# Annual Report 2008

2008











International Energy Agency

HEAT PUMP PROGRAMME

IEA
OECD

Implementing Agreement for a Programme of Research, Development, Demonstration and Promotion of Heat Pumping Technologies

# Contents


| | | | |
|---|---|---|---|
| 3 | International Energy Agency | 13 | Annex 30 |
| 4 | IEA Heat Pump Programme | 14 | Annex 31 |
| 5 | Chairman's Statement 2008 | 15 | Annex 32 |
| 6 | The 9th International Energy Agency Heat Pump Conference | 16 | Annex 33 |
| | | 17 | Annex 34 |
| 8 | Highlights of 2008 | 18 | Programme Contacts |
| 10 | Programme Achievements 2008 | 20 | Summary of Annexes |
| 12 | Annex 29 | | |


## Ongoing Annexes

Bold text indicates Operating Agent.

| | | |
|---|---|---|
| 29 | **Annex 29**<br>Ground-Source Heat Pumps – Overcoming Market and Technical Barriers | **AT**, CA, JP, NO, SE, US |
| 30 | **Annex 30**<br>Retrofit Heat Pumps for Buildings | **DE**, FR, NL |
| 31 | **Annex 31**<br>Advanced Modeling and Tools for Analysis of Energy use in Supermarkets | CA, DE, **SE,** UK (partly), US |
| 32 | **Annex 32**<br>Economical Heating and Cooling Systems for Low Energy Houses | AT, CA, **CH**, DE, FR, JP, NL, NO, SE, US |
| 33 | **Annex 33**<br>Compact Heat Exchangers in Heat Pumping Equipment | AT, JP, SE, **UK**, US |
| 34 | **Annex 34**<br>Thermally Driven Heat Pumps for Heating and Cooling | AT, CA, CH, **DE**, IT, NL, NO, US |

The IEA Heat Pump Programme participating countries are: Austria (AT), Canada (CA), France (FR), Germany (DE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), South Korea (KR), Sweden (SE), Switzerland (CH), the United States (US). All countries are members of the Heat Pump Centre (HPC). Sweden is the Operating Agent of the Heat Pump Centre.

Pictures front cover: the 9th IEA Heat Pump Conference in Zürich, photographer Mrs Daniela Kohler, Uznach, Switzerland and the Heat Pump Centre

# International Energy Agency

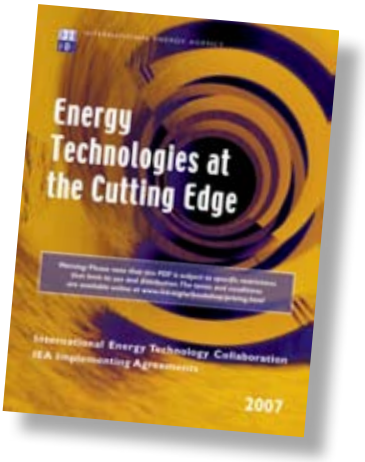
The International Energy Agency (IEA) acts as energy policy advisor for its 28 member countries as they work for reliable, affordable, clean energy for their citizens. Founded during the oil crisis of 1973-74, the IEA initially co-ordinated measures addressing oil supply shortages. Since then, evolving energy markets have brought new challenges. The IEA's portfolio now focuses equally strongly on climate change policies, market reform, energy technology collaboration and outreach to the rest of the world. Scenario analysis and roadmapping play a prominent part in the work of the IEA's teams of close to 200 staff. Energy experts and statisticians from member countries conduct a broad programme of energy research, data compilation, publishing and public dissemination of the latest energy policy analysis and good-practice recommendations. Following up on work for the G8, initiated in 2005, the IEA was entrusted at the 2008 G8 Hokkaido Summit in Hokkaido, Japan, with a second set of tasks for leaders of the world's major industrialised nations.

For more than 30 years, IEA technology collaboration has been crucial in advancing more efficient, cleaner energy technologies. The collaborative vehicles are IEA energy technology R&D Programmes, or Implementing Agreements. These allow interested member and non-member governments to pool resources for R&D and deployment focusing on particular technologies. Operating within the standard rules and regulations of the "IEA Framework", these Implementing Agreement Programmes currently number 42. They cover the areas of: End-Use (Buildings, Industry and Transport); Fossil Fuels, Renewable Energies and Hydrogen; Fusion and Cross-Cutting Activities. The IEA Committee on Energy Research and Technology (CERT) and its Working Parties provide guidance and review the effectiveness, achievements and strategies of each Implementing Agreement.

This publication concerns the *"Implementing Agreement for a Programme of Research, Development, Demonstration and Promotion of Heat Pumping Technologies"*, known as the IEA Heat Pump Programme (HPP).

www.iea.org

More information about the Implementing Agreements can be found on **www.iea.org/Textbase/techno** and in the publication *"Energy Technologies at the Cutting Edge"* (free to download from the IEA website)



# IEA Heat Pump Programme

**Heat Pump Programme Co-ordination**
Heat Pump Centre
SP Technical Research Institute of Sweden
Box 857
SE-501 15 Borås
Sweden
Tel. +46 10 516 55 19
Fax: +46 33 13 19 79
hpc@heatpumpcentre.org

www.heatpumpcentre.org

Organised under the umbrella of the International Energy Agency since 1978, the IEA Heat Pump Programme is a non-profit organisation funded by its member countries. The scope of the Programme covers heat pumps, air conditioning and refrigeration, commonly denoted as heat pumping technologies.

**HPP member countries are:**
Austria, Canada, France, Germany, Italy, Japan, the Netherlands, Norway, South Korea, Sweden, Switzerland and the United States.

## Vision

The Programme is the foremost worldwide source of independent information and expertise on environmental and energy conservation benefits of heat pumping technologies (including refrigeration and air conditioning).
The Programme conducts high value international collaborative activities to improve energy efficiency and minimise adverse environmental impact.

## Mission

The Programme strives to achieve widespread deployment of appropriate high quality heat pumping technologies to obtain energy conservation and environmental benefits from these technologies. It serves policy makers, national and international energy and environmental agencies, utilities, manufacturers, designers and researchers.

## Strategic Objectives

***Energy and Environment***
To quantify and publicise the energy saving potential and environmental benefits (local and global) of heat pumping technologies.

***Market and Deployment***
To develop and deliver information to support deployment of appropriate heat pumping technologies.

***Technology***
To promote and foster international collaboration to develop knowledge, systems and practices in heat pumping technologies through RDD&D (research, development, demonstration and deployment).

***Information Management***
To provide effective flow of information to, from and between stakeholders and other relevant entities.

***Visibility and Status***
To improve significantly the visibility and status of the Programme, and to be an outstanding Implementing Agreement within the IEA.

