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 be the energy forum for 25 industrialised countries and to implement an international energy programme. IEA member countries are committed to taking joint measures to meet oil supply emergencies. They share energy information and cooperate in the pursuit of rational energy policies and programmes. The IEA promotes the development of alternative energy sources and increased energy efficiency. In recent years, the Agency has devoted much attention to integrating environment and energy policies.

Fostering energy technology innovation is a central part of the IEA's work. Development of safer, more efficient technologies is imperative for energy security, environmental protection and economic growth. Equally essential is the widespread deployment of more economical and environmentally benign technologies. IEA experience has shown that international collaboration on these activities avoids duplication of effort, cuts cost and speeds progress.

IEA Implementing Agreements offer the framework for collaborative research projects. Benefits include pooled resources, shared costs, harmonisation of standards and hedging of technical risks.

The subject of this report is one IEA Agreement, the "Implementing Agreement for a Programme of Research, Development, Demonstration and Promotion of Heat Pumping Technologies", more commonly known as the IEA Heat Pump Programme, which began in 1978.

Programme Coordination

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The IEA Heat Pump Programme

Organised under the umbrella of the International Energy Agency in 1978, the IEA Heat Pump Programme, is a non-profit organisation funded by its member countries. The scope of the Programme covers heat pumps, as well as refrigeration and air conditioning. The participating countries are: Austria • Belgium • Canada • Denmark • France • Germany • Italy • Japan • Mexico • Netherlands • Norway • Spain • Sweden • Switzerland • United Kingdom • United States.

The Programme has an Advisory Board, made up of representatives from utility, industry and research sectors, to strengthen links between the Programme and its customers and to provide advice on strategic matters.

Activities of the Programme include the Heat Pump Centre, collaborative international projects, so-called Annexes, workshops and analysis studies.

One country, the Operating Agent, generally coordinates an Annex, which runs for a specific period and focuses on tasks ranging from information exchange to technology development and implementation. A description of the achievements of the ongoing Annexes during 1999 is given in this report as well as a summary of all the Annexes completed so far.

Vision

The IEA Heat Pump Programme is the foremost worldwide source of independent information and expertise on heat pumping and cooling systems for buildings, commerce and industry. Its mechanisms for international collaboration, information dissemination and market analysis support the work of its stakeholders and agencies concerned with energy efficiency and minimising environmental impact.

Mission

The Programme strives to develop and disseminate factual, balanced information concerning the application of heat pumping and refrigeration technologies for environmental and energy efficiency benefits.

The Programme serves the needs of policy makers, utilities, manufacturers, designers, researchers, installers and end-users.

Goal

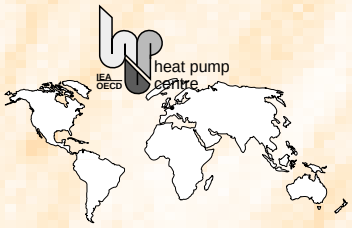
The overall goal of the Programme is to increase the knowledge base and broaden market acceptance of heat pumping technologies.

Strategic Activity Areas

- Disseminating best practice accounts of the technology, its application and deployment
- Facilitating fair comparison of heating and cooling technology options
- Influencing policy determination
- Enhancing the reputation, effectiveness and sustainability of the Programme

The Heat Pump Centre

The Heat Pump Centre operates an international communication network with its member countries.



The IEA Heat Pump Centre (Annex 16) links people and organisations worldwide in support of heat pump technology. From its office in the Netherlands, the Heat Pump Centre communicates through National Teams in its member countries. Each of these National Teams are made up of people and organisations representing the full spectrum of national heat pump activities.

The Heat Pump Centre has forged close links with other IEA Information Centres and with other international organisations concerned with heat pumps, including:

- *International Institute of Refrigeration (IIR)*
- *American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)*
- *United Nations Environment Programme (UNEP)*
- *European Heat Pump Network (EU-Thermie project)*

Contents

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Yellow text indicates Operating Agent.

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

Chairman's Statement

Hermann Halozan,
Chairman
IEA Heat Pump programme

The beginning of a new millennium is the right time to look back on the circumstances at the time the Programme was established and on the achievements during the past years, and for looking forward to identify the challenges and tasks that have to be worked on in the future. Since the inception of the Programme the general energy situation has changed significantly. Today there is no need for energy conservation to cope with shortage of energy carriers. However, there is a strong need for reducing the use of fossil fuels to inhibit the ongoing effects of global climate change. Despite the Kyoto Protocol, not all politicians are fully convinced that climate change will have a negative impact on their country. Insurance companies already know that they are being confronted with changing climatic conditions.

