEA.

Canada Electric resistance heating is the principle heating method for about 30% of Canadian households and offers a large potential for reducing CO_2 emissions. Ontario Hydro have estimated that annual electricity demand could be reduced by 7.6 TWh in Ontario through the use of heat recovery heat pumps in single-family homes. Based on average emissions of 0.26 kg CO_2/kWh from total Canadian power generation, this equates to a saving of about 2 million tonnes of CO_2. In 1990, Canada's energy-related emissions totalled 435 million tonnes CO_2 according to IEA statistics.

Italy Air-to-air electric heat pumps, with an average COP of 2.7, are now installed in about 1% of Italian homes, where it is estimated that they avoid around 15% of the CO_2 emitted from conventional heating systems. This amounts to a little less than 0.2% of the total CO_2 emissions resulting from the total demand for home heating. The potential of heat pumps to reduce CO_2 emissions is now recognized by the government which offers subsidies for heat pump systems.

Japan The Japanese National Team estimates that heat pumps will save between 1 and 2% of the total energy supply in the year 2000. This will result in a 2 to 4% reduction in emissions of CO_2, SO_x and NO_x. However, they point out that the fact that most heat pumps are sold as air conditioners complicates matters. The widespread diffusion of air conditioners has significantly increased electricity consumption. In addition, the use of CFCs has also been an environmental drawback. The latter problem will be resolved when government measures to encourage recovery and recycling, currently under discussion, are realized.

Netherlands In conjunction with their work for Annex 21 of the IEA Heat Pump Programme, Dutch research group TNO has estimated that industrial heat pumps could save an annual 12.7 TWh energy which would result in a CO_2 emissions reduction of 2.34 million tonnes CO_2 per year. Currently, less than 5% of this potential is realized today. In its newly initiated heat pump programme, the government has set a target of saving 10 PJ (2 TWh) in the year 2000 with heat pumps. IEA data on the Netherlands report energy-related emissions of 183 million tonnes CO_2 in 1990. Total primary energy supply was 896 TWh.

(continued on page 14)

conventional fossil-fuel heating systems, especially when SPFs (Seasonal Performance Factors) improve. A reduction in CO_2 emissions from power generation would also be beneficial, but IEA statistics suggest that the average CO_2 emissions from all OECD countries will remain at around 0.6 kg CO_2/kWh in the year 2000. Only Denmark, Greece, Ireland and the UK are predicting significant CO_2 reductions, while emissions from Belgium, Finland and New Zealand are increasing.

More studies are being made to assess the current and projected impact of heat pumps on the environment. Articles further in this issue of the Newsletter highlight the views of experts in Japan, Germany, the Netherlands, United Kingdom and the United States. Some environmental assessments from HPC member countries are highlighted in the blue sections of this article.

Commitment

Despite the growing evidence on the environmental benefits of heat pumps, only a few governments explicitly include heat pump technology as part of their energy policy.

Switzerland's Energy 2000 programme includes a commitment to increase the contribution of renewable energy to 3% of total heat production, or 3000 GWh. Heat pumps are expected to contribute roughly 40% towards the attainment of this target by the replacement of fossil fuel boilers by electric heat pumps. The policy considers the environmental effect of the increased electricity capacity this demands: It stipulates that the electricity used to drive newly installed heat pumps must come firstly from the replacement of existing electrical heating systems, or secondly from cogeneration plants running on a portion of the fuel saved by replacing oil or gas-fired heating systems.

(continued from page 13)

Norway

Estimates by Energidata A/S show that the technical potential of heat pumps is an avoidance of 3.27 million tonnes CO_2. More realistically, an avoidance of 2.43 million tonnes CO_2 is considered to be economically viable for the country as a whole although this would be reduced to between 0.96 and 2.28 million tonnes (depending on interest rates) when left to private investments. For comparison, the IEA estimate of the total energy-related CO_2 emissions in Norway in 1990 was 31.9 million tonnes.

Sweden

Chalmers Industrieteknik has studied the options available for reducing the CO_2 emissions currently emitted from its many oil-fired district heating systems. Electrically driven heat pumps were shown to be a more cost-effective option than cogeneration plants using natural gas or biomass fuel, or than solar plants. This result is not very sensitive to electricity prices - the main limiting factor is the availability of suitable fuel sources. Of course, Sweden's electricity mix (mainly nuclear and hydro) favours the electric heat pump. However, this study went on to show that heat pumps in combination with cogeneration based on biomass fuel is also a cost-effective option for CO_2 emissions reduction.

Switzerland

Heat pumps currently in operation here reduce CO_2 emissions by 410,000 tonnes through the replacement of fossil-fuel fired boilers. This is equivalent to about 0.9% of the total energy-related CO_2 emissions from Switzerland in 1990 estimated by the IEA. Every year, additional heat pump installations reduce the annual emissions by a further 42,000 tonnes. Under the Energy 2000 programme, heat production from electric heat pumps is planned to rise to 2.25 TWh/year leading to an avoidance of 800,000 tonnes of CO_2 emissions every year. This will be realized through the installation of some 100,000 25 kW_{heat} electric heat pumps (or the equivalent number for the same heat production) between 1990 and 2000.

USA

The Environmental Protection Agency (EPA) has recently released a report titled "Space Conditioning: The Next Frontier." In it, EPA clearly states its view that heat pumps have a strong potential to reduce pollutant emissions. It finds that ground-source heat pumps have the lowest CO_2 emissions of all the technologies available, emitting 23 - 44% less than air-source heat pumps and 63 - 73% less than air conditioners with electric resistance heating. Energy Research Group Inc. has estimated the potential CO_2 savings from using heat pumps in the commercial sector. In the year 2000, ground-source heat pumps could avoid 43.5 million tonnes CO_2, and heat pump water heaters 49.6 million tonnes CO_2. The total energy-related CO_2 emissions in the USA was estimated by the IEA to be 5,020 million tonnes in 1990.

In the Netherlands, the government is moving towards a commitment to the promotion of heat pump technology, although details of this policy are still being formulated.

In Japan, the government is supporting many important R&D programmes which focus on heat pumps for large district heating and cooling systems. These heat pumps will use unused energy sources such as renewable energy in nature and waste heat energy from industry, and will be combined with thermal storage systems.

In Norway, a three-year heat pump programme focusing on knowledge transfer and education was completed last year, and helped to increase sales of heat pumps there. A new four-year programme puts renewed emphasis on research, especially on the use of natural refrigerants, and aims to stimulate manufacturing.

Gaining Experience

As more and more experience is gained, the potential of heat pumps to help meet environmental aims will become clearer. Policy makers should be made aware of the progress being made by heat pump programmes currently underway in some countries. Only when heat pump programmes can be shown to be cost-effective in comparison to other CO_2 emissions reduction measures, will there be more widespread support for this technology.

Author:

Mike Steadman, IEA Heat Pump Centre, P.O. Box 17, 6130 AA Sittard, the Netherlands.
Tel.: +31-46-595-236; Fax: +31-46-510-389.

The Environmental Case for Heat Pumps

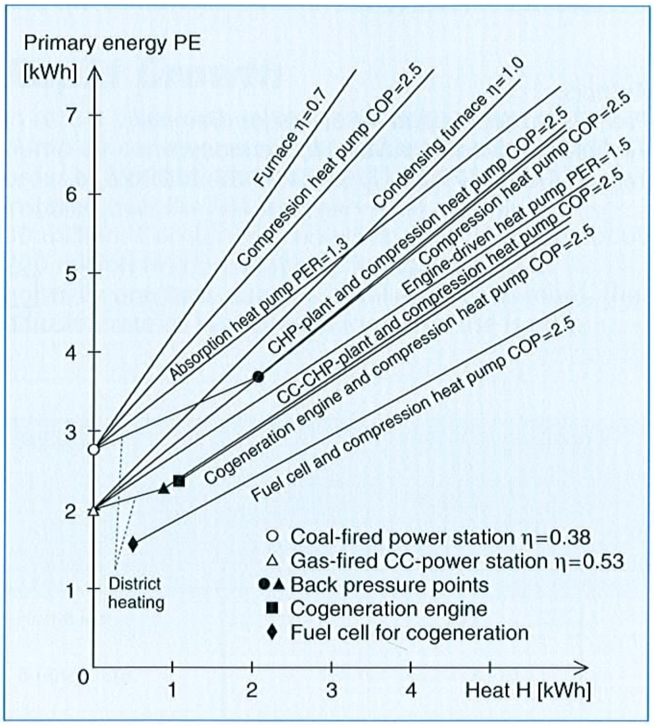
Georg Alefeld and Sebastian Demmel, Germany

A true assessment of the environmental benefits of heat pumps can only be made when the complete picture is drawn. For electric compression heat pumps, that means that the source of power must be taken into account. Furthermore, heat pumps should be considered as part of an energy system which must be optimized to meet both a power and a heat demand. This article illustrates that a careful analysis of the complete picture makes a powerful case for heat pumps.

* * *

To evaluate the CO_2 saving potential of electric compression heat pumps, it is important to consider the source of power which drives them. It makes a difference whether the source is a coal-fired power station, a gas-fired combined cycle power stations, or a system producing combined heat and power. Equally important is the ratio of heat and power which has to be provided by the energy system of which the heat pump is a part. Figures 1 to 3 illustrate the significance of both of these vital notions.

Figure 1: Primary energy consumption for the production of one unit of power, and 'H' units of heat.