## Activities

The activities of the Programme include an information service, the Heat Pump Centre, international collaborative projects (Annexes), workshops, analysis studies and a triennial international conference.

# Chairman's Statement 2008



It is once again my great pleasure to write the Chairman's Statement for the IEA Heat Pump Programme. In its 30 years of existence, the Programme has fostered information exchange and dissemination on heat pumping technologies, and stimulated the development of advanced heat pump systems. It is a tribute to the excellent collaboration of all members that the Programme is now well established and recognised. So, on this 30 year anniversary of HPP, I would like to thank all members for their active and continuing participation. With increasing energy demand, heat pumps are even more pertinent now than they were 30 years ago. We must continue our efforts to facilitate the implementation of heat pump systems as a central component of efficient energy systems.

This year has been marked by the accession of two new member countries: South Korea and Italy. On behalf of the Executive Committee, I am delighted to welcome them. I am convinced that they will be major contributors to the development of the Programme. Their presence will increase HPPs visibility and contribute to the Programme deployment in their respective countries.

The major event of the year was the 9th International Heat Pump Conference held in Zürich. In this report you can read more about how successful this conference was in terms of quality of conference programme, number of participants and presentations. A first class organisation was a major reason for its success. All our congratulations go to the members of the National and International Organising Committees for this event and particularly to Professor Thomas Kopp and Dr Rune Aarlien who chaired these committees. During the conference the Ritter von Rittinger award was presented for the second time. Professor Predrag Hrnjak (USA), Professor Eric Granryd (Sweden) and Mr Gerald Groff (USA) received the award for having distinguished themselves in the advancement applications in heat pumping technologies, market development and related dissemination activities that provide lasting international impact. Also, for the first time two awards were presented for best posters at the conference.

Two Executive Committee meetings were held, one in Zürich, in June and one in Seoul, in November. In conjunction with the Seoul meeting, a workshop was organised by the Korean representatives to present their national heat pump activities and to obtain more information on the IEA Heat Pump Programme. HPP was also present at other international events such as the IEA Building Coordination Group meeting in Paris in January and the Chillventa trade fair in Nürnberg, Germany, in October, which was an opportunity to promote the Programme. HPP also holds regular meetings with the International Institute of Refrigeration and the European Heat Pump Association.

For the coming year, I would like to draw your attention to the portfolio of exciting new topics for collaborative projects that are being developed. We anticipate that they will materialise in new Annexes very soon. I encourage you to visit the Heat Pump Centre website. You will learn all about our new activities and remain at the forefront of heat pump developments.

Finally, I would like to thank the Heat Pump Centre team for their exceptional support to the Programme.

*Sophie Hosatte*
*ExCo Chairman*












# The 9th International Energy Agency Heat

**"Advances and Prospects in Technology, Applications and Markets"**

The 2008 conference was the ninth in a series of triennial conferences sponsored by the International Energy Agency (IEA) Heat Pump Programme (HPP), and it attracted 450 attendees from 34 different countries – the largest IEA Heat Pump Conference ever staged. Experts from research institutions, government, energy companies and manufacturers provided 72 oral presentations and 106 poster presentations, which also included six technical tours. The conference is one of the primary activities of HPP, and is recognised as one of the most important international conferences devoted to air conditioning, heat pumps and related refrigeration technologies.

There are two primary objectives with these conferences. The first is to give the audience a snapshot of international developments within the field of heat pumping technologies over the last three years, and a sense of direction for future trends. The second is to create a forum that will spur new thoughts and ideas for international cooperation and more widespread deployment of heat pumps. In a world with growing concerns over the global environment and the consequences of escalating energy use, we know that heat pumping technologies play, and will continue to play, a vital and important role.

**Conference organisation**

The International Organising Committee consisted of members from nine different IEA HPP member countries. The Chairman was Dr Rune Aarlien from Norway. The Swiss National Organising Committee consisted of Professor Thomas Kopp (Chairman), Mr Stephan Peterhans, Mr Fabrice Rognon and Mrs Luzia Arpagaus. The Regional Coordinators, Dr Monica Axell (for Europe and Africa), Mr Makoto Tono (for Asia/Oceania) and Mr Gerald Groff (for America), were responsible for the conference technical programme.

**Oral program**

The oral programme with 72 presentations was organised in different sessions with the following titles:

- Plenary Opening Session
- Heat Pumps for a Sustainable Society
- Technology Advancements – 1
- Ground and Water Source Heat Pump Systems
- Heat Pump Applications
- Market and Application Studies
- Heat Pump Applications to Low Energy Buildings
- Technology Advancements – 2
- Country Research Reports/Emerging Technologies
- Plenary Closing Session

**Poster program**

The poster programme was a success not only because of the record number shown, but also for the general high quality. Authors and presenters had an interested and large audience. For the first time, the Best Poster Award was introduced. The award consisted of a diploma, publicity and the printing of the papers in the IEA HPP Newsletter. The award winners were S. Takeda-Kindaichi, K. Nagano, T. Katsura, S. Hori and K. Shibata (Japan) for the poster *"System performance of HVAC in a low-energy house in the cold region of Japan"* and J.M. Corberan and J. Gonzalvez Macia (Spain), and C. Radulescu (Ireland) for the poster *"Performance characterisation of a reversible water-to-water heat pump"*.

# Pump Conference

**May 20 - 22, 2008, in Zürich, Switzerland**

**The Ritter von Rittinger award**
The Ritter von Rittinger award recognises deserving individuals or teams that have distinguished themselves in the advancement of heat pumping technologies applications, market development and related dissemination activities with lasting international impact. This award is named for Peter Ritter von Rittinger, an Austrian engineer credited with the design and installation of the first practical heat pump system at a salt works in Upper Austria in 1856. The award was presented for the first time at the 8th IEA International Heat Pump Conference in 2005, in Las Vegas, USA. The 2008 awardees were announced at the conference gala dinner. The awardees were: Professor Eric Granryd, Sweden, Professor Predrag Hrnjak, USA and Mr Gerald C Groff, USA.