The challenge is to reduce greenhouse gas emissions, particularly as largely populated developing countries are on the road to industrialisation. The developed countries must reduce their greenhouse gas emissions, while developing countries need to minimise the increase of such emissions. To achieve these goals, highly efficient technologies must be used and heat pumping technologies are an excellent option. Heat pumps can deliver low-temperature heat, as required in the building sector, with a Primary Energy Ratio of at least 200%. In industrial applications, where small temperature lifts are required, this ratio can be much higher – up to 500% or more by using mechanical vapor recompression (MVR) systems. However, this is not the end, because there is considerable scope for further improvement of energy systems using heat pumps.

Air conditioning is also a promising area for using advanced systems with significantly reduced energy consumption. Increasing numbers of energy recovery systems are being used for refrigeration. The main task is to design and optimise systems in buildings (the entire building and its energy supply) and industry by considering the entire production process.

Almost 100 million heat pump units with a total thermal capacity of 600 TWh per year have been installed to date. They save around 0.12 Gt CO_2 emissions per year. The IEA Heat Pump Programme envisions contributing to an increase in the reduction by a factor of 10, which is equivalent to a 6% reduction of the worldwide CO_2 emissions, one of the largest potentials for a single technology.

Highlights of 1999

A New Strategy under Development

The Executive Committee has devoted much effort to revising their strategy, to guide the Heat Pump Programme over the next four years. The environmental benefits of heat pump technologies provide the framework for the new strategy, which will be finalised and implemented in 2000. At a special workshop the Advisory Board, with participation from industry and utility representatives, developed strategy recommendations. In anticipation of this new strategy, the Executive Committee initiated several activities in late 1999.

As part of the new activities, a committee has been established that will make recommendations for technical programme development and monitoring. Another task deals with the ongoing restructuring of the Heat Pump Centre. The new Heat Pump Centre programme and membership structure should enable broad membership at reasonable cost. Other tasks that have been assigned include:

- environmental country studies;
- raising stature and awareness of the Heat Pump Programme;
- establishing formal strategic alliances with related IEA Programmes and international organisations.

6th IEA Heat Pump Conference

The 6th IEA Heat Pump Conference in Berlin, Germany was a great success. The conference, entitled Heat Pumps – A Benefit for the Environment, attracted many foreign visitors. While millions of heat pumps are used in Japan, the USA and increasingly in China, their use in Europe cannot be compared in terms of market volume, even though the technology is considered reliable and proven and their working fluids safe. Hence the main reason for holding the conference in Berlin was to increase the exchange of knowledge and experience between the regions of the world, and to promote renewed market interest for heat pump technology in Europe for the benefit of the environment.

From 31 May to 2 June, participants were able to attend plenary sessions covering topics ranging from Markets and Market Strategies, Technology, Heat Pump Systems, to Applications. A total of 35 papers were presented, as well as 78 poster papers. The exhibition formed an important element of the conference. It provided an excellent forum for the informal exchange of ideas, information and networking. A number of technical tours were offered, giving participants the opportunity to visit and study heat pump installations and energy systems in practice. These ranged

from a visit to an advanced absorption heat pump system for heating and cooling a university building, to the ground-coupled heating and cooling system of the Reichstaggebäude, where the German Parliament is now housed. A cultural programme offered many choices for visiting Berlin's highlights, including a boat trip on the river Spree.

Increasing collaboration with the European Union

The European Heat Pump Network operates under the auspices of the European Commission to support the European heat pump industry. Their main task is to provide and exchange information concerning heat pumps among member states. The Executive Committee has been trying to enhance collaboration with the EU for some time, and these efforts are now starting to pay off. Collaboration has been implemented through the Heat Pump Centre. Joint activities include the European Heat Pump Network newsletter (the European Heat Pump News), which was distributed within the Heat Pump Centre network together with the IEA Heat Pump Newsletter, and an industry workshop on Natural Working Fluids in Paris.