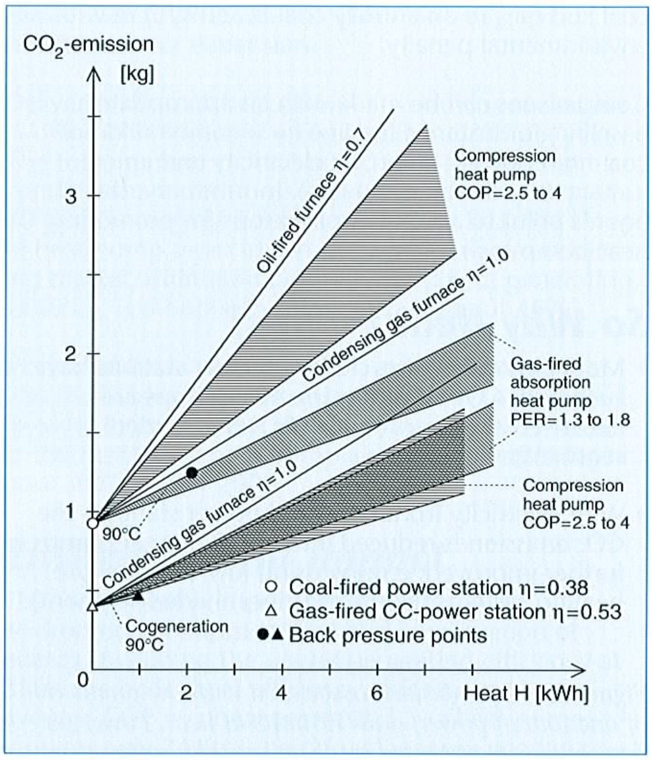


Figure 2: CO_2 emissions associated with the production of one unit of power, and 'H' units of heat. The shaded areas show the range of efficiencies for compression heat pumps (COP) and absorption heat pumps (PER).

Complete Picture

The figures show the primary energy consumption and CO_2 emissions from a variety of energy systems. Figure 1 shows the primary energy demand which is required for the production of one unit of power, and a variable amount ('H' units) of heat. In buildings in central Europe, 'H' will be 2 to 3; i.e. the demand for heat in buildings is on average two to three times as large as the demand for power.

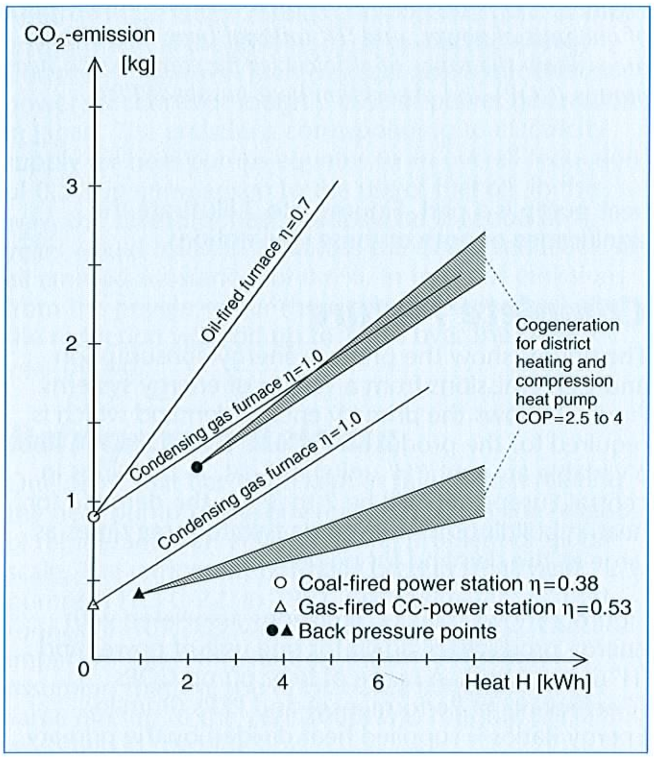
Figure 2 shows the CO_2 emissions associated with energy production, again for one unit of power and 'H' units of heat. A range of heat pump COPs (Coefficients of Performance) and PERs (Primary Energy Ratios = supplied heat divided by the primary energy demand) is shown to illustrate the significance of the ongoing technological developments. Figure 3 is similar, but here the CO_2 emissions are shown from heat pump systems where the power is exclusively provided by combined heat and power (CHP) generators for district heating. Note that the combination of coal-fired CHP with compression heat pumps, yields as much saving in CO_2 emissions as the combination of the best coal-fired power stations with the best condensing gas boilers. Thus it is possible to convert a 'state-of-the-art' energy system based on coal and gas, to an entirely coal-based system without environmental penalty.

Comparisons can be made with an appropriate baseline, for instance the line for a combination of coal-fired power station for electricity and an oil furnace (top line in all figures). In summary, the figures point to a number of reasons for promoting heat pump technology:

So Why Heat Pumps?

- Modern combined-cycle (CC) power stations have such high COPs that electric heat pumps are effective CO_2 savers (Figure 2, lower shaded segment).
- With electricity from coal-fired power stations, the CO_2 emission is reduced if the COP of heat pumps is further improved, e.g. by using low-temperature heating systems (Figure 2, upper shaded segment).

Figure 3: CO_2 emissions associated with the production of one unit of power, and 'H' units of heat. Power for heat pumps is produced by co-generation units.



- Even more important: With electricity produced in cogeneration plants or other combined heat and power (CHP) plants, heat pumps are powerful CO_2 savers, even for coal-fired plants (see Figure 1 and shaded areas of Figure 3).
- Electricity is available with negligible CO_2 emissions (not shown in the figures).
- Absorption heat pumps are excellent CO_2 savers. They save as effectively as compression heat pumps driven with power from CHP systems (compare shaded segment for absorption heat pumps in Figure 2 with shaded areas in Figure 3). The reason is that absorption heat pumps operate internally according to the same principle: the heat emitted from the power producing cycle (i.e. the absorber heat) is released at such a temperature level at which it is useful heat.

Convincing Message

The message from the graphs is convincing: strategies and technologies for systems based on the combination of heat pumps and combined heat and power must be developed.

An additional conclusion from the graphs is that burning natural gas in individual homes can only be considered an intermediate technology for emission reduction. This gas supply would be better used either in absorption heat pumps, or in efficient power stations (if possible in co-generations systems), with the surplus power used to operate compressor heat pumps.

Authors:
Prof. Georg Alefeld and Mr Sebastian Demmel,
Technical University of Munich, Germany.
Tel.: +49-89-3209-2531; Fax: +49-89-3209-2536.

Small Heat Pump Air Conditioners

- The Environmental Impact of their Rapid Growth

Tomoyasu Nishiyama, Japan

In view of the rapid expansion of the heat pump market in Japan, a rough calculation has been made to determine the expected impact of the increased use of heat pump air conditioners on the environment. It was found that, through the use of heat pumps, the emission rate of substances into the environment can be reduced in comparison to the use of fuel oil. To make efficient use of this characteristic, measures to prevent the release of refrigerant from heat pumps are required.

* * *

The share of different types of air conditioning equipment has changed drastically in recent years. The primary factor behind these changes has been the expansion of the small heat pump air conditioner market. In home and office building air conditioning, small heat pump air conditioners are replacing the conventional kerosene stove and boiler. This drastic increase in small heat pump air conditioners brings with it a large impact on the environment.

The majority of heat pump air conditioners in Japan are small models with a power consumption in the range of 1 to 10 kW. The refrigerant used is HCFC-22, and the compressors are driven by electric motors.

Rapid Growth

In recent years, annual domestic deliveries of heat pump air conditioners for home use have been in the order of 5 million units, and the number of units installed over the last ten years total roughly 30 million. Considering, however, that there are about 200 million residential rooms in Japan and that normally one heat pump is installed in each room, the diffusion rate of heat pumps for home use is only about 15% (30 M/200 M), which certainly leaves much room for expansion.

Deliveries of small heat pump air conditioners for use in office buildings add up to 1 million units per year. The total number of heat pump type package air conditioners for business use delivered over the past 10 years is roughly 5.5 million units. In fact, the share of heat pump types in the office building air conditioning market, estimated on the basis of heat generating capacity, is thought to have reached about 40%.

In view of these circumstances, a rough calculation was made based on the assumptions given in Table 1, in order to project the impact of a continued increase in the number of heat pump air conditioners between now and the year 2000.

Environmental Impact

The use of heat pumps is certain to result in environmental improvement and conservation of energy. Assuming the power generating efficiency at 35%, the boiler heat efficiency at 90%, and the average COP of a heat pump at 3.5, a heat pump requires only 74% of the primary energy needed to produce the same thermal capacity as an oil-fired boiler in homes and office buildings. This means that the use of heat pumps for heating could result in energy conservation of 26% when replacing oil-fired boilers. The amount of energy conserved was then calculated for each application area and for all of Japan. The result showed that, in the year 2000, energy equivalent to roughly 1.4 million m^3 of crude oil could be conserved annually by replacing oil-fired boilers and kerosine stoves with heat pump air conditioners. This amount corresponds to 0.3% of Japan's primary energy supply.

Application	Millions of units delivered			Share of total heat demand	
	Annual	Total by the year 2000	Net increase after deduction of scrapped units	1993	2000
Home use	5	35	20	15%	25%
Business use	1	7	4	40%	70%

Table 1: The heat pump market in Japan.

Ozone depletion impact

- Annual delivery volume of CFCs in Japan : 95,000 tonnes (1991)
- Annual delivery volume of HCFC-22 in Japan : 37,000 tonnes (1991)

The impact of HCFC-22, in terms of COP, is approx. 2.1% that of CFCs.

Global warming impact

- Annual CO_2 emission rate in Japan : 1,170,000 tonnes
- Annual delivery volume of HCFC-22 in Japan : 37,000 tonnes

The impact of HCFC-22, in terms of GWP, is approx. 2.2% that of CO_2 emissions.