**Workshop program**
In connection with the conference, eight workshops and larger meetings were organised. This "merging of events" is very successful and may have contributed to the increased number of participants. The following workshops and meetings were held:
- Ground Source Heat Pumps – Overcoming Market and Technical Barriers (HPP Annex 29)
- Retrofit Heat Pumps for Buildings (HPP Annex 30)
- Advanced Modeling and Tools for Analysis of Energy Use in Supermarkets (HPP Annex 31)
- Economical Heating and Cooling Systems for Low Energy Houses (HPP Annex 32)
- Thermally Driven Heat Pumps (HPP Annex 34)
- Compact Heat Exchangers in Heat Pumping Equipment (HPP Annex 33)
- General Assembly of the European Heat Pump Association (EHPA)
- Groundreach Workshop (EU project within IEE Programme)

**Technical tours**
The attendees had the opportunity to join their favourite of four technical tours and two non-technical tours:
- Soccer Campus with $CO_2$ heat pump and postal building with ammonia heat pump (two tours)
- Zero energy building with tap water heat pump and heating heat pumps
- Zürich City Hall with the first heat pump installation in Switzerland
- City tour and lake cruise
- Above Zürich the Uetliberg railway up to the little mountain

**Conference proceedings**
The conference proceedings can be ordered from the website **www.heatpumpcentre.org**.

*Hope to see you at the 10th IEA Heat Pump Conference in 2011!*

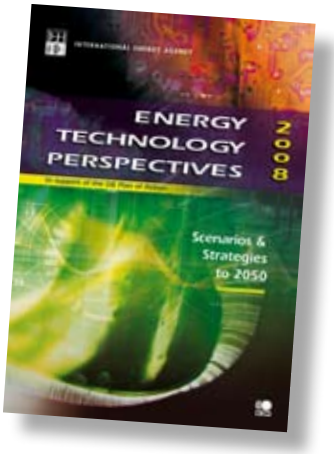













The *IEA Energy Technology Perspectives 2008* is available from **www.iea.org/Textbase/techno/etp**

## Executive Committee meetings

Two meetings of the HPP Executive Committee were held in 2008:

- May 23-24, in Zürich, Switzerland
- November 13-14, in Seoul, South Korea

# Highlights of 2008

## Roadmap

During spring 2008, HPC together with representatives from member countries, contributed with a roadmap for heat pumping technologies to the *IEA Energy Technology Perspectives 2008* publication. The results showed that heat pumps can have a large impact in abating GHG emissions, and is pointed out by the IEA as one of the key technologies in the building sector for a better energy future. These important conclusions were also stressed by Dr Antonio Pflüger, Head of Energy Technology Collaboration Division in IEA, in a speech at the 9th IEA Heat Pump Conference in Zürich.

The *IEA Energy Technology Perspectives 2008,* which was issued in June, responds to the G8 call on the IEA to provide guidance for decision makers on how to bridge the gap between what is happening and what needs to be done in order to build a clean, clever and competitive energy future.

The findings in the report werediscussed in HPP where it is believed that better statistics on heat pumps could, in fact, improve the figures even more.

## The brochure "Heat pumps can cut global $CO_2$ emissions by nearly 8%"

This brochure describes the potential and environmental benefits of heat pumps. It is estimated that heat pumps could save 50% of the building sector's and 5% of the industrial sector's $CO_2$ emissions. This corresponds to a cut in global $CO_2$ emissions of nearly 8%.

The brochure is available free of charge on **www.heatpumpcentre.org**




## The Seoul workshop

In connection with the Executive Committee meeting in Seoul, a workshop was held to present ongoing activities in South Korea in the heat pumping field. Dr Sophie Hosatte gave a presentation on the Heat Pump Programme, Mr Jun Y. Choi from the Korea Testing Laboratory described the market and the certification process for heat pumps in Korea. Other invited speakers were Mr Hyug-Bum Park from Samsung, Mr Sang-Hun Lee from LG Electronics, Mr Min Soo Kim from Seoul National University and Mr Jeong Tae Woo from the Korea Refrigeration & Air-Conditioning Assessment Center.



*National Teams meeting in Malmö*

## National Teams meeting in Malmö

On the 11-12th of September a National Teams meeting was held in Malmö, Sweden. 24 participants, representing both member countries and industry, were present. The main focus of the meeting was to discuss and develop ideas for research projects within HPP.

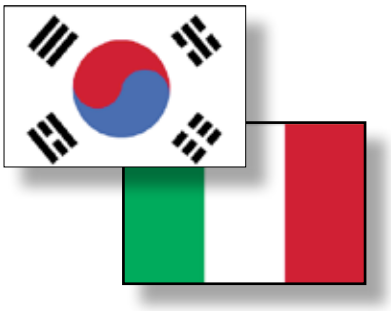
The meeting began with the ten participating countries giving a short presentation highlighting new research topics of interest in their country. The main part of the meeting was devoted to discussion and brainstorming in order to give the final shape to a number of research ideas. The primary areas discussed were industrial heat pumps, free cooling, domestic hot water heat pumps and seasonal performance factors.

## Welcome to two new member countries – South Korea and Italy!

The Heat Pump Programme had the pleasure of welcoming two new member countries in 2008.

The new contracting parties are:

- The Ministry of Commerce, Industry and Energy (MOCIE) designated by the Government of the Republic of Korea
- The Italian Research Council designated by the Government of Italy



## The Heat Pump Centre visited Chillventa

The Heat Pump Centre exhibited at the Chillventa trade fair in Nürnberg, Germany, October 15-17. Chillventa is an international exhibition on refrigeration, air conditioning and ventilation and heat pumps, with more than 1500 exhibitors. The fair provided an excellent opportunity to promote the Programme and to meet professionals in the field, as well as to listen to several interesting presentations.




In conjunction with the exhibition, an International Heat Pump Symposium was held on *"Experiences and possibilities of industrial heat pumps for heating, cooling and air conditioning"*. It was arranged by DKV - Deutscher Kälte- und Klimatechnischer Verein - and a number of interesting presentations were given. A final workshop on the IEA HPP Annex 30 *"Retrofit Heat Pumps for Buildings"* was also held.




*International Heat Pump Symposium, Nürnberg*

## IEA Building Coordination Group

In January, the Heat Pump Centre attended the IEA Building Coordinated Group's (BCG) annual meeting in Paris. This meeting is intended to inform IEA Implementing Agreements about each others' activities, and also to give and receive information to IEA Headquarters.

## "The needs of the IEA Heat Pump Programme's stakeholders" - Survey about HPP

HPP is conducting a survey in order to better understand the needs of its stakeholders. The aim is to find out about the concerns and interests of professionals in the heat pumping field as well as their expectations from the Programme. The answers to the questions will help HPP to focus its activities on areas of widespread interest and to tailor its information services to the needs of its target groups.

Questionnaires were handed out at the 9th IEA Heat Pump Conference in Zürich and e-mailed to all subscribers to the HPC e-Newsletter. In addition to the questionnaires, interviews have been held to get more in-depth answers. Representatives from both the industry and the research community have contributed to the survey. The survey will be completed during spring 2009 and will result in an action plan for the further work of the Programme.



*Survey about HPP*

# Programme Achievements 2008

**Contact**
Dr Monica Axell
Heat Pump Centre
SP Technical Research
Institute of Sweden
Box 857
SE-50115 Borås
Sweden
Tel. +46 10 516 55 19
hpc@heatpumpcentre.org
*www.heatpumpcentre.org*



## Heat Pump Centre

The Heat Pump Centre plays a central role in the IEA Heat Pump Programme. It aims to disseminate factual and balanced information on heat pumping technologies and promoting the activities of the Programme. The ExCo has approved an extension of SP Technical Research Institute of Sweden's mandate to manage the Centre until 2011.