UK joins Heat Pump Centre

In March the UK proudly announced its membership of the Heat Pump Centre. Efforts to build interest and momentum had resulted in full participation in the Heat Pump Programme. This included several informative meetings with stakeholders and potential participants. The Heat Pump Centre contributed presentations and promotional material. Supported by both industry and the government, notably the Department of Trade and Industry (DTI) and the Department of the Environment, Transport and the Regions (DETR), a UK Heat Pump Network has been established including a National Team to ensure maximum benefit from UK membership. Industry provides support through the Heat Pump Association (HPA), a trade association representing the best interests of organisations involved in the chain of design and supply of heat pump components, systems and energy supply industries. Other partners include the Energy Technology Support Unit (ETSU) and the Buildings Research Energy Conservation Support Unit (BRECSU). The UK heat pump network was launched in July to help the UK heat pump market develop according to best practice on environmental and economic grounds. With a strong heat pump R&D background and a prospering market for heat pumps in commercial/institutional buildings, the UK will be a strong and dedicated member of the Heat Pump Centre.

Heat Pump Centre programme restructured

The year 1999 marked the first year of operating the new Heat Pump Centre work programme. The new programme structure consists of a base programme and a tailored collaborative programme that provides flexibility and closer control by the member countries. Implementing this new programme required considerable effort, innovative thinking and response from both National Teams and Heat Pump Centre staff. Final organisational details and procedures were defined at a special meeting with the National Teams in Berlin. The tailored collaborative programme formed the greatest challenge, but eventually five projects were defined for 1999, ranging from surveys to developing an advanced heat pump project R&D database portal for use on the Internet (see also under Annex 16). The Heat Pump Centre will certainly not remain stagnant in the years to come. On the contrary, the Heat Pump Centre programme and membership structure will stay in a flux situation, continually aiming to ensure optimal satisfaction and broad membership.

Success Stories

Since its inception in 1978, the Heat Pump Programme has generated many publications. Each article, brochure, newsletter, proceedings and report is accessible through the Heat Pump Programme bibliography of abstracts on the Internet (http://www.heatpumpcentre.org). The bibliography now contains over 1,800 items dealing with a wide spectrum of topics. This is one of the most frequently requested sections of the Heat Pump Centre Internet site.

Annex 18, *Thermophysical Properties of Environmentally Acceptable Refrigerants*, was terminated with a paper presented by the Operating Agent at the 20th International Congress of Refrigeration in Sydney, Australia. This nine-year Annex has brought together properties experts in a cooperative, task-sharing arrangement. CFC and HCFC alternatives, including HFCs and their mixtures, and natural working fluids have been considered. The Annex can count many successes and the results of this collaboration are immediately usable. These include internationally accepted formulations for the thermodynamic properties of R123, R134a, R32, R125 and R143a. A comparison of available models has facilitated the dissemination of a new approach for the thermodynamic properties of HFC mixtures. Also included are surveys of the available thermodynamic

$$\alpha_{mix} = \frac{A_{mix}}{RT} = \sum_{j=1}^{n}\left[x_j\left(\alpha_j^{id} + \alpha_j^{r}\right) + x_j \ln x_j\right] + \sum_{i=1}^{n-1}\sum_{j=i+1}^{n} x_i x_j F_{ij} \alpha_{ij}^{excess} \quad .$$

and transport property data of numerous working fluids. An experimental database, which was made available on the Internet (http://www.itt.uni-stuttgart.de/~krauss/midas.htm), completed the work. The products of this Annex, embedded in several reports, enable considerable progress to be made in the science and knowledge of new working fluids in heat pump, air conditioning and refrigeration technology.

Another most successful Annex that came to an end was Annex 22, *Compression Systems with Natural Working Fluids*. The products of the Annex consist of a final report – Guidelines for Design and Operation of Heat Pump, Air Conditioning and Refrigeration Systems with Natural Working Fluids – an Internet home page (http://www.maskin.ntnu.no/kkt/annex22), proceedings from two international workshops and an international status report. Within the Annex, 25 R&D projects have been conducted in participating countries, which provided unique information ranging from laboratory to operational data from various installations. The Operating Agent presented the results at two international conferences: the Gustav Lorentzen conference in Oslo (1998) and the 6th IEA Heat Pump Conference in Berlin (1999).

Annex 23, *Heat Pump Systems for Single-Room Applications*, was successfully completed in 1998. The Heat Pump Centre published the final report from this Annex in early 1999. The main conclusion was that "Distributed heating and cooling systems have a tremendous potential to save energy and improve comfort in residential and commercial buildings".