- Reduction of CO_2 emissions by the year 2000 due to an increase of heat pumps
  1170 x 0.6% = 7 million tonnes/year

- Progressive global warming effect of HCFC-22 (converted to CO_2) if not recovered (released into the atmosphere)
  7- 20 millions tonnes/year

There is a strong possibility that the progressive effect on global warming resulting from release of the refrigerant (HCFC-22) of heat pumps will be considerably greater than the effect of suppressing global warming expected from a reduction of CO_2 emissions through the use of heat pumps.

The environmental impact of heat pump refrigerant (HCFC-22).

One of the effects on the environment that the expansion of the heat pump market is expected to have is improvement through energy conservation. In terms of CO_2 emission, a reduction of approximately 0.3% of the total CO_2 from combustion of fossil fuels in all of Japan could be achieved. Virtually the same effect can be expected with regard to SO_X and NO_X.

Another main factor resulting in improvement of the environment is the shift from oil to electric energy. Currently, non-fossil fuels (nuclear and hydroelectric power) account for roughly 40% of power generation in Japan. The emissions corresponding to electricity supply for heat pumps equates to an overall reduction of 0.3% in comparison to the use of fuel oil. In this way, the spread of heat pumps over a period of 7 years would result in an across-the-board reduction of all emitted substances of 0.6%. In terms of emissions from the private sector (households, businesses) alone, the reduction will add up to 3-4% over the same 7-year period.

Refrigerant Release

One point that has to be kept in mind when relating the heat pump to the environment is that the release of refrigerant is an environmental problem of global scale. The refrigerant normally used in small heat pumps is HCFC-22. In 1991, approximately 37,000 tonnes of HCFC-22 were used as refrigerant. The impact of this refrigerant on the environment, assuming that the use of HCFC-22 continues at the same rate up to the year 2000, was roughly calculated as shown in the blue box.

Concerning the impact on the ozone layer, greater importance will have to be attached to HCFC-22 in this regard in view of the sudden moves to reduce the use of CFCs. Regarding the influence on global warming, measures must be adopted to prevent the release of refrigerant from scrapped small heat pump air conditioners. Otherwise, the effect of suppressing global warming by reducing CO_2 emissions will be more than offset by the progressive effect of the diffusion of refrigerants.

Positive and Negative Impact

Compared with oil-burning equipment, the use of small heat pump air conditioners in Japanese homes and office buildings can reduce SO_X, NO_X and CO_2 emissions by roughly 0.6% over a 7-year period. On the other hand, the release into the atmosphere of HCFC-22, has the striking negative potential of contributing to the progress of global warming. This shows that the environmental impact of the increasing use of heat pumps will only be beneficial when measures are taken to prevent the release of refrigerant.

Author:

*Mr Tomoyasu Nishiyama, Manager Techno-Economics Dept., Mitsubishi Research Institute Inc., Time & Life Bldg. 3-8, Otemachi 2-chome, Chiyoda, Tokyo, Japan.
Tel.: +81-3-3277-0533; Fax: +81-3-3277-0545.*

Global Warming Impacts of Chillers

James M. Calm, USA

As users and policy makers look for alternatives to using traditional CFC refrigerants in chillers, it is important that the environmental consequences of the alternatives are fully understood. A new study by the author makes a thorough examination of the global warming impacts of using compression chillers with alternative refrigerants, or of switching to absorption technologies. Extending earlier work on the net global warming impact of refrigerants, the study uses a systems rather than a components approach. The findings give further evidence that once CFCs are phased out, measures such as improving energy efficiency and reducing emissions, are far more significant than the choice among refrigerants. The study also shows that direct-fired absorption chillers add more to global warming than do vapour-compression machines.

* * *

With the phase-out of CFCs, chiller manufacturers have three primary refrigerant options: HCFC-22 (high pressure), HCFC-123 (low pressure) and HFC-134a (medium pressure). While propane and ammonia are also candidates, flammability and toxicity concerns limit their use. Absorption systems also are an option, with the working pairs ammonia/water used in small capacities (generally < 60 RT or 210 kW), and water/lithium bromide for larger units.

Total Equivalent Warming Impact

When determining the global warming impact of the refrigerant options, both the direct effect (from refrigerant emissions) and the indirect effect (associated with the energy consumption of the equipment) should be considered. By expressing both the direct (chemical) and indirect (energy-related) effects as equivalent carbon dioxide emissions, a net effect referred to as the Total Equivalent Warming Impact (TEWI) can be calculated. This approach was used in a study conducted by Oak Ridge National Laboratory and Arthur D. Little Inc. for the Alternative Fluorocarbons Environmental Acceptability Study (AFEAS) and the US Department of Energy (DOE) (see HPC Newsletter Vol. 10, No. 3 pp. 22-25).

New Study

A new study (see References) by the author, sponsored by the US Electric Power Research Institute (EPRI), focuses on the global warming impact of chillers. This study used a more rigorous methodology to calculate the global warming impacts of power generation. The data used included the projected fuel mix and the transmission, distribution and other losses in the United States in 1995. Net greenhouse emissions have fallen steadily as the efficiency of power plants has improved. Similarly, generation using non-fossil energy sources, including nuclear, hydro, and - to a lesser extent - geothermal, wind, and solar, has

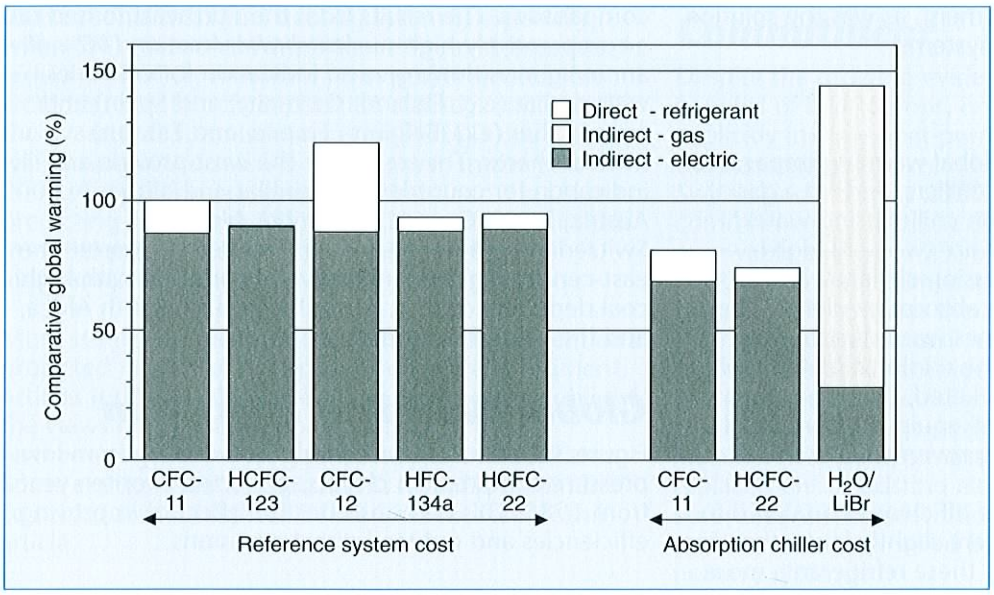
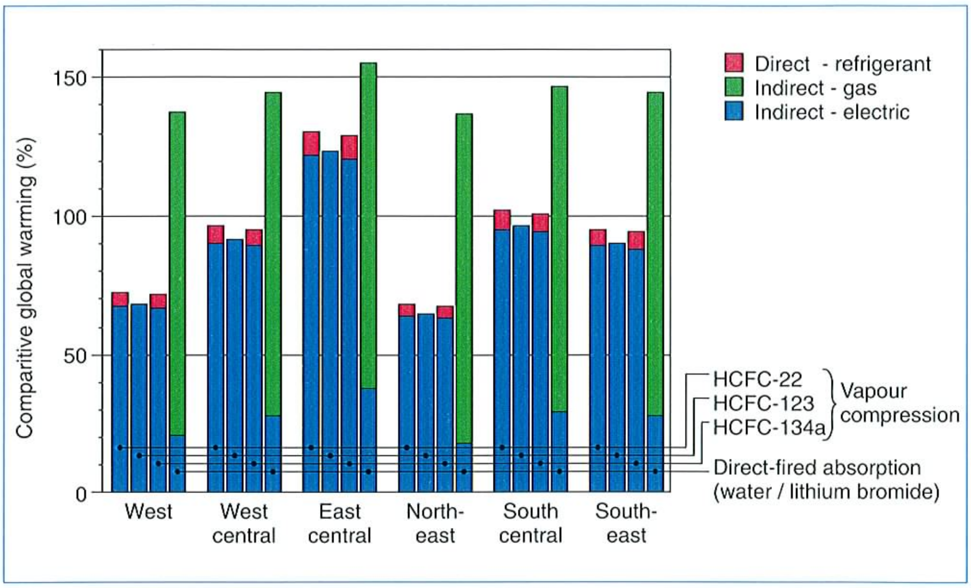


Figure 1: Net global warming impacts of 300 RT (1 MW) vapour-compression and double-effect absorption chillers.

Figure 2: Regional global warming impacts of chillers in the United States.



increased. The study also considered the regional differences of power generation in the United States.

The calculations of indirect emissions were adjusted to reflect seasonal and hourly changes in both chiller loads and generation fuels. For example, hydroelectric power, which does not contribute to global warming, is most abundant in the winter and spring, but the highest cooling loads generally occur in the summer. Similarly, gas turbines, which are widely used to meet peak generation needs (often driven by air conditioning loads), generally produce less CO_2/kWh of electricity generated than do base-load, coal-fired plants.

The study also used updated data for refrigerant Global Warming Potentials (GWPs) and examined the impacts of improved equipment efficiency and refrigerant management practices. The energy required by condenser water pumps, and cooling towers was included. Condenser fan power also was included for air-cooled equipment, as was the solution pump power for absorption systems.