### Activities

One of the main activities is the publication of the Heat Pump Centre Newsletter. Each issue covers a particular topic and contains articles, news and events, together with a contribution from a guest columnist. Four issues were published in 2008, available free of charge from the HPC website to the HPP member countries. Non-member countries can subscribe to the Newsletter.

A short version of the Newsletter, an e-Newsletter, is available free of charge to all countries, either by e-mail subscription or by downloading from the HPC website. The number of subscribers to the e-Newsletter increased by over 50% in 2008. In addition, the newsletter is also disseminated through the National Teams in the member countries.

The Heat Pump Centre also plays an active part in generating new activities within HPP. For example, it publishes ongoing descriptions of project proposals on the website in order to stimulate the initiation of new Annexes. HPC has also compiled a report with information on research and development and market development in HPP member countries. The report is available to the National Teams in the member countries.

Another important activity is the website, which is continuously updated with news, events and contact information. Descriptions of ongoing and completed HPP Annexes are also available on the website as well as HPP publications, which are accessible via a data base. During 2008 the website was enhanced with two new sections, one about the IEA Heat Pump Conferences and one about the Ritter von Rittinger award.




One of the main activities of HPC in 2008 was the close involvement in the arrangement of the 9th IEA Heat Pump Conference held in Zürich, Switzerland, in May.

Two other important activities of HPC during 2008 were the production of a roadmap for heat pumping technologies for the *IEA Energy Technology Perspectives 2008* publication and the production of a brochure about the potential of heat pumps to significantly cut global $CO_2$ emissions.

In September, HPC arranged a National Teams meeting in Malmö, Sweden. The main focus on the meeting was to discuss and develop ideas for research projects within the IEA Heat Pump Programme.

*Website: www.heatpumpcentre.org*

A survey in order to better understand the needs of HPP's stakeholders was started in 2008. Questionnaires were handed out at the 9th IEA Heat Pump Conference in Zürich and e-mailed to all subscribers of the HPC e-Newsletter. In addition to the questionnaires, interviews have been held. Representatives from both the industry and the research community have contributed to the survey.

Finally, the Centre has a supportive function in assisting Operating Agents (project leaders) of HPP Annexes and the HPP Executive Committee in their work.

*HPP publications can be ordered from the Heat Pump Centre.*

## International collaboration and promotion

The Heat Pump Programme and the Heat Pump Centre have good relations with a number of national and international organisations, including EHPA[1], IIR[2], ASHRAE[3] and ARI/ARTI[4].

HPC has been promoting the Programme at different events such as the Chill-venta trade fair in Nürnberg, Germany, in October, at the EU project ProHeatPump "GSHPScotland" event in Edinburgh, Scotland, in September, and in the 6. Forum Wärmepumpe in Berlin, Germany, in November. HPC was also present at the IEA Building Coordination Group meeting in Paris, France, in January.

Professor Hermann Halozan, Executive Committee delegate, participated in the IIR 2008 HVAC Energy Efficiency Best Practice Conference held in Melbourne, Australia, in September. The event covered the latest research and applications in the fields of solar air conditioning and heating of buildings; comfort and indoor environment quality in energy efficient buildings; and energy efficient building integration.

[1)] The European Heat Pump Association
[2)] The International Institute of Refrigeration
[3)] The American Society of Heating, Refrigerating and Air-Conditioning Engineers
[4)] The Air-Conditioning and Refrigeration Institute/Air-Conditioning and Refrigeration Technology Institute

## New publications in 2008

The brochure *"Heat pumps can cut global $CO_2$ emissions by nearly 8%"*, which describes the potential and environmental benefits of heat pumps, was published. In addition, a number of promotional materials were produced and exhibited at the 9th IEA Heat Pump Conference in Zürich.




## Newsletters 2008

Four Newsletters and e-Newsletters were published in 2008, and these are available on the Heat Pump Centre website.
The topics were:
1. Air Source Heat Pumps
2. Heat Pumps for Low Energy Buildings
3. 9th IEA Heat Pump Conference
4. Natural Working Fluids



# Annex 29

## Ground-Source Heat Pumps – Overcoming Market and Technical Barriers

**Contact**
Prof Hermann Halozan
Graz University of Technology
Institute of Thermal Engineering
Inffeldgasse 25 B,
A-8010 Graz
Austria
Tel. +43 316 873 7303
halozan@tugraz.at

alternatively,
Waltendorferhoehe 20
A-8010 Graz
Austria
Tel. +43 316 422 242
hermann.halozan@chello.at



**Participating countries:** Austria (Operating Agent), Canada, Japan, Norway, Sweden and the United States

Annex 29 is investigating the present status of ground-source heat pump systems (GSHP), which varies widely all over the world, and identifying systems - depending on climate and application - that could improve the performance and market attractiveness of these heat pump systems. The objective is to demonstrate the economic and environmental benefits of ground-coupled heat pump systems. The following are some of the findings on the topic of overcoming barriers.

**Overcoming legal barriers** is the basis for wider take-up of the technology. The points that must be considered include:

- Heat extraction from the ground - and heat delivery to the ground, in the case of cooling operation - must be carried out using fluids with no toxic component.
- Leakages of refrigerants must be avoided.
- Refrigerants with low GWP, such as hydrocarbons, ammonia and $CO_2$, must be promoted.
- Drilling by certified drilling companies should be the basis for preventing groundwater pollution.

**Overcoming economic barriers** is the most important part. A technology will finally be accepted by customers when it is economic.

The economic barriers are mainly based on the lack of awareness of this highly efficient technology, an inadequate infrastructure and the high first cost of the majority of GSHP systems. To overcome these barriers it is important to reduce first cost by lowering installation costs and using life cycle cost analysis to demonstrate the economic advantages of these systems.

Measures include regulations such as the EU directive on the energy performance of buildings (EPBD) and the EU directive on the promotion of the use of energy from renewable sources (RES directive). Additionally, subsidies can be used to demonstrate the importance of the technology, to support industry to become competitive and to support customers.

Different contracting models can be used in this context, covering the ground heat source/heat sink system, the total heating system, or the total heat generation system (as in the case of district heating systems). Examples are:

- Loop leasing
- Chauffage
- Integrated community systems
- Loop guarantee
- Performance contracting

**Increasing the acceptance** is the final measure, and can be carried out by:

- Information to policy-makers, decision-makers, planners, architects, the research community and installers.
- Training for planners, installers, drilling companies, excavation companies.
- Advertisements for customers.
- Conferences and workshops at international and national level.