Annex 24, *Ab-sorption Machines for Heating and Cooling in Future Energy Systems*, resulted in three products that can be used by researchers, designers, utilities, end-users and governmental bodies to assess and facilitate the development and application of sorption systems:

- Workshop proceedings I (Maastricht, 1997);
- Workshop proceedings II (Tokyo, 1998);
- A final report, which outlines sorption technology and potential applications, and summarises experiences, technical developments and country-specific issues. Emphasis was also placed on global assessment and strategies for further technology deployment.

International Networking

Countries considering joining

Heat pump technology is increasingly valued as an important strategy for governments and the energy sector in trying to meet their Kyoto commitments. Some countries are considering joining the Heat Pump Programme. In Sydney, Australia, a meeting was arranged with government and industry representatives to discuss how to mobilise the Australian interest and secure firm support from government and industry. A similar meeting was also held in Sydney to discuss New Zealand's interest in joining. A representative of the European Commission's DG XVII attended the autumn Executive Committee meeting and the IEA Heat Pump Conference in Berlin.

The Executive Committee discussed policies for future collaboration with China, whose representatives have indicated interest in the Heat Pump Programme. Observers from China were invited to attend the Executive Committee meetings. Dealing with the appropriate authorities in China is one of the main problems. The possibility of arranging a workshop in China is currently being discussed, which would provide an ideal opportunity for forging the right contacts. An invitation to attend meetings was also sent to Polish representatives, who are interested in international collaboration on heat pumps.

Joint Heat Pump Centre-EU workshop on Natural Working Fluids

The first joint IEA/EU (European Heat Pump Network) heat pump-related workshop was held on 9 November 1999. *Natural Working Fluids – a Challenge for the Future*, was the title of this workshop, which was held in conjunction with the Interclima/Interconfort exhibition in Paris. The use of natural working fluids causes a lot of discussion in Europe and abroad, and raises several important issues such as safety, liability, etc. Representatives from European installers, equipment manufacturers, refrigerant producers and standards committees gathered for this meeting. The workshop highlighted barriers to the further use of ammonia, CO_2 and hydrocarbons in residential and small commercial heat pumps. An important result from the workshop is a set of recommendations for the EC's DG XI concerning their support for training of natural working fluid heat pump equipment installers.

Collaboration with ASHRAE, IIR and the EU

The Heat Pump Centre continues to work closely with ASHRAE. Several heat pump-related technical committees under ASHRAE provide an excellent source of information. ASHRAE co-sponsored the 6th IEA Heat Pump Conference in Berlin, demonstrating that they are an international organisation that supports energy-efficient heat pump technologies. Through the Heat Pump Centre, ASHRAE's International Committee has created a regional link with their central and southern European members.

In 1999 the International Institute of Refrigeration (IIR) contributed to Heat Pump Centre studies in a scientific review capacity. The Heat Pump Centre has forged strong links with IIR through representation in Commission E2 (Heat Pumps and Heat Recovery). Further areas for collaboration were explored and steps were made to establish formal alliances with the IIR in the near future. Representatives of the Heat Pump Programme attended the 20th International IIR Congress of Refrigeration in Sydney, Australia, where results of Annexes 16, 18 and 22 were presented. IEA representatives have been appointed IIR officials for the period 1999-2003. The new director of IIR, Mr François Billiard, attended the autumn meeting of the Executive Committee in Paris.

The Heat Pump Centre participates in the EU-SAVE project *Transforming the Market for Electrical Heating of Domestic Dwellings*. Project partners from the UK, Sweden, Austria, Finland, Romania, Germany, Denmark and the Czech Republic work together to stimulate the market introduction of electric heat pumps in Europe. The Heat Pump Centre's role is to provide advice, international information and contacts in support of project tasks. Part of the work is to facilitate the foundation of a European Heat Pump Association. A draft constitution has been developed and the Association should be fully established in 2000. The Heat Pump Centre has been invited to take on a role as international information provider.

Annex Achievements 1999

Annex 16: The Heat Pump Centre

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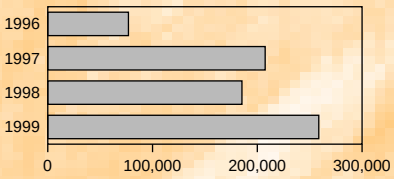

Page requests from the Heat Pump Centre website.