Findings

Figure 1 compares the net global warming impacts for electric vapour-compression chillers, and for a gas-fired, double-effect absorption chiller using water/lithium bromide. Also shown are two very high-performance vapour-compression chillers with the same fabrication costs as the absorption chiller. The performance of these machines was estimated by chiller manufacturers to be the minimums attainable at this cost. They are not marketed, however, since the cost increments over standard equipment are much higher than the efficiency improvements.

Figure 1 shows that while the efficiencies analyzed for the alternative refrigerants were slightly lower than for the CFCs, the lower GWPs of these refrigerants more than offset the difference. As shown, the indirect (energy-related) components of global warming far exceeds those from the direct (refrigerant) effects. In addition, all the vapour-compression machines yielded lower net global warming impact than the direct-fired, double-effect absorption chiller.

Regional Analysis

Figure 2 shows the variation in net global warming impact for chillers in different regions of the United States. As shown, for the northeast, where nuclear power use is highest, and for the west, where hydroelectric power generation is highest, the net global warming impact of vapour-compression chillers is substantially less than in the east central region, where coal generation dominates. Absorption chillers have a much higher net global warming impact even in that region.

These findings provide an indication for international comparisons. The results from the northeast, based on a comparatively high nuclear power fraction (36% of annual generation), give an indication for countries with similar (e.g. Finland, Germany, and Spain) and even higher (e.g. Belgium, France, and Taiwan) nuclear shares. The results for the west provide an indication for countries with similar and higher (e.g. Austria, Brazil, Canada, Colombia, Norway, Switzerland, and Venezuela) hydroelectric shares. The east-central region is indicative of countries with high coal dependence (e.g. Australia, Poland, South Africa, and the United Kingdom).

Global Warming Reduction

Figure 3 shows the trend in global warming from low-pressure compression chillers, projected over ten years from 1985. This demonstrates the effect of improving efficiencies and reduced direct emissions.

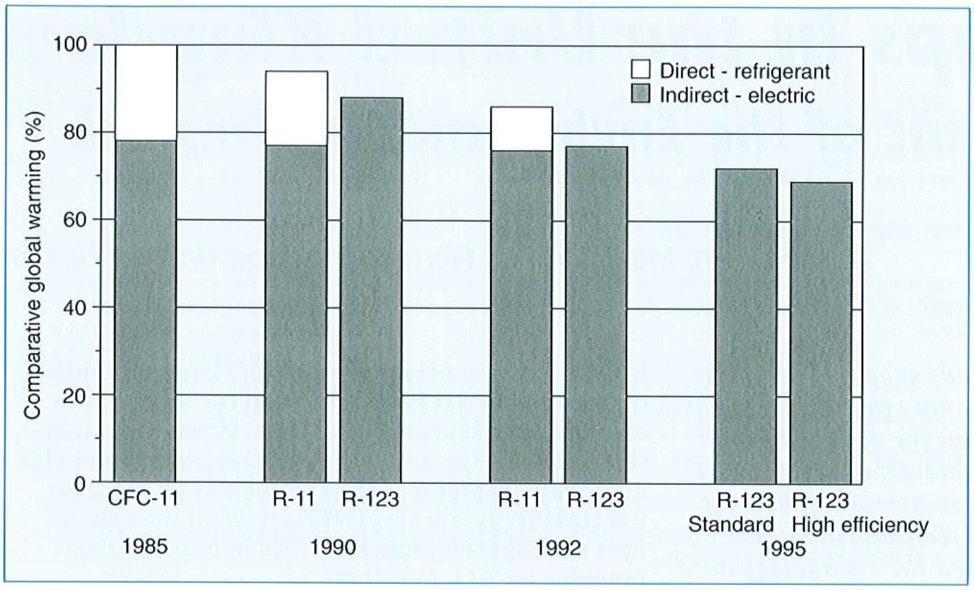


Figure 3: Net global warming impacts of vapour-compression chillers for constant (1995) generation fuel mix and losses.

Refrigerant Emissions

Refrigerant losses are much lower in new equipment. For example, one manufacturer has introduced a 'near zero emissions chiller' with annual losses projected at less than 0.5% compared with up to 25% in the past. Much of the earlier losses stemmed from service practices rather than actual leaks. The reduction is achieved by improvements in the construction (e.g. improving gasket materials and fittings), in purge unit performance, in leak testing techniques, and in refrigerant handling and recovery methods. Also significant is the reduction in the amount of refrigerant used in new equipment with the introduction of improved designs, such as the use of highly enhanced heat-exchangers with lower internal volume.

Efficiency

Figure 3 also shows the effect of performance improvement on global warming impact. For typical CFC-11 machines, COPs improved from 5.25 to 5.5 (0.67 to 0.64 kW/RT) at standard rating conditions. A more dramatic improvement appears in the HCFC-123 chillers, since the initial designs were based on equipment optimized for CFC-11. Figure 3 also reflects the results of further design improvements projected for 1995, by showing global warming emissions from a standard and a high-efficiency HCFC-123 chiller. Interestingly, the difference between these two chillers is larger than the differences among the three alternative refrigerants (HCFC-22, HCFC-123 and HFC-134a) shown in Figure 1. This comparison clearly shows that once the high-GWP CFCs are eliminated, far greater opportunity exists to reduce global warming by efficiency improvement or emission reduction than by refrigerant substitution. Another way to view the result is that the global warming effect from refrigerant emissions is equivalent to less than a 0.1 to 1.1% change in efficiency (depending on refrigerant), once CFCs are eliminated and service and disposal losses are reduced.

Conclusions

The study shows that electric vapour-compression equipment using HCFC-22, HCFC-123 or HFC-134a, offers a better means to minimize the net global warming impact of chillers than does absorption technology. Two mechanisms - reduction of refrigerant emissions and use of high-efficiency equipment - are shown to have far greater benefit than selection among the three alternative refrigerants. Finally, the new information presented reaffirms the finding of prior studies, that regulation of refrigerants based on their GWP, without regard to the commercially attainable efficiency of equipment using their alternatives, would increase rather than decrease environmental harm.

References:

Calm, J.M., 'Global Warming Impacts of Chillers,' Heating/Piping/Air Conditioning, February 1993.

Calm, J.M., 'Comparative Global Warming Impacts of Electric Vapor-Compression and Direct-Fired Absorption Equipment', Draft Report, Electric Power Research Institute (EPRI), Palo Alto, California, USA, December 1991. (The final report will be available from the EPRI Reports Center - not from the author - by the time this article is published.

Author:

Mr James M. Calm, P.E.
Engineering Consultant
10887 Woodleaf Lane, Great Falls
VA 22066 USA.

Heat Pumps in the United Kingdom - An Assessment of the Environmental Impact

Rob Green, Mark Bertinat, Norman Maloney, United Kingdom

With its cool summers and ready supply of low-cost gas, the United Kingdom does not offer the most favourable economic conditions for the widespread application of heat pumps. However, environmental concerns have recently led to an increasing interest in heat pumps in this country. To find out more about this trend, the HPC asked EA Technology to report on the situation in the UK regarding CO_2 and CFC emissions, and on the impact this has on the application of heat pumps. As an independent R&D company whose major customers are the electricity supply companies of the UK, EA Technology Ltd is well placed to reflect the current UK situation. It should, however,be emphasized that the views expressed as to the future impact of heat pumps are, of course, entirely their own and do not necessarily reflect those of either the UK Government or the individual UK electricity supply companies.

* * *

With CO_2 emissions from electricity generation set to reduce due to increasing efficiency and a shift in the fuel mix, the environmental case for using heat pumps is becoming stronger. Proposed building regulations could stimulate the use of heat pumps in new homes since they encourage mechanical (fan-assisted) ventilation by insisting on tighter insulation. Heat pumps are already finding increased application in commercial buildings, and are well established in some industrial sectors.

CO_2 Production and Fuel Mix

The CO_2 production rate for electricity generation in the UK, based on 1992 data for the annual average fuel mix, is 0.72 kg/kWh. For gas the accepted value is 0.21 kg/kWh of fuel delivered. These figures are those currently used by the UK's Building Research Establishment. If we take a seasonal efficiency of 85% for a gas condensing boiler then a heat pump with a seasonal COP in excess of 2.9 will give savings in CO_2 production rate. This value is achievable, with careful design, in a wide range of applications both in commercial and domestic premises and in industrial processes.

Since the electricity industry was sold into private ownership, there has been a rapid increase in the building of new power plant, a very large proportion of these being gas-fired combined cycle plant with expected efficiencies of over 50%. When these new stations come on stream, the CO_2 production rate for electricity generation will fall, probably to less than 0.6 kg/kWh by the late 1990's, making the case for heat pumps even more attractive in terms of their potential for CO_2 reduction.

However there are a number of factors which make it likely that heat pumps will not achieve their full potential in the UK, the most important being firstly, the wide availability and low cost of gas (which makes an economic return difficult in many applications) and secondly an attitude to heat pumps which, in commercial and domestic buildings, equates them with unnecessary air-conditioning.

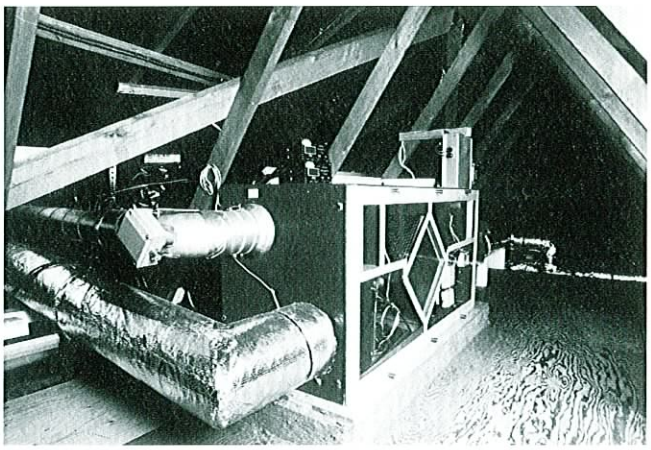
CO_2 Reduction

The UK Government committed itself at the Rio Earth Summit to returning CO_2 emissions to 1990 levels by the year 2000. The Government has produced a consultative document to outline ways and means of achieving this target. Heat pumps do not feature as an option to be promoted.