A workshop was held in connection with the 9th IEA Heat Pump Conference in Zürich, Switzerland, in May. The final report of Annex 29 will be completed during spring 2009.

www.annex29.net

# Annex 30
## Retrofit Heat Pumps for Buildings

**Participating countries:** France, Germany (Operating Agent) and the Netherlands

The present heat pump market for space and water heating and cooling in Europe, with the exception of Sweden, is largely concentrated on new buildings, and particularly on one and two-family houses. There is, however, a very large potential in the retrofit market to replace old conventional oil-, gas- and coal-fired heating systems with highly energy-efficient and environmentally friendly heat pumps.

The main barrier to the use of heat pumps for retrofitting is the high distribution temperature of conventional heating systems in existing residential buildings, with design temperatures up to 70-90°C, which is too high for the present heat pump generation for which the maximum, economically acceptable heat distribution temperature is up to 55°C.

The primary focus of this Annex has been on domestic buildings. In order to reach the goals of the Annex, solutions have been studied and experience gained on:

- The application of available heat pumps in standard buildings that have been improved, resulting in a reduced heat demand.
- The development and market introduction of new, compact, high-temperature heat pumps for application in existing buildings.
- The use of reversible (heating-cooling) heat pumps (air-to-air) in buildings without centralised heat distribution systems.

To achieve this promising potential as quickly as possible, barriers need to be removed or overcome. It is, for example, difficult to distinguish between different types of heat pumps, to decide which type of heat pump best suits a particular application, and which requirements a building should fulfil. A chart has therefore been created to simplify the selection of heat pumps (see chart below).

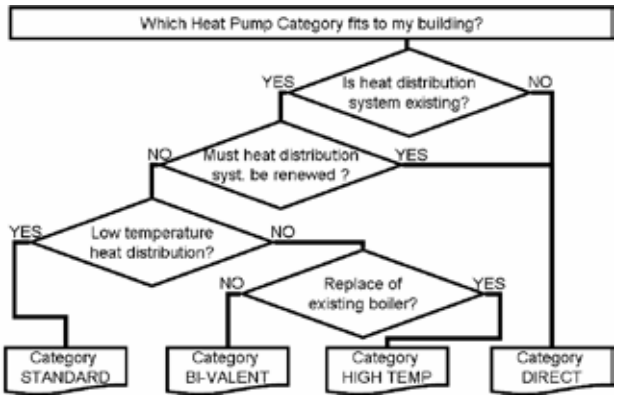
The Annex was completed at the end of 2008. The last meeting, held in February 2008 in Utrecht, the Netherlands, was therefore concentrated on final discussions of the results achieved and preparation of the Annex report and related appendices, in particular the presentations of case studies and RD&D projects. Two public workshops were organised in 2008, presenting the major findings of the Annex as well as new developments related to the objectives of the Annex in Germany, France, the Netherlands and Sweden. The workshops were held in connection with the 9th IEA Heat Pump Conference in Zürich, Switzerland, in May, and the DKV International Heat Pump Conference at the Chillventa trade fair in Nürnberg, Germany, in October.

As a result of this work, it is today clear that in many cases heat pumps already can, or will soon, be used as a preferable retrofit choice. The use of heat pumps results in greatly improved efficiency of heat generation, reduction in use of fossil energy and, at the same time, permits the choice of geothermal, hydrothermal or aerothermal renewable energy sources.

The final results of the Annex will be published in three reports, intended for different target groups: an executive summary that will be public, a full report with all details for internal use of the participating organisations/companies, and special reports for information to specific target groups, e.g. politicians, the heat pump industry and R&D organisations and sponsors.

**Contact**
Prof Dr - Ing Hans-Jürgen Laue
Information Centre on Heat Pumps and Refrigeration
(Informationszentrum Wärmepumpen und Kältetechnik)
IZW e.V.
Unterreut 6
DE-76135 Karlsruhe
Germany
Tel. +49 721 98 62 85 6
Fax +49 721 98 62 85 7
laue.izw@t-online.de





# Annex 31
## Advanced Modeling and Tools for Analysis of Energy Use in Supermarkets

**Contact**
Dr Samer Sawalha, Dr Jaime Arias and Prof Per Lundqvist
Royal Institute of Technology
Dept. of Energy Technology
SE-100 44 Stockholm
Sweden
Tel. +46 8 790 78 89,
+46 8 790 86 42
samer.sawalha@energy.kth.se,
jaime.arias@energy.kth.se,
per.lundqvist@energy.kth.se
*www.energy.kth.se*



**Participating countries:** Canada, Germany, Sweden (Operating Agent), United Kingdom (partly) and the United States

Supermarkets are the most energy-intensive buildings in the commercial sector. It has been estimated that 3-5% of the total use of electricity stems from supermarkets in industrialised countries. In addition, it is estimated that the annual refrigerant losses may be as high as 15-30% of the total charge, thus making supermarkets the second largest emission source after mobile air conditioning, according to the most recent report from the UN Intergovernmental Panel on Climate Change. The supermarket sector has therefore a significant role to play, not only from an energy consumption point of view but also from the point of view of the impact of refrigerant leakage.

The overall objective of Annex 31 is to provide new knowledge, methods and tools for enhanced energy efficiency of, and therefore reduced environmental impact from, supermarkets. The aim is also to share ideas and best practices among participating countries, as well as information on available tools for modelling and analysis, in order to further improve supermarket refrigeration systems. The Annex builds on experience and findings from Annex 26, *"Advanced Supermarket Refrigeration/Heat Recovery Systems"*.

In order to achieve the objectives of the Annex, the following task-sharing activities are planned:

**Task 1** Collection of available data from different supermarkets (benchmarking)
**Task 2** Development of performance indices for supermarkets
**Task 3** Development and validation of a model library for specific supermarket equipment
**Task 4** Development of whole-building simulation models
**Task 5** Comparison of the results obtained with the different whole-building simulation models for selected case studies
**Task 6** Future perspectives and possibilities
**Task 7** Deployment of the knowledge developed (indices, guidelines, papers, fact sheets)



Meetings and workshops that were organised during 2008 were:
- Meeting at ASHRAE Winter Meeting, New York, US, in January
- Internet-based meetings throughout the year
- Workshop at the 9th IEA Heat Pump Conference in Zürich, Switzerland, in May

Annex 31 is now in the phase referred to as Tasks 3, 4 and 5. A template to report sub-models (Task 3) and whole supermarket systems (Task 4) has been distributed and information on several whole system supermarket models has been collected. Notable here is a rich description of the supermarket modules to energy plus (US contribution). Another initiative is the supermarket module for RETScreen® software developed by Natural Resources Canada.

A year prolongation of the Annex has been granted. This means that evaluation and validation of proposed supermarket models will start in 2009. Work on Tasks 6 and 7 and final report will start late spring 2009.