Participating countries in the Heat Pump Centre: Austria, Japan, the Netherlands (Operating Agent), Norway, Switzerland, the United Kingdom and the United States. The United Kingdom joined the Heat Pump Centre in the course of 1999. By the end of the year their National Team was established and in full operation.

The Heat Pump Centre plays a central role within the IEA Heat Pump Programme. Using its National Team network, along with other organisations, the Heat Pump Centre works towards the aims of the Programme by providing a worldwide, independent information exchange service. The objective of the Heat Pump Centre is to accelerate the implementation of heat pump technology by exchanging information and transferring knowledge on an international level. The Heat Pump Centre is one of the world's leading information centres on heat pumps and one of the largest publishers of heat pump literature.

First experience with the new programme structure

The base programme of the Heat Pump Centre contains fixed elements including the production of the Heat Pump Newsletter, the Internet site (http://www.heatpumpcentre.org), and coordination with member countries and related international organisations. A Frequently Asked Question section has been added to the website, which replaced the Enquiry Service of the Heat Pump Centre. The website will also be extended to include a bulletin board. The Internet site draws an increasing number of visitors, with the US clearly leading the way (54%). In 1999 the average number of page requests stabilised around slightly more than 20,000 per month.

Under the tailored collaborative programme the following projects have commenced.

- *Residential heat pumps and energy-efficient heating (and cooling) distribution and ventilation systems.* This project aims to compare existing energy-efficient distribution systems, in combination with residential heat pumps, covering air systems, ventilation and hydronic systems.
- *Heat pumps for retrofit.* The project will document and evaluate the technical and market status of residential and small commercial heat pump systems for retrofitting, as well as impediments to their application.
- *Natural working fluids.* See joint HPC/EU workshop.
- *Screening R&D and P&D databases.* This project screens and documents available information sources providing data concerning ongoing R&D and P&D projects.

1999 National Teams Working Meeting, Utrecht, the Netherlands

- *Transforming the market for electrical heating of domestic dwellings.* The aim of this EU study is to undertake key tasks to transform the market for residential electrical heating by using heat pump technology. Key tasks include developing suitable design tools, providing information and training initiatives.

The first two projects are surveys that could lead to new Annexes or Analysis Studies. For the first time since the inception of the Heat Pump Centre, a task has been undertaken that focuses on retrofitting with heat pumps – this being an important and potentially large market for heat pumps.

It is too early to draw any conclusions as to the effect of the new Heat Pump Centre programme structure, but the first impression is encouraging, even though it took some time to organise and implement the new structure.

Publications during 1999

Topics covered in the quarterly Heat Pump Newsletter during 1999 were:

- Ground-source Heat Pump Systems;
- Sorption Heat Pumps;
- 6th IEA Heat Pump Conference/Environmental Benefits;
- Industrial Heat Pumps.

Summary translations were made available to German and French readers of the magazine. Most subscribers live in member countries. Distribution there was as follows:

Austria	144	Norway	795	UK	500
Japan	1205	Switzerland	650	USA	950
Netherlands	449				

The Conference issue provided a snapshot of the state of the art of the technology and international markets.

For the first time the newsletter of the European Heat Pump Network (European Heat Pump News) was distributed jointly with the Heat Pump Magazine. This marks the beginning of a more substantial collaboration with the EU on heat pump publications.

The Heat Pump Centre published three Analysis reports in 1999:

- The Role of Heat Pumping Technologies in a Deregulated Energy Market;
- Environmental Benefits of Heat Pumping Technologies;
- International Heat Pump Status and Policy Review 1993-1996.

The last of these reports is an update of an earlier study conducted in 1992. An interesting conclusion is that the overall worldwide heat pump market has grown at an average annual rate of 15%. In Europe the average annual growth rate lies around 13%. In some mainly-heating countries heat pumps are making promising progress. In the study on the environmental benefits the concept of life cycle analysis was applied for both energy and working fluid. An important conclusion is that the energy of operation dominates unitary heat pumps and air conditioners. The study on the impact of liberalisation of electric utilities on heat pumps provided a useful state-of-the-art overview of the restructuring process in industrialised countries.