There are two major initiatives in the buildings sector.

- The Building Research Establishment Environmental Assessment Method (BREEAM) for commercial

Mechanical ventilation heat pump installed in an EA Technology test house.



buildings has been formalized as a method of assessing buildings on their environmental impact and energy performance.

- New building regulations will be imposed in 1994. A draft set has been published to allow comments from the building industry.

As well as increasing statutory insulation levels, the proposed new building regulations will introduce the requirement on the part of the architect/developer to demonstrate that there is a need for mechanical ventilation or air-conditioning (positive cooling) for buildings of over 500 m^2 floor space, prior to such systems being specified. Mechanical ventilation is allowed for domestic premises.

CFCs

The UK has accepted the European phase-out date of January the 1st 1995. On HCFCs, new European regulations are under discussion and we understand that the UK want the phase-out to be brought forward to 2015. EA Technology do not see the working fluids issue as being a hindrance to the development of heat pumps or to their application. New fluids are now widely available for CFC replacement. The major concern is with the replacement for HCFCs and in particular HCFC-22. Here again the evidence suggests that alternatives will be developed, with a return to ammonia or the use of flammable refrigerants being a possibility, with the draft European Standard on the use of flammable refrigerants expected to supersede the British Standard.

Heat Pump Applications

EA Technology believe that there will be a number of important applications for heat pumps in the UK which will help meet the target for returning CO_2 production levels to 1990 values.

Commercial Buildings

Mechanical ventilation will continue to be a viable option with clear advantages in control of indoor air quality. Heat pumps will be increasingly used as heat recovery options where mechanical ventilation has been selected.

Mechanically-driven air-conditioning will continue to be the best means of dealing with excessive heat generation within many offices and other commercial premises, but will come under increasing threat from gas absorption systems. Heat pumps will be increasingly used in such buildings to provide some or all of the winter heating as well as the summer cooling, as witnessed by the rapid uptake of heat pump VRV (Variable Refrigeration Volume) systems in recent years. In these multi-split systems, each indoor unit can be individually set to heating or cooling mode.

The current low cost of gas means that it is unlikely that there will be many heating-only applications of heat pumps unless they are in a locality with no access to natural gas. The vast majority of heat pumps will thus be linked to air-conditioning or mechanical ventilation and will be air-source.

Domestic Buildings

Tighter sealing of buildings against air infiltration means that mechanical ventilation is becoming an increasing requirement at a domestic level. Mechanical ventilation (exhaust air) heat pumps are being promoted as part of a low-energy strategy for new houses (see photograph). Air-conditioning heat pumps are now being actively marketed in the UK, but the mild climate means that a large uptake is unlikely. Air-to-water heat pumps are receiving attention and are seen to be more environmentally friendly than split-refrigerant systems since they confine all their refrigerants to a single factory-sealed unit.

Industrial Applications

While there is no UK policy for industrial heat pumps, it is understood that they have considerable potential for the reduction of CO_2 emissions. Applications include Mechanical Vapour Recompression (MVR) evaporation, heat pump assisted distillation and drying, and heat recovery schemes.

MVR, where COPs up to 40 are achievable, can give rise to 40 to 50% reductions in CO_2 compared with the best thermal practices. In addition to traditional evaporation applications, there is a growing potential for MVR evaporation in effluent treatment, giving additional environmental benefits of reduced disposal volume plus often a combustible final product.

Heat pump assisted distillation applications include solvent recovery and steam stripping, again offering environmental benefits. Drying applications include wood products, grains, textile products and, more topical from an environmental viewpoint, sewage and paper sludge drying. COPs of 4 to 6 are possible for these application areas.

Much work is being done by EA Technology to produce lower cost, packaged, small capacity plant, to open up the market for these technologies. This work is starting to generate interest.

Authors:

Mr Rob H. Green, Dr Mark P. Bertinat, Mr Norman Maloney, EA Technology, Capenhurst, Chester CH1 6ES, United Kingdom.
Tel.: +44-51-339-4181;
Fax: +44-51-357-1581.

Reducing CO_2 Emissions - How do Heat Pumps Compete with Other Options?

Peter Okken, the Netherlands

The potential contribution of heat pumps to the reduction of CO_2 emissions in the Netherlands has been calculated with the aid of the IEA's MARKAL model. This model examines how a wide range of energy technologies would be applied in order to achieve a chosen reduction in a country's CO_2 emissions. In the residential sector, electric heat pumps were found only to be cost-effective in a relatively high CO_2 reduction scenario. However, they find much wider application if the figures used for investment cost are reduced by 20%. Residential gas absorption heat pumps were not found to be competitive in this sector.

The situation in the commercial sector contrasts with the residential sector. Gas absorption, gas engine and electric heat pumps are cost-effective in all scenario calculations.

* * *

Many energy technology options for reducing CO_2 emissions are available. Energy systems analysis provides a tool for the design of cost-effective long-term CO_2 reduction scenarios, taking into account competition and synergism amongst individual CO_2 reducing options. In this study, scenarios are calculated using the IEA MARKAL model for the period 2000-2040, with CO_2 reductions ranging from 20 to 80%. A wide variety of new prospective energy technologies is incorporated in this model, including hydrogen, CO_2 removal, nuclear, renewables, fuel cells, alternative automotive fuels, high-efficiency appliances, as well as heat pumps.

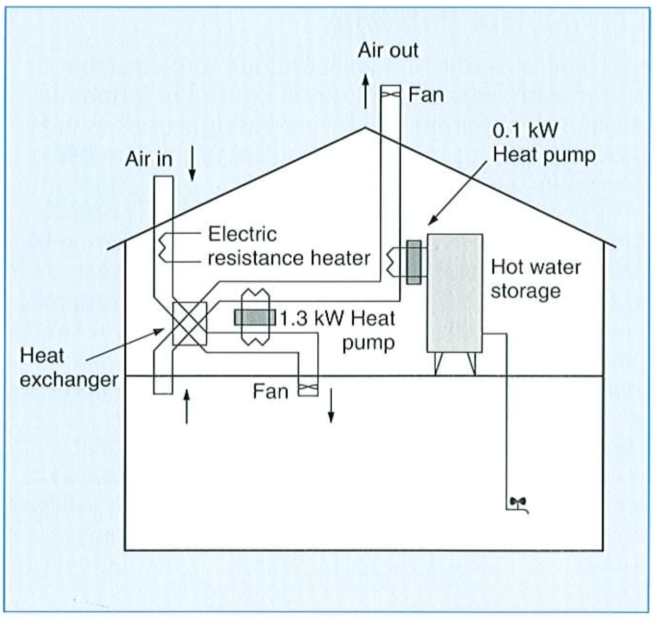
The MARKAL Model

Using detailed characteristics of available and prospective energy technologies, and projecting the costs and availability of fuels, MARKAL configures an optimal mix of technologies to satisfy the energy demands at minimal cost while complying with maximum allowable emissions of NO_X, SO_2 and CO_2. The model optimizes the energy system for the period 2000 to 2040 simultaneously in steps of 5 years each. Gradual efficiency improvements of existing energy technologies are incorporated, and several new energy technologies are projected to be available at fixed points in the future, thus reflecting the promises of ongoing energy and environmental R&D. Few institutional and market barriers are assumed. However, limits are imposed on the speed of market penetration for new energy technologies to prevent unrealistic solutions, and lower boundaries ensure that older technologies are not phased out too rapidly. MARKAL is currently operated in 12 IEA countries in the Energy Technology Systems Analysis Programme [1].

Residential Heating

As a result of strict standards for insulation of newly-built and renovated dwellings, and public energy awareness campaigns, the 1990 average energy demand of 58.5 GJth/year per household for space heating is expected to drop to 42 GJth/year by the year 2000. To reduce CO_2 emissions from space heating both additional conservation options and various heat production options have been considered. Using well-defined heat balance models, options have been characterized for three types of dwellings: newly-built single-family, existing single-family, and apartments, with specific heat demands of 21, 42 and 22 GJth/year respectively.

Figure 1: Electric heat pump system for new single-family houses in the Netherlands.



Option	Investment (NLG 1990)	Energy efficiency [1]	Energy conservation [2]
extra insulated+heat recovery	2750		0.37
+ coated double glazing	4500		0.49
+ triple glazing and aerogels	8150		0.68
conventional gas boiler	1750 [3]	0.85	
condensing gas boiler	2200 [3]	1.0	
district heating	4700	0.95	
solar pond residence	10000	1.72	
electric heat pump	8500	4.0	
gas absorption heat pump	6000	1.53	

[1] based on lower heating value for gas
[2] reduction factor on useful energy demand
[3] addition NLG 1000 required for hot water supply

Table 1: Space heating options for new houses in 2030 [4].

In the Netherlands today, 98% of the residential sector is connected to the natural gas grid. Costs and efficiencies are well known for gas boilers, as are insulation options. Costs and efficiencies are still uncertain for gas absorption heat pumps, which are still undergoing development, as well as for other new options such as solar heating. A suitable electric heat pump system for new single-family dwellings in the Netherlands was selected from data on Japanese and US equipment. The heat pump produces space heat and hot water using ventilation air, supplemented with outside air, as heat source (see Figure 1). The mean annual COP of the system is calculated at 4.0, the extra investment costs are NLG 8500 (NLG 1 (Netherlands Guilder) = US$ 0.54) [2]. A gas absorption heat pump using outside air as heat source was also considered.