# Annex 32

## Economical Heating and Cooling Systems for Low Energy Houses

**Participating countries:** Austria, Canada, Germany, France, Japan, the Netherlands, Norway, Sweden, Switzerland (Operating Agent) and the United States

Heat pumps are the only devices which can generate heating and cooling energy, even at the same time. Multifunctional heat pump systems for space heating, domestic hot water (DHW) production, ventilation and space cooling may therefore be a cost-effective means of meeting all building needs with one integrated system.

The aim of this Annex is to investigate different system configurations of heat pump systems, including the respective energy source and distribution systems, for application in low- and ultra-low-energy buildings. The principal objectives are:

- to improve and further develop multifunctional heat pump systems in terms of overall energy use, achievable comfort and costs,
- to gather more field experience from real-world operation of heat pump systems, and
- to derive design guidelines for multifunctional heat pump systems and their control.

The Annex has been structured into four tasks:

**Task 1** State-of-the-art survey of low-energy buildings and respective systems
**Task 2** Assessment of system solutions and development of prototype systems
**Task 3** Field testing of systems (in parallel with Task 2)
**Task 4** Develop guidelines for systems and their control and document best-practice systems

The Annex started in January 2006, and has been extended to a four-year working period, and will finish at the end of 2009. In the beginning of 2008, the Annex 32 website was launched, which gives an outline of the national project contributions and offers national heat pump links of the participating countries as well as downloadable publications.

Activities in 2008 were dedicated to the work of Task 2, the investigation and assessment of prototype systems, and Task 3, the field monitoring of present systems on the market and new developments. Interim results of these tasks were presented on a workshop in conjunction with the 9th IEA Heat Pump Conference in Zürich, Switzerland, in May. After the conference France joined Annex 32 as the 10th member country. France is represented by Electricité de France (EdF) and will mainly investigate economical air-to-air heat pump solutions for low energy houses. The results have been summarised in an interim report of Annex 32 for the HPP ExCo, which was published in November.

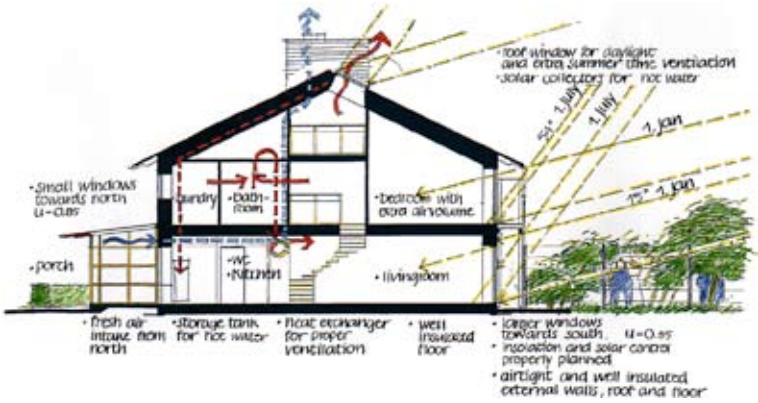
Main activities in the national projects are dedicated to laboratory testing of prototypes of new concepts of integrated heat pump systems including systems using natural refrigerants. On the other hand, field testing of marketable heat pump systems or new developments is ongoing. In 2009, results of the national projects shall be transferred to design recommendations, standard system solutions and best practice systems.

**Contact**
Mr Carsten Wemhöner
Institute of Energy in Building
University of Applied Sciences
North-Western Switzerland
St.-Jakobs-Str. 84
CH - 4132 Muttenz
Switzerland
Tel. +41 61 467 4573
Fax. +41 61 467 4543
carsten.wemhoener@fhnw.ch
*www.fhnw.ch/habg/iebau*



www.annex32.net

*Passive house by Hans Grönlund, EFEM Arkitektkontor, Sweden*



# Annex 33
## Compact Heat Exchangers in Heat Pumping Equipment

**Contact**
The Annex has as Operating Agent the School of Engineering and Design, Brunel University in London, UK, represented by

Prof David Reay,
David Reay & Associates
PO Box 25, Whitley Bay
Tyne & Wear NE26 1QT, UK
Tel. +44 191 251 2985
Fax: +44 191 252 2229
D.A.Reay@hw.ac.uk



Dr Peter Kew
Mechanical Engineering,
School of Engineering &
Physical Sciences
Heriot-Watt University,
Edinburgh EH14 4AS, UK
Tel. +44 131 451 8015
Fax: +44 131 451 3129
P.A.Kew@hw.ac.uk



**Participating countries:** Austria, Japan, Sweden, United Kingdom (Operating Agent) and the United States

This Annex is directed at widening the use of compact heat exchangers (CHEs) in heat pumping systems. It is believed that these will improve efficiencies, minimise fluid inventories and reduce package size. The data collected during the Annex will, it is hoped, quantify the possible benefits from CHE use, and also highlight any concerns. Ultimately, the use of compact heat exchangers should significantly improve the acceptability of heat pumps across all applications, by allowing improved COPs and reduced materials content.

The principal objective of this Annex is to present a compilation of possible options for compact heat exchangers, used as evaporators, condensers and in other roles in heat pumping equipment. The aim is to minimise the direct and indirect effect on the local and global environment due to manufacture operation and final disposal of the equipment.

Specific technical goals involve identifying and documenting reasonably accurate methods of predicting heat transfer, pressure drop and void fractions in CHEs, thereby promoting their commercial use by heat pump manufacturers by simplifying the design and selection procedures. Integral with these activities will be an examination of manifolding/flow distribution in compact/micro-heat exchangers, in particular in evaporators.



During 2008, Austria (represented by Arsenal Research) joined the Annex, bringing the number of participants to five.

The Annex meeting in 2008 was held at the 9th IEA Heat Pump Conference in Zürich, Switzerland, in May, and was in the form of an open workshop at which presentations by the Annex members were given. Included in the presentations was an overview of research on compact heat exchangers relevant to heat pumps by Professor Björn Palm, of the Royal Institute of Technology (KTH), Sweden. Typical of the new compact geometries being examined for the application is the aluminium unit from KTH shown in the figure.

In 2009, meetings are planned in Chicago (held in February) and in the UK (planned for September). This will be the final Annex meeting.

As examples of work within the Annex, the air-side performance of flat-tube heat exchangers, a configuration offering compactness, has been studied in the USA, as has super and near critical heat transfer of R410A in small diameter tubes. In Sweden, the use of natural refrigerants and hydrocarbons is of interest and KTH has examined the use of propane in systems involving compact plate evaporators and condensers. Compact heat exchangers of other types, some commercially available, have been successfully tested with $CO_2$ as the working fluid.