The Proceedings of the Annex 24 workshop *Ab-Sorption Machines for Heating and Cooling in Future Energy Systems* held in Tokyo, Japan, were also published, as well the final reports from Annexes 22 *Guidelines for Design and Operation of Compression Heat Pumps, Air Conditioning and Refrigeration Systems with Natural Working Fluids* and 23 *Heat Pump Systems for Single Room Applications.*

Annex 24: Ab-Sorption Machines for Heating and Cooling in Future Energy Systems

Participating countries: Canada, Italy, Japan, the Netherlands, Norway, Sweden (Operating Agent), the United Kingdom and the United States.

Annex 24 aims to further increase and promote the use of thermally driven systems, i.e. absorption systems, adsorption systems and compression/absorption systems, for heating and cooling in future energy-efficient and environmentally acceptable energy systems. The Annex work focuses on gaining a better understanding of the market opportunities for thermally driven systems in a global perspective, and examining how different factors (i.e. economic, political, environmental and knowledge) will affect the promotion and application of such systems in residential, commercial and industrial sectors.

Experts meeting

During 1999, a workshop was held in Turin, Italy, which focused on preparing the final Annex report and remaining work. Regulations concerning pressure, machinery and electrical codes were also discussed.

Release of workshop proceedings

The Proceedings of the 2nd workshop, held in Tokyo, Japan, on 28-30 October 1998 was published in the spring of 1999. The papers originated from no less than eight countries including China, South Korea, Japan, Malaysia, Sweden, Norway, the UK and the Netherlands. The workshop also attracted many representatives from utilities, manufacturers of absorption/adsorption equipment, as well as end-users. This indicates the widespread interest in applications and development of thermally activated heat pump technologies. The workshop included a broad range of presentations, ranging from R&D activities to applications of absorption/adsorption technology.

Preparation of final report

In conducting the various Annex 24 assessments, the participating countries have performed various tasks including:

- preparing a detailed report;
- estimating the potential and applications for absorption systems;
- conducting case studies;
- starting up demonstration projects;
- assessing codes and regulations, environmental impacts, etc.

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Annex 25: Year-Round Residential Space Conditioning Systems Using Heat Pumps

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Participating countries of Annex 25: Canada, France (Operating Agent), the Netherlands, Sweden and the United States.

Annex 25's objective is to define and demonstrate the technical feasibility of new packaged systems for year-round residential space conditioning that use a heat pump. These systems, which include all components used for heating and cooling, are mainly for new residences and use either water or air to distribute the energy. The work carried out within the framework of this Annex covers elements such as low investment and operating costs, comfort, suitability to customer demands, design and installation requirements, performance, integration into the building, and aesthetics.

The participating countries will implement a programme that is structured into three main tasks.

Task 1: State-of-the-art study
- Analysis of existing systems in individual homes
- Market needs on heating and cooling systems for residences
- Definition of new concepts for heating and cooling systems

Task 2: Cooperation with manufacturers
- Communication with domestic manufacturers
- Prototype system development
- Preparation of demonstration projects

Task 3: Demonstration and dissemination
- Field tests
- Dissemination of results and information

Task 1 is nearly complete. Each participating country has examined the domestic economic, technical and societal aspects of the heating and air-conditioning market. The perspectives for heat pump technology development resulting from these studies will be used to define the most suitable system for heating and/or cooling of new and retrofitted homes.

Further to the analysis of existing heating systems, **Canada** will focus on retrofitting direct electrical baseboard heaters, which dominate the heating market. The strategy consists of developing a single controller for both an individual air-to-air heat pump and the direct electrical backup heater.

The contribution from **France** focuses on hydronic systems, floor heating and cooling, and fan-coil units. By analysing the existing systems, several new concepts have been defined. A hybrid system, consisting of floor heating and cooling combined with water terminal units, has been chosen for field-testing.

Studies carried out in **the Netherlands** are exploring the heat pump market and the competitive position of residential and commercial heat pumps. The target for new residences will probably be space and water heating, with space cooling as an extra. A solar-assisted ground-source heat pump may be the system that will be developed and shared with the Annex.

Sweden provides relevant information on the expectations of consumers, architects and installers, on the owner's perception and recommendations before installing a heat pump system, and on service demand. R&D efforts are needed for optimised heat pump performance and to define a suitable innovative heat distribution system.

The **US** project covers three main areas:

- assessing existing space conditioning and distribution system performance and problems;
- investigating design alternatives to reduce losses;
- laboratory validation of potential system improvements.

Initial analysis is being conducted for an air-to-air heat pump equipped with a small diameter, high-velocity duct system. A field test of a hydronic fan coil distribution system is also planned.