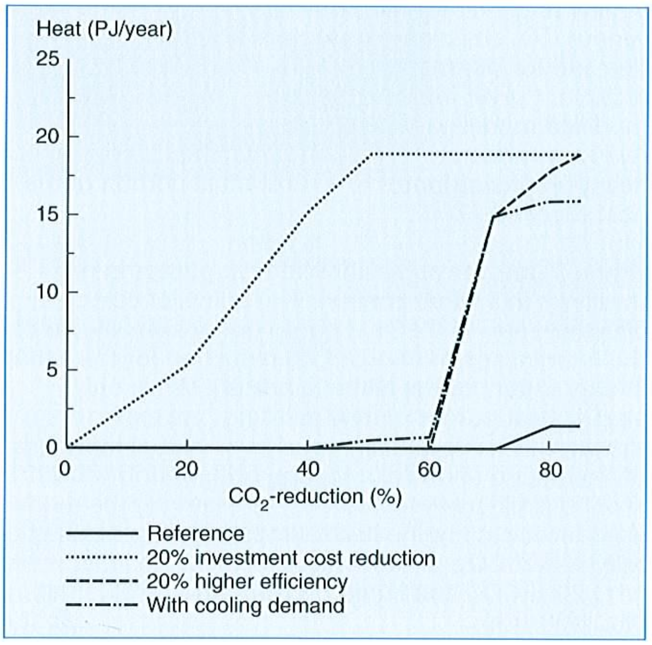
Key parameters for other options concerning space heating are summarized in Table 1. These figures are for a standard single-family house meeting the 1994-building insulation codes (insulation factor R = 3.0 W/m.K) with an annual space heating demand of 21.4 GJ/y, and an additional hot water demand of 12.6 GJ/y. Investments for heat delivery inside the dwelling (radiators, air channels, etc), chimneys and the connection to the gas grid are excluded in Table 1.

The study took account of operation and maintenance costs as well as lifetime factors. Hydrogen is considered as an alternative fuel to natural gas. The natural gas price for residences was projected to increase linearly during the period 2000 to 2040 from 17.8 to 27.6 NLG/GJ. Electricity and hydrogen price trends are calculated by the model.

Results

In the base case calculation, without CO_2 constraints, residential electric heat pumps are not competitive. Residential space heating in the base case is mainly supplied by condensing gas boilers. At mild 20 to 40% CO_2 emission reduction, energy conservation by means of heat recovery and additional building insulation is most attractive. At severe, 50 to 80% CO_2 emission reductions, natural gas is substituted by hydrogen, produced from natural gas with CO_2 removal. Hydrogen is used for stationary purposes (e.g. space heating in the residential and commercial sector using a modified gas grid) as well as automotive transport purposes. At severe CO_2 constraints, electric heat pumps are introduced. The absorption heat pump is not competitive with the insulation options.

Figure 2: Market penetration of electric heat pumps in new single-family houses in 2030. Total heat demand is assumed to be 40 PJ.



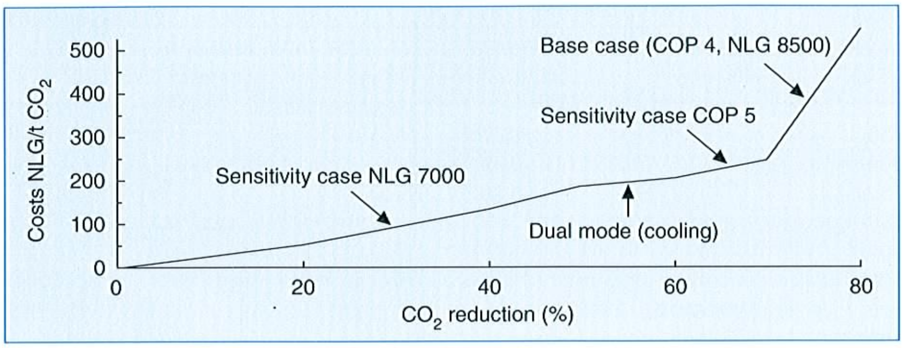


Figure 3: Electric heat pump for new single-family houses: cost-effective introduction in the Netherlands energy system in 2030, at various national CO_2 reduction constraints and marginal costs of CO_2 reduction.

Sensitivity

A sensitivity analysis was performed to illustrate the importance of model input assumptions, for the electric heat pump option. Three additional model calculations were performed, with modified model parameters for the introduction of electric heat pumps in new single-family homes [3]. The following options were added:

The investment costs were reduced by 20%. This could reflect the potential cost savings through not connecting the new house to the gas grid, or a price drop of heat pumps through technological developments.

The energetic efficiency was increased by 20% to a COP of 5.0, reflecting a possible technical potential for ultra-fast rotating compressors in electric heat pumps.

The heat pump is used for cooling during summertime by switching flaps in the air channels. Although the Netherlands summer climate is relatively cool, up to 1000 kWh/y per house may be required for summer cooling, if an air conditioner was available.

The results of the sensitivity analyses are shown in Figures 2 and 3. Figure 2 shows how the heat demand in new single-family houses is met by heat pumps at various CO_2 emissions constraints. The total heat demand for this market sector is assumed to be 40 PJ in 2030. Curves indicate the base case and for the modified model parameters. As shown, even at relatively moderate CO_2 constraints, the 20% cheaper heat pump contributes to a substantial portion of the heat demand.

Figure 3 puts the application of heat pumps in new dwellings in a wider context. The points of cost-effective entry of the heat pump options are shown on the marginal cost curve of CO_2 reduction for the entire energy system of the Netherlands [4]. While only electric heat pumps in new dwellings are explicitly shown, this curve actually consists of several hundreds of alternating and/or competing options, introduced at various different cost levels. For example, the model introduces gas-engine heat pumps for office heating at NLG 50/tCO_2, photovoltaic electricity generation at NLG 200/tCO_2, and liquid transportation biofuels at NLG 400/tCO_2.

Severe Competition

Residential electric heat pumps for new single-family dwellings in the Netherlands would contribute to reducing CO_2 emissions at relatively high costs. For the Netherlands the reduction in investment costs is essential to enhance the opportunities for the heat pump. The model suggests that a 20% cost reduction is required to make the heat pump a prominent CO_2 reduction technology for new dwellings at moderate to tight CO_2 constraints (over 40% emission reduction). Better results for heat pumps were found in similar MARKAL calculations for other countries, where the natural gas penetration rate in the residential sector is smaller and the heating and/or cooling demands are higher [1].

The situation in the commercial sector contrasts with the residential sector. Office heating requires large heating systems which have lower investment costs per unit of heating capacity. Gas absorption, gas engine and electric heat pumps are cost-effective in all scenario calculations, despite severe competition from combined heat and power units and fuel cells [4].

References

[1] *Kram, T. et al. 'Final Report IEA/ETSAP-Annex IV: Greenhouse Gas Emissions and National Energy Options'. ECN, Petten, the Netherlands, ECN-C-93-046.*

[2] *Koetzier, H. 'Electric Compression Heat Pumps in Residences'. KEMA, Arnhem, the Netherlands, May 1992 (in Dutch) WPB-92-669.*

[3] *Linnsen, B. 'CO_2 Benefits from Heat Pumps'. Technical University Eindhoven, ECN/Petten, December 1992 (in Dutch) ECN-I-92-004.*

[4] *Okken, P.A., T.Kram, P.Lako, J.R.Ybema, J.v.Doorn, D.Gerbers, D.Gielen. 'Energy Systems and CO_2 Constraints; An Integrated Assessment of Options for Reducing CO_2 Emissions in the Netherlands Energy System up to 2040'. ECN, Petten, the Netherlands, June 1993, ECN-C-93-014.*

Author:
Peter A. Okken, ECN/Policy Studies,
R&D Policy Programme, P.O. Box 1,
1755 ZG Petten, the Netherlands.
Tel.: +31-2246-4430; Fax: +31-2246-3338.

Taking a Measured Approach - Heat Pump Promotion in Switzerland

Karl-Heinz Handl, Switzerland

Heat pumps are set to make a significant contribution to the long-term aims of the Swiss federal energy programme - ENERGY 2000. New heat pump installations shall save approximately 200,000 tonnes of fossil fuel-based heat energy at the turn of the century - more than doubling the current contribution of heat pumps. This amounts to an additional heat supply in the order of 2.5 billion kWh per year and requires the installation of approximately 100,000 new heat pump units in the next eight years. The benefit to the environment equates to the reduction of hundreds of tonnes of harmful substances caused by combustion processes.

To meet these objectives, heat pumps are being promoted through the Swiss Heat Pump Promotion Association - a collaboration of parties concerned with the application of heat pumps. An important element in the Swiss promotion programme is a Test and Training Centre which ensures the high performance of heat pump equipment and is a centre of expertise on heat pump technology.

* * *

Through the Swiss Heat Pump Promotion Association, a programme of R&D, testing and application of heat pumps has been set into action. Efforts in the fields of technology and manufacturing are aimed at raising seasonal performance factor (SPF), safe operation, simplified installation in a modular system, and substantial lowering of the investment costs.

The "bivalent design principle" is one area of big interest since it can avoid additional peak load electric power supply during the winter season. Air-to-air heat pumps are also receiving attention for application in new buildings with high-quality insulation standards.

With the introduction of many new heat pump systems, a major role for the Heat Pump Promotion Association is the testing of new equipment.