In Japan, the compact heat pump water heater, using a novel heat exchanger design, has a large potential market and the Japanese team expects to deliver the following: market trends of refrigeration and air-conditioning systems, a survey of R&D needs in heat exchangers, recent research on heat exchanger technology and recent development on heat exchanger technology.

**www.compactheatpumps.org**

# Annex 34
## Thermally Driven Heat Pumps for Heating and Cooling

**Participating countries:** Austria, Canada, Germany (Operating Agent), Italy, the Netherlands, Norway, Switzerland and the United States

Most heat pumps are driven by electricity. However, the use of heat as the driving force of a heat pumping device used for heating or cooling buildings might lead to significant primary energy savings, especially if the heat source is solar or waste heat.

The objective of this Annex is therefore to reduce the environmental impact of heating and cooling by the use of thermally driven heat pumps. It will continue from the results from Annex 24, *"Absorption Machines for Heating and Cooling in Future Energy Systems"*, and cooperate with Task 38, *"Solar Air-Conditioning and Refrigeration"* of the IEA Implementing Agreement Solar Heating and Cooling.

One of the main objectives is to quantify the economic, environmental and energy performance of integrated thermally driven heat pumps in cooling and heating systems in a range of climates, countries and applications. From this, those areas and applications with the greatest environmental benefit, the most favourable economics and the greatest market potential will be identified.

In the last year several working points have been accomplished. The Annex and its goals have been presented at a workshop at the 9th IEA Heat Pump Conference in Zürich, Switzerland, in May. A first Task C meeting has been held in July in Messina, Italy. As a result, standard conditions for measurements of adsorption characteristics and a format of a database have been defined and will be tested in a round robin test with several partners. Furthermore a Task B meeting was held in Vienna, Austria. Rules for the characterisation of an apparatus and possible system performance definitions have been proposed and a test apparatus database has been initiated.

In October the third Annex meeting and in addition an Austrian national workshop have successfully been held at Arsenal Research.

Summary of the status within the Tasks and results of meetings:

**Task A** Market overview and state-of-the-art - A first draft for a country report regarding existing technologies and applications for thermally driven heat pumps has been prepared by Energy Research Centre of the Netherlands and was sent to all partners for completion.

**Task B** Performance evaluation - A collection of existing standards for related technologies has been started and is available on the Annex website and a first proposal for the performance standard has been initiated.

**Task C** Apparatus technology - A first proposal for standard measurements of sorption materials has been prepared and test materials for a round robin test have been defined. In addition the round robin test was started. The results are presented in the new material database at the Annex 34 internal website.

**Task D** System technology - A first test setup for the system tests has been finished and test methods have been discussed.

**Task E** Implementation - The Annex 34 website has been set up with an internal and an external part. A first outline of the planed handbook has been discussed.

At the next meeting, planned for April in Bolzano, Italy, the work plan will be finalized and the first results of national projects will be presented.

**Contact**
Dr Peter Schossig
Dept. Thermal Systems and Buildings
Fraunhofer-Institut für Solare Energiesysteme ISE
Heidenhofstraße 2
79110 Freiburg
Germany
Tel. +49 7 61/45 88 5130
Fax/VoiceMailbox
+49 7 61/45 88 9130
peter.schossig@ise.fraunhofer.de
*www.ise.fraunhofer.de*



www.annex34.org

*Vienna meeting*





# Programme Contacts
## – Executive Committee Delegates

### AUSTRIA
Prof Hermann Halozan
Graz University of Technology
Institute of Thermal Engineering
Inffeldgasse 25/B,
A-8010 Graz
Tel. +43 316 873 7303
halozan@tugraz.at

alternatively:
Waltendorferhoehe 20
A-8010 Graz
Tel. +43 316 422 242
herman.halozan@chello.at

### CANADA
Dr Sophie Hosatte
Natural Resources Canada
CETC – Varennes
1615 Bd Lionel Boulet
P.O. Box 4800
Varennes
J3X 1S6 Québec
Tel. +1 450 652 5331
sophie.hosatte@nrcan.gc.ca

### FRANCE
Mr Johan Ransquin
ADEME
Département Marchés et Services
d'Efficacité Energétique
500 route des Lucioles
06560 Sophia Antipolis
Tel. +33 4 93 95 79 50
johan.ransquin@ademe.fr

### GERMANY
Dr Claus Börner
Division ERG
Project Management Organisation Jülich (PTJ)
Forschungszentrum Jülich GmbH
DE-52425 Jülich
Tel. +49 2461 613816
c.boerner@fz-juelich.de

Dr Rainer Jakobs (Alternate)
IZW e.V.
Kreuzfeldstr. 10a
DE-64747 Breuberg
Tel. +49 6163 5717
Dr.Rainer.Jakobs@T-Online.de
Jakobs@izw-online.de

### ITALY
Dr Giovanni Restuccia
Italian National Research Council
Institute for Advanced Energy Technologies (CNR – ITAE)
Via Salita S. Lucia sopra Contesse 5
98126 Messina
Tel. +39 090 624 229
giovanni.restuccia@itae.cnr.it

Dr Angelo Freni (Alternate)
Italian National Research Council
Institute for Advanced Energy Technologies (CNR – ITAE)
Via Salita S. Lucia sopra Contesse 5
98126 Messina
Tel. +39 090 624 229
angelo.freni@itae.cnr.it

### JAPAN
Mr Kazunori Nagai
New Energy and Industrial Technology Development Organization (NEDO)
Energy Conservation Technology Development Department
Muza Kawasaki Central Tower Bldg. 18F
1310 Ohmiya-cho, Saiwai-ku,
Kawasaki-City, Kanagawa 212-8554
Tel. +81 44 520 5280
nagaikzn@nedo.go.jp

Mr Makoto Tono (Alternate)
Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ)
1-28-5 Nihonbashi, Kakigara-cho
Chuo-ku, Tokyo 103-0014
Tel. +81 3 5643 2404
tono.makoto@hptcj.or.jp

## THE NETHERLANDS

Mr Onno Kleefkens
SenterNovem
P.O. Box 8242
3503 RE Utrecht
Tel. +31 30 2393 449
o.kleefkens@senternovem.nl

Mr Roger Ravelli (Alternate)
SenterNovem
P.O. Box 8242
3503 RE Utrecht
Tel. +31 30 239 3763
r.ravelli@senternovem.nl

## NORWAY

Mrs Trude Tokle
Enova SF
Abelsgate 5
7030 Trondheim
Tel. +47 73 19 04 54
Trude.Tokle@enova.no

Dr Rune Aarlien (Alternate)
SINTEF Energy Research
Dept. Energy Processes
7465 Trondheim
Tel. +47 73 59 39 29
rune.aarlien@sintef.no

## SOUTH KOREA

Mr Seong-Ryong Park
Korea Institute of Energy Research
Department of Renewable Energy
71-2, Jang-dong, Yuseong-gu,
Daejeon
Republic of Korea 305-343
Tel. +82 42 860 3224
srpark@kier.re.kr