Annex 26: Advanced Supermarket Refrigeration/Heat Recovery Systems

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Participating countries of Annex 26: Canada, Sweden, the United Kingdom and the United States (Operating Agent).

This is the first Annex within the Programme to combine refrigeration and space conditioning. The objective of the Annex is to demonstrate and document the benefits of advanced system design for food refrigeration and space heating and cooling for retail supermarkets. A specific goal is to identify advanced systems design options to reduce total equivalent warming impact (TEWI) of supermarkets. Candidate advanced supermarket refrigeration systems will be analysed and compared to state-of-the-art systems. These concepts include:

- secondary loop systems;
- distributed compressor systems;
- self-contained display cases.

The **US** has analysed two advanced (low-TEWI) refrigeration system options (secondary loop and distributed compressors), and compared this to the most typical US baseline system (multiplexed compressors located in one area with long connections to display cases, air-cooled condensers for refrigeration heat rejection, with unitary rooftop units for space conditioning). The results indicated that a water-cooled distributed system coupled to water-source heat pumps for store space conditioning can yield 8-20% energy savings while reducing refrigerant charge by about two-thirds compared to the typical multiplex systems used today. A field test of a distributed compressor/water-source heat pump system has been started. In addition, a spreadsheet analysis model is being developed to provide supermarket planners and equipment designers with an easy-to-use tool for making relatively quick comparisons of energy use and environmental impact of different technical solutions for store refrigeration needs.

Sweden is working on supermarket refrigeration technologies as part of their national programme Klimat 21. A principal goal is to develop a user-friendly computer model to deal with technical solutions, life cycle costs, and environmental impact of supermarket energy systems. Six case studies are planned, four of which have started. Technologies under consideration include distributed compressor systems, secondary loop systems, and an energy storage system.

Two **Canadian** organisations are conducting projects for Annex 26. In one project a number of technology options are evaluated, including secondary loop systems with brines or CO_2 and heat rejection to a water loop and cooling tower or geothermal loop. Another project concerns field testing an advanced system and a conventional system in supermarkets located in the same area.

The **UK** has confirmed participation and they are in the process of identifying their project work from a wide area of interest.

Annex 27: Selected Issues on CO_2 as Working Fluid in Compression Systems

Participating countries in Annex 27: Norway (Operating Agent), Japan, Sweden, the United Kingdom and the United States.

The main objective of this Annex is to bring CO_2 heat pump technology closer to commercialisation, by addressing critical issues of both a basic and applied nature. This Annex requires industry participation from manufacturers as well as research organisations, and the participating countries will conduct R&D work and establish and monitor prototype and demonstration projects.

The tasks and work programme for the Annex were defined at the kick-off meeting in Mainz. The Annex will focus on remaining CO_2 technology challenges of a basic and pre-competitive nature and on implementation (bringing CO_2 technology closer to commercialisation). At the following meeting, which was held in conjunction with the IIR Congress in Sydney, countries confirmed their participation.

RD&D projects

Japan will focus on Heat Transfer Characteristics of CO_2. Three test rigs are being independently constructed to analyse the boiling heat transfer (at subcritical pressures) and the heat transfer (at supercritical pressures) inside smooth tubes. Another project will focus on the feasibility of residential and commercial heat pumps and mobile air conditioners, using studies carried out by private enterprises.

The input from **Norway** will consist of CO_2 Heat Transfer and Pressure Drop Characteristics, notably during condensation. The impact of different lubricants will also be studied, and correlations will be analysed for both oil-free and oil-contaminated CO_2. In two other projects they will:

- experimentally study the effect of initial conditions, liquid fill level and crack size on the occurrence of Boiling Liquid Expanding Vapour Explosion in a CO_2 vessel;
- study oil issues in actual CO_2 systems.

Specific aspects studied in the latter project include the thermophysical properties of mixtures, the impact of water entrainment, the impact of oil on system performance and oil return.

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The **UK** project will demonstrate novel face seals for positive displacement compressors with an integral expansion device that will allow the system to be used successfully with CO_2. A new seal has been devised that should have all the necessary characteristics. A detailed design and computer simulation will be made of the candidate seal, followed by rig testing.

The **US** will also contribute two projects. One will study evaporation heat transfer coefficients of CO_2 with tests in microchannel passages. The second project deals with the feasibility of transcritical CO_2 systems for mobile space conditioning applications. In the latter project a transcritical CO_2 system will be built for a typical sport utility vehicle and used for experimental verification of the heat exchanger and system models.