Testing

At an investment cost of more than 2.5 million Swiss Francs (SFR) (US$ 1.65 million) the Heat Pump Test and Training Centre has been set up to carry out a rigorous test programme. The electric utility NOK has provided a venue for the Centre at its Winterthur-Töss substation. This reflects the requirement by electric utilities for high-efficiency heat pumps with trouble-free operation and no disturbance to the electric grid.

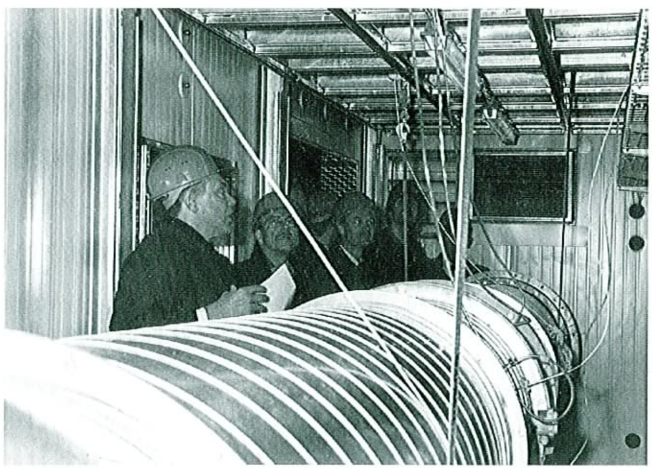
At the Centre, practically all marketable heat pump systems can be examined:

- air/water units up to 50 kW capacity;
- air/air units up to 25 kW capacity;
- water/water units up to 100 kW capacity.

Testing goes beyond the examination of heat pumps as separate appliances: the interaction of a heat pump with the building installations and structure must also be analyzed. The Centre therefore includes a climate chamber, which provides temperatures of between -23 and 37°C, and relative humidity between 30 and 95%. Tests cover not only the Swiss AWP (Association of Heat Pump Manufacturers) standards and the standards of the Heat Pump Promotion Association, but also, with the export market in mind, the relevant DIN and European standards.

At the time of writing, tests were booked from 22 companies for a total of 40 heat pump types with heating capacities ranging from 4 to 65 kW. Manufacturers are charged just SFR 500 (US$ 330) for a single test run, although a separate charge is made for follow-up consulting work. The true cost of testing

The author (left) outlines the measurement techniques used at the Heat Pump Test and Training Centre at Winterthur-Töss.



is made up through substantial contributions from the federal and cantonal authorities, and from utilities and other interested parties. Units passing the test are marked with a quality sign.

One important supplementary task of the Centre is to re-examine newly installed heat pumps on-site to determine that the actual performance meets the expectations of the tests made at the Centre. A mobile test rig is currently being designed by the Centre for this purpose.

Training

As part of a nation-wide effort on training and education on environmentally-based energy systems, the Centre offers courses to equipment design engineers, architects, energy consultants and plumbers. In addition, students of technical schools are given a chance to participate in test and measuring runs.

In parallel, the Centre supports the R&D activities of science and industry concerning new environmentally compatible refrigerants. Researchers will also make use of the precision equipment available at the Centre to study the use of various materials and new components for isolation between various ground-water levels.

Support

The large significance of heat pumps in meeting the objectives of the renewable energy component of the Swiss ENERGY 2000 programme, means that heat pumps receive significant public sponsorship. Based on the energy utilization resolution of 1 May 1991, the authorities of the Federal Department of Energy have introduced a heat pump support programme including:

- support of pilot and demonstration plants;
- intensified training and post-school instruction;
- information support;
- target-aligned subsidies.

The text in the blue box gives details on the subsidy scheme introduced from 1 March 1993. The authorities of the canton of Zurich, have committed an additional measure to support heat pumps by exempting restrictions on flue gas losses of fossil fuel-fired furnaces (below 70 kW heating capacity) when a heat pump unit is installed and meets at least 50% of the local heat demand per year.

A Marketing Opportunity

Due to intensified environmental protection regulations, many fossil fuel-based heating plants will become obsolete and will have to be replaced in the coming years. This presents a big marketing opportunity for heat pump systems. The provision of information and consultation, together with targeted financial incentives should help to avoid the installation of fossil fuel heating systems. The replacement of resistance heating is also encouraged since this releases additional electric power capacity which can be used to drive more heat pumps.

Promotion of heat pumps in Switzerland is based on the motto "utilization of all environmental energy sources available". The target is to install 100,000 heat pump units by the turn of the century, compensating more than 200,000 tonnes of distillate fuel equivalent. The long-term aim is to install 200,000 new heat pump units replacing 480,000 tonnes of distillate fuel oil equivalent. This target requires the hard work and collaboration of all disciplines and contractors which are able to make a contribution. These, and similar efforts in other countries, raise the chances of the heat pump becoming a significant element of modern heating systems within the shortest time.

Heat Pump Subsidies in Switzerland

From May 1st 1993, a Federal subsidy of SFR 300 (US$ 200) per kW thermal capacity installed is available for a limited period when the following criteria are satisfied:

- application is for heating only;
- installation after March 1st;
- must be bivalent air/water system or monovalent ground/water or water/water system;
- peak demand must not be met by resistance heating;
- maximum heating capacity of 12 kW for air/water systems or 18 kW for water/water or ground water systems[1];
- minimal COP of 3.0 for air/water, 3.2 for ground/water, or 3.8 for a water/water system[1];
- bivalent systems must meet an annual average efficiency of 105% (based on primary fuel consumption);
- performance data must meet Swiss standards and from 1 January 1994 heat pumps must be tested at the Töss Heat Pump Test and Training Centre;
- the installation must meet local regulations such as on water use and noise.

[1] Defined at a supply (output) water temperature of 35°C and a source (input) temperature of 7°C for air, 0°C for ground or 10°C for water.

Author:
Mr Karl-Heinz Handl, Project Manager of the TÖSS Heat Pump Test and Training Centre and vice president of the NOK, Nordostschweizerische Kraftwerke AG in Baden, Switzerland. Tel.: +41-56-203366;
Fax: +41-56-203752.

Bibliography

Energy Efficiency in Refrigeration and Global Warming Impact

International Institute of Refrigeration (IIR), 177, Bd Malesherbes, F-75017, Paris, France (Fax: +33-1-47-631798), 363 pp, ISBN: 2 903 633 622 (English/French) - price US$ 39 / 220 French Frank.

Proceedings of the International Conference held at the University of Ghent, Belgium on May 12-14, 1993. Some 35 presentations and keynote addresses examine the possible alternatives to CFC refrigerants. Many papers address natural refrigerants including ammonia, propane/butane, water and CO_2. Others consider mixtures of HFCs and HCFCs.

Solid Sorption Refrigeration

International Institute of Refrigeration (IIR), (see above), 316 pp, ISBN: 2 903 633 592 (English/French) - price US$ 60 / 300 French Frank.

Proceedings of the meeting of Commision B1 (Thermodynamics and Transfer Processes) in Paris, France on November 18-20, 1992. Papers cover the topics adsorption, chemical reactions, metal hydrides, heat and mass transfer, desiccant cooling and solar cooling.

1st Carinthian Heat Pump Day

"1 Kärtner Wärmepumpentag", Leistungsgemeinschaft Wärmepumpe, Vienna, Austria (Tel:. +43-222-50105-3519; Fax: +43-222-50509-28), 90 pp (German).

Proceedings of a meeting held on March 11, 1993 in the southern Austrian province of Carinthia. The eleven papers presented discussed the heat pump situation in Austria including market developments, electric tariffs and subsidies and legal problems concerning ground-source (especially direct-evaporation systems). Several papers report on successful heat pump applications in Carinthia, many of which concern hotel and recreational facilities for the local tourist industry.

The Use of CFCs Comes to an End

"Bruken av KFK skal avvikles", NTH-SINTEF Refrigeration Engineering, N-7034 Trondheim, Norway, 12 pp (Norwegian).

This colour brochure summarizes the problems facing the owners of refrigeration and heat pump equipment using CFC refrigerant, when the import of CFC to Norway is banned from 31st December, 1994. Owners are encouraged to examine their systems, prevent leaks and then choose to replace the refrigerant, retrofit the equipment for HFC-134a or HCFC-22, or to install new equipment using HFC-134a, ammonia or non-HCFC mixtures. Examples are given of applications where CFCs have been replaced in systems in buildings, transport, shops and the dairy industry. An English language version of this brochure is being considered.

Heating With a Heat Pump - a Safe Clean and Efficient Way to Use Renewable Environmental Energy

Renewable Energy Action Group, Switzerland, 16 pp (French/German/Italian).

Available in French, German or Italian, this colour brochure gives a simple explanation of heat pump technology, and highlights the environmental and energy-saving benefits. Examples of heat pump applications include information on actual energy use and equipment costs. Copies are available from the HPC.

Software

NIST Thermophysical Properties of Refrigerants and Refrigerant Mixtures

National Institute of Standards and Technology (NIST), Gaithersburg, USA (Tel.: +1-301-975-2208; Fax: +1-301-926-0416) (English) - price US$ 465 or US$ 100 when upgrading.

The latest version of the database - REFPROP Version 4.0, now covers 36 refrigerants with the addition of ten fluids including pentane, butane, ammonia and HFC-32. It informs the user on 14 properties of pure refrigerants and mixtures of up to five components. The MS-DOS compatible program uses Carnahan-Starling-DeSantis-Morrison coefficients and takes dipole moment into account. Properties available include viscosity and thermal conductivity.

IEA Heat Pump Programme

Heat Pumps and Thermal Storage

IEA HPC, Order No. HPC-WR-11, 171 pp (English) - price 50 Dutch Guilders.