## SWEDEN

Mr Mattias Törnell
Swedish Energy Agency
Energy Technology Department
P.O. Box 310
SE-631 04 Eskilstuna
Tel. +46 16 544 2169
mattias.tornell@
energimyndigheten.se

Dr Björn Sellberg (Alternate)
FORMAS
P.O. Box 1206
SE-111 82 Stockholm
Tel. +46 8 775 4028
bjorn.sellberg@formas.se

## SWITZERLAND

Mr Andreas Eckmanns
Federal Department of the Environment,
Transport, Energy and Communications
Swiss Federal Office of Energy
Energy Research Section
CH-3003 Bern
Tel. +41 31 322 54 61
andreas.eckmanns@bfe.admin.ch

Dr Thomas Kopp (Alternate)
Hochschule Rapperswil
On behalf of the
Swiss Federal Office of Energy
Energy Renewable Division
Oberseestrasse 10
CH-8640 Rapperswil
Tel. +41 55 222 4923
tkopp@hsr.ch

## THE UNITED STATES

Mr Antonio M. Bouza
US Department of Energy
1000 Independence Ave, SW
Washington, DC 20585
Tel. +1 202 586 4563
antonio.bouza@ee.doe.gov

# Summary of 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, United Kingdom, the United States | 1980 |
| 2. Vertical Earth Heat Pump Systems | Sweden | Austria, Canada, Denmark, Sweden, the United States | 1983 |
| 3. Heat Pump Systems Applied in Industry | Belgium | Austria, Belgium, Canada, Denmark, Finland, Germany, Italy, Japan, the Netherlands, Sweden | 1984 |
| 4. Heat Pump Centre | Germany | Austria, Belgium, Canada, Finland, Germany, Italy, Japan, the Netherlands, Norway, Sweden, the United States | 1990 |
| 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, Sweden, the United States | 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, the United States | 1992 |
| 9. High Temperature Industrial Heat Pumps | Belgium | Belgium, Germany, Finland, Japan, the Netherlands, Sweden, Switzerland, the United States | 1990 |
| 10. Technical and Market Analysis of Advanced Heat Pumps | the United States | Sweden, the United States | 1991 |
| 11. Stirling Engine Technology for Application in Buildings | the United States | Japan, Sweden, the United States | 1989 |
| 12. Modelling Techniques for Simulation and Design of Compression Heat Pumps | the United States, Italy | Austria, Belgium, Germany, Italy, Japan, Switzerland, the United States | 1992 |

# Summary of Annexes

| Annex | Operating Agent | Participants | Completed |
|---|---|---|---|
| 13. State and Transport Properties of High Temperature Working Fluids and Non-Azeotropic Mixtures | Sweden | Canada, Germany, Japan, Norway, Sweden, the United States | 1992 |
| 14. Working Fluids and Transport Phenomena in Advanced Absorption Heat Pumps | Japan | Belgium, Denmark, Germany, Japan, Sweden, the United States | 1991 |
| 15. Heat Pump Systems with Direct Expansion Ground Coils | Canada | Austria, Canada, Japan, the United States | 1993 |
| 16. Heat Pump Centre | the Netherlands | Austria, Japan, the Netherlands, Norway, United Kingdom, the United States | 2003 |
| 17. Experiences with New Refrigerants in Evaporators | Sweden | Canada, the Netherlands, Norway, Sweden, Switzerland | 1993 |
| 18. Thermophysical Properties of Environmentally Acceptable Refrigerants | the United States | Austria, Canada, Germany, Japan, Sweden, United Kingdom, the United States | 1999 |
| 19. Cancelled | | | |
| 20. Working Fluid Safety | Belgium | Belgium, Japan, the Netherlands, Norway, Switzerland | 1993 |
| 21. Global Environmental Benefits of Industrial Heat Pumps | the United States | Canada, France, Japan, the Netherlands, Norway, Sweden, United Kingdom, the United States | 1996 |
| 22. Compression Systems with Natural Working Fluids | Norway | Canada, Denmark, Japan, the Netherlands, Norway, Switzerland, United Kingdom, the United States | 1999 |
| 23. Heat Pump Systems for Single-Room Applications | Canada | Canada, France, Switzerland, Sweden, the United States | 1999 |
| 24. Ab-Sorption Machines for Heating and Cooling in Future Energy Systems | Sweden | Canada, Italy, the Netherlands, Norway, Japan, Sweden, United Kingdom, the United States | 2000 |
| 25. Year-Round Residential Space Conditioning Systems using Heat Pumps | France | France, the Netherlands, Sweden, the United States | 2005 |

# Summary of Annexes

| Annex | Operating Agent | Participants | Completed |
|---|---|---|---|
| 26. Advanced Supermarket Refrigeration/Heat Recovery Systems | the United States | Canada, Denmark, Sweden, United Kingdom, the United States | 2003 |
| 27. Selected Issues on $CO_2$ as Working Fluid in Compression Systems | Norway | Japan, Norway, Sweden, Switzerland, United Kingdom, the United States | 2004 |
| 28. Test Procedure and Seasonal Performance Calculation of Residential Heat Pumps with Combined Space and Domestic Hot Water Heating | Switzerland | Austria, Canada, France, Germany, Japan, Norway, Sweden, Switzerland, United Kingdom, (partly), the United States | 2005 |
| 29. Ground Source Heat Pumps – Overcoming Market and Technical Barriers | Austria | Austria, Canada, Japan, Norway, Sweden, the United States | Ongoing |
| 30. Retrofit Heat Pumps for Buildings | Germany | France, Germany, the Netherlands | Ongoing |
| 31. Advanced Modeling and Tools for Analysis of Energy use in Supermarkets | Sweden | Canada, Germany, Sweden, United Kingdom (partly), the United States | Ongoing |
| 32. Economical Heating and Cooling Systems for Low Energy Houses | Switzerland | Austria, Canada, Germany, France, Japan, the Netherlands, Norway, Sweden, Switzerland, the United States | Ongoing |
| 33. Compact Heat Exchangers in Heat Pumping Equipment | United Kingdom | Austria, Japan, Sweden, United Kingdom, the United States | Ongoing |
| 34. Thermally Driven Heat Pumps for Heating and Cooling | Germany | Austria, Canada, Germany, Italy, the Netherlands, Norway, Switzerland, the United States | Ongoing |



**IEA Heat Pump Programme**
**Heat Pump Centre**
c/o SP Technical Research Institute of Sweden
Box 857, SE-501 15 BORÅS, Sweden
Telephone: + 46 10 516 50 00, Telefax: + 46 33 13 19 79
E-mail: hpc@heatpumpcentre.org, Internet: www.heatpumpcentre.org