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Summary of the Annexes

Annex	Operating Agent	Participants	Completed
1. *Common Study of Advanced Heat Pumps*	Germany	Austria, Belgium, Canada, Denmark, Germany, Italy, Japan, The Netherlands, Spain, Sweden, Switzerland, UK, USA	1980
2. *Vertical Earth Heat Pump Systems*	Sweden	Austria, Canada, Denmark, Sweden, USA	1983
3. *Heat Pump Systems Applied in Industry*	Belgium	Austria, Belgium, Canada, Denmark, Finland, Germany, Italy, Japan, The Netherlands, Sweden	1984
4. *IEA Heat Pump Centre*	Germany	Austria, Belgium, Canada, Finland, Germany, Italy, Japan, The Netherlands, Norway, Sweden, USA	1989
5. *Integration of Large Heat Pumps into District Heating and Large Housing Blocks*	Sweden	Denmark, Germany, Italy, Sweden	1986
6. *Study of Working Fluid Mixtures and High Temperature Working Fluids for Compressor Driven Systems*	Sweden	Austria, Denmark, Finland, Germany, Japan, USA	1986
7. *New Development of the Evaporator Part of Heat Pump Systems*	Sweden	Canada, Denmark, Finland, Norway, Sweden	1989
8. *Advanced in-ground Heat Exchange Technology for Heat Pump Systems*	Canada	Canada, Germany, Switzerland, USA	1992
9. *High Temperature Industrial Heat Pumps*	Belgium	Belgium, Germany, Finland, Japan, The Netherlands, Sweden, Switzerland, USA	1990
10. *Technical and Market Analysis of Advanced Heat Pumps*	USA	Sweden, USA	1991
11. *Stirling Engine Technology for Application in Buildings*	USA	Japan, Sweden, USA	1989
12. *Modeling Techniques for Simulation and Design of Compression Heat Pumps*	USA, Italy	Austria, Belgium[1], Germany, Italy[1], Japan, Switzerland, USA	1992
13. *State and Transport Properties of High Temperature Working Fluids and Non-Azeotropic Mixtures*	Sweden	Canada, Germany, Japan, Norway, Sweden, USA	1992

[1] *Phase 1 only*

Annex	Operating Agent	Participants	Completed
14. Working Fluids and Transport Phenomena in Advanced Absorption Heat Pumps	Japan	Belgium, Denmark, Germany, Japan, Sweden, USA	1991
15. Heat Pump Systems with Direct Expansion Ground Coils	Canada	Austria, Canada, Japan, USA	1993
16. IEA Heat Pump Centre	the Netherlands	Austria, Japan, The Netherlands, Norway, Switzerland, UK, USA	ongoing
17. Experiences with New Refrigerants in Evaporators	Sweden	Canada, The Netherlands, Norway, Sweden, Switzerland	1993
18. Thermophysical Properties of Environmentally Acceptable Refrigerants	USA	Austria, Canada, Germany, Japan, Sweden, UK, USA	1999
19. Cancelled			
20. Working Fluid Safety	Belgium	Belgium, Japan, The Netherlands, Norway, Switzerland	1993
21. Global Environmental Benefits of Industrial Heat Pumps	USA	Canada, France, Japan, The Netherlands, Norway, Sweden, UK, USA	1996
22. Compression Systems with Natural Working Fluids	Norway	Canada, Denmark, Japan, The Netherlands, Norway, Switzerland, UK, USA	1999
23. Heat Pump Systems for Single-Room Applications	Canada	Canada, France, Switzerland, Sweden, USA	1999
24. Ab-Sorption Machines for Heating and Cooling in Future Energy Systems	Sweden	Canada, Italy, the Netherlands, Norway, Japan, Sweden, UK, USA	ongoing
25. Year-Round Residential Space Conditioning Systems using Heat Pumps	France	Canada, France, The Netherlands, Sweden, USA	ongoing
26. Advanced Supermarket Refrigeration/Heat Recovery Systems	USA	Sweden, Canada ,UK, USA	ongoing
27. Selected Issues on CO_2 as Working Fluid inCompression Systems	Norway	Japan, Norway, Sweden, UK, USA	ongoing

Publications from all these Annexes are available from the Heat Pump Centre:
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