Proceedings from the HPC Workshop "Heat Pumps and Thermal Storage", held in Japan in May this year are now available (ordering details are given on the back inside cover). All the papers presented are included along with a summary of the subsequent discussions. Topics include:

- the Japanese Super Heat Pump Programme;
- heat pumps combined with ice or water thermal storage;
- seasonal thermal storage in aquifers;
- a modular adsorption heat pump / heat storage unit known as SWEAT;
- adsorption developments for high output temperatures.

Conferences

*Call for Papers

Energex '93 - The 5th International Energy Conference
October 18-22, 1993 / Seoul, (Republic of Korea)
Contact: Energex '93 Secretariat, c/o the Korean Institute of Research, P.O. Box 77, Taedok Science Town, Taejon 305-343, Republic of Korea.
Tel.: +83-42-861-6230; Fax: +83-42-861-6231.

Meeting Customer Needs with Heat Pumps - 1993
October 20-22, 1993 / New Orleans, Louisiana (USA)
Contact: Pam Turner, EPRI, P.O. Box 10412, Palo Alto, CA 94303, USA.
Tel.: +1-415-855-2010.

Clima 2000
November 1-3, 1993 / London (UK)
Organized on behalf of the Federation of European Heating and Ventilation Associates.
Contact: Anne Gibbins, CIBSE headquarters, 222, Balham High Road, London SW12 9BS, UK.
Tel.: +44-1-81-6755211; Fax: +44-1-81-6755449.

Cold Climate Conference
November 17-19, 1993 / Nuremburg (Germany)
Contact: Deutsche Kälte und Klimatechnischer Verein, Pfaffenwaldring 10, 7000 Stuttgart 80, Germany.
Tel.: +49-711-685-3200; Fax: +49-711-685-3242.

Symposium on Heat Pump Design, Analysis and Application (1993 ASME Winter Annual Meeting)
November 28 - December 3, 1993 / New Orleans, Louisiana (USA)
Contact: Karen R. DenBraven, Mechanical Engineering Dept., University of Idaho, Moscow, Idaho 83843, USA.
Tel.: +1-208-885-7655; Fax: +1-208-885-9031.

International Seminar on Heat Transfer, Thermophysical Properties and Cycle Performance of Alternative Refrigerants
December 6-8, 1993 / Kitakyushu (Japan)
Contact: Prof. Shigeru Koyama, Institute of Advanced Material Study, Kyushu University, 6-1 Kasuga-Kohen, Kasuga-shi 816, Japan.
Tel.: +81-92-573-9611-ext-661; Fax: +81-92-575-3634.

International Absorption Heat Pump Conference '94
January 19-21, 1994 / New Orleans, Louisiana (USA)
Contact IAHPC '94 Conference Secretary, Mechanical Engineering Dep't, University of Maryland, College Park, Maryland 20742-3035, USA. Fax: +1-301-314-9477.

1994 Winter ASHRAE Meeting and Exhibition
January 22 - 26, 1994 / New Orleans, Louisiana (USA)
Contact: ASHRAE Meetings Department, 1791 Tullie Circle, NE Atlanta, GA 30329, USA.
Tel.: +1-404-636-8400; Fax: +1-404-321-5478.

Cold Climate HVAC '94
March 15-18, 1994 / Rovaniemi (Finland)
Organized by the Federation of Societies of Heating, Air-Conditioning and Sanitary Engineers in Finland (FINVAC).
Contact: FINVAC/Cold Climate HVAC '94, Mr Ilpo Nousiainen, Sitratori 5, SF-00420 Helsinki, Finland.
Tel.: +358-0-563-3600; Fax: +358-0-566-5093.

AIRAH 1994 International Conference and Exhibition
April 15-18, 1994 / Gold Coast, Queensland (Australia)
Organized by the Australian Institute of Refrigeration, Air Conditioning and Heating
Contact: Conference Manager, 191 Royal Parade, Parkville VIC 3052, Australia.
Tel.: +61-3-347-4777; Fax: +61-3-347-8571.

***New Applications of Natural Fluids in Refrigeration and Air-Conditioning**
May 10-13, 1994 / Hannover (Germany)
(IIR Commission B2)
Deadline for abstracts: November 1, 1993.
Contact: Prof. Kruse, University of Hannover, Welfengarten 1A, 3000 Hannover 1, Germany.

Calorstock '94
6th International Conference on Thermal Energy Storage
August 22-25, 1994 / Otaniemi, Espoo (Finland)
Contact: Mr Markku Kangas, Helsinki University of Technology, Department of Technical Physics, Otakaari 3, 02150 Espoo, Finland.
Tel.: +358-0-451-3212; Fax: +358-0-451-3195.

Annual Conference of the International District Heating and Cooling Association (IDHCA)
June 18-22, 1994 / Seattle, WA (USA)
Contact: Ms. C. Millunzi IDHCA, 1101 Connecticut Ave. N.W., Suite 700, Washington D.C., 20036.

***International Conference CFCs - The Day After (IIR Commissions B1, B2, E1 and E2)**
September 21-23, 1994 / Padua (Italy)
Deadline for abstracts: January 31, 1994.
Contact: Organizing Committee, IIR-AICARR Conference, c/o AICARR - viale Monte Grappa, 2, I-20124 Milano MI, Italy. Fax: +39-2-29000004.

***49th National Congress of the Italian Thermotechnical Association**
September 26-30, 1994 / Perugia (Italy)
Deadline for abstracts: January 31, 1994
Contact (for heat pump topics): Carlo Nazareno Grimaldi, Instituto di Energetica, Str. S. Lucia-Canetola, 06125 Perugia, Italy. Tel.: +39-75-5852735.

Future Issues

Vol./No.	*Topic*	*Deadlines*
11/4	Trends in Heat Pump Technology & Applications	1 September 1993
12/1	Heat Pump Working Fluids (including Alternative Refrigerants)	1 December 1993

Available from the HPC

Title	*Publication type*	*Order No.*	*Price (NLG)*
Domestic Hot Water Heat	Analysis Report	HPC-AR2	80
Heat Pumps and Thermal Storage	Workshop Proceedings	HPC-WR11	50
The Impact of Heat Pumps on the Greenhouse Effect	Analysis Report	HPC-AR1	80
	Workshop Proceedings	HPC-WR10	80
Heat Pumps - Better by Nature	Promotion Brochure	HPC-BR2	free
Heat Pumps - An Opportunity for Reducing the Greenhouse Effect	Promotion Brochure	HPC-BR1	free
The IEA Heat Pump Programme	Promotion Brochure	B1-HPP	free
A Clear View for the Future: Heat Pumps to the Year 2000 - Strategy Plan	Promotion Brochure	B2-HPP	free

Name

Company

Address

City / Postal Code

Country

☐ My country participates with the IEA Heat Pump Centre. Please send me my free copy of the HPC Newsletter each quarter.

☐ My country does not participate with the IEA Heat Pump Centre, but I would like to subscribe to the HPC Newsletter. (Annual subscription charge NLG 110, including postage).

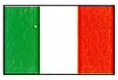
☐ Please cancel my subscription to the HPC Newsletter as of the next issue.

Date ____________________

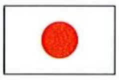
Signature ____________________

Austria
Mr Hermann Halozan, TU Graz
Inffeldgasse 25
A-8010 Graz, Austria
Tel.: +43-316-873-7303
Fax: +43-316-873-7305

Canada
Mr Douglas Cane, CANETA Research Inc.
6981 Millcreek Dr., Unit 28
Mississauga, Ontario, Canada L5N 6B8
Tel.: +1-416-542-2890
Fax: +1-416-542-3160



Italy
Mrs Laura Manduzio, ENEA - C.R.E. Casaccia
Via Anguillarese, 301
00060 S. Maria di Galeria, Rome, Italy
Tel.: +39-6-3048-6445
Fax: +39-6-3048-6306



Japan
Mr Yoshio Igarashi, Heat Pump Technology Center of Japan
Shuwa-Shibazonobashi Bldg., 1-20, Shiba 2-Chome,
Minato-ku, Tokyo 105, Japan
Tel.: +81-3-5442-3822
Fax: +81-3-5442-3823

The Netherlands
Mr Jan Bosma
Novem, P.O. Box 8242
3503 RE Utrecht , The Netherlands
Tel.: +31-30-363-431
Fax: +31-30-316-491

Norway
Mr Ulf Rivenæs
NVE's National Heat Pump Programme
P.O. Box 131, Vinderen, N-0319 Oslo, Norway
Tel.: +47-22-492-600
Fax: +47-22-492-600

Sweden
Mr Bernt Bäckström
Chalmers Teknikpark
S-41288 Göteborg, Sweden
Tel.: +46-31-7724-226
Fax: +46-31-418-056

Switzerland
Mrs Luisa Prista, Info ENERGIA
c/o Dipartimento del Territorio
CH-6500 Bellinzona, Switzerland
Tel.: +41-92-243-755
Fax: +41-92-243-736

USA
Mr Martin A. Broders, Oak Ridge National Laboratory
Building 3147, P.O. Box 2008
Oak Ridge, TN 37831-6070, USA
Tel.: +1-615-576-2731
Fax: +1-615-574-9338

IEA Heat Pump Centre
Swentiboldstraat 21, 6137 AE Sittard
P.O. Box 17, 6130 AA Sittard, The Netherlands
Tel.: +31-46-595-236
Fax: +31-46-510-389

STAMP

IEA Heat Pump Centre
P.O. Box 17
6130 AA SITTARD
THE NETHERLANDS

For your subscription please use the attached card.

The IEA Heat Pump Centre Newsletter will be published quarterly.

Subscribers from countries participating with the IEA Heat Pump Centre (see list above) will receive the Newsletter free of charge.

Subscribers from other countries will be charged NLG 110, a year, which includes postage.

Cancellation of the subscription must be made at least one month before the end of the subscription year.