ANNUAL REPORT 2014

International Energy Agency

HEAT PUMP PROGRAMME

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

Contents

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

International Energy Agency

The International Energy Agency (IEA) is an autonomous agency established in 1974. The IEA carries out a comprehensive programme of energy co-operation among 29 advanced economies, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The aims of the IEA are to:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

To achieve these goals, increased co-operation between industries, businesses and government energy technology research is indispensable. The public and private sectors must work together, share burdens and resources, while at the same time multiplying results and outcomes.

The IEA Energy Technology Initiatives, or ETIs (formally organised under the auspices of an Implementing Agreement), are a flexible and effective framework for IEA member and non-member countries, businesses, industries, international organisations and non-government organisations to research breakthrough technologies, to fill existing research gaps, to build pilot plants, to carry out deployment or demonstration programmes – in short to encourage technology-related activities that support energy security, economic growth and environmental protection.

More than 6 000 experts representing 310 organisations in 54 countries carry out a vast body of research through these ETIs (more than 1 600 topics have been addressed to date). There are currently 39 ETIs working in the areas of:

- Cross-cutting activities (modelling, technology transfer and finance)
- End-Use (buildings, electricity, industry, transport)
- Fossil fuels (exploration, safety, environment, carbon capture and storage)
- Fusion power (devices, technologies, materials, physics)
- Renewable energies and hydrogen (technologies and deployment policies)

The ETIs are at the core of a network of senior experts consisting of the Committee on Energy Research and Technology (CERT), four working parties and two experts' groups. The Working Parties (end-use, fossil fuels, fusion and renewables) evaluate the activities and outcomes of the ETIs at the end of each term.

The Heat Pump Programme (HPP) belongs to the end-use category above. Views, findings and publications of the HPP do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries. For further information on the IEA, the CERT and the ETIs, please consult www.iea.org/techinitiatives/.

www.iea.org

IEA Heat Pump Programme

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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, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, South Korea, Sweden, Switzerland, the United Kingdom, 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, with a Newsletter for member countries and a website, international collaborative projects (Annexes), workshops, analysis studies and a triennial international conference.

www.heatpumpcentre.org

Messages from the past and present chairman

Last year, I decided that after ten years as Chairman of the Programme it was time for me to move on and let someone else take the lead. It is my great pleasure to inform you that following elections that took place in November, Stephan Renz has been appointed Chairman and Antonio Bouza Vice-Chairman. I wish them all the best. I am convinced that they will successfully lead the Heat Pump Programme (HPP) and continue to foster heat pumps as the technology of choice for heating and cooling.

For HPP, the most significant event in 2014 has undoubtedly been the International Heat Pump Conference held in Montreal in May. With a participation of 295 attendees from 31 different countries, this event was a great success. The Conference program included 93 oral and 84 poster presentations. Participants took advantage of five technical tours and site visits. The Social Program included a Welcome Reception and a banquet at which the Rittinger Awards were presented.

Nine Workshops were also held on the day preceding the Conference, about recently completed and on-going Annexes, including a special workshop on Net Zero Energy Buildings, held with the collaboration of Concordia University in Montreal. A special side event on ground-source heat pumps was held the day following the conference. I would like to address special thanks to the organizers, the International Organizing Committee chaired by Antonio Bouza, the National Organizing Committee chaired by Denis Tanguay, and the Heat Pump Centre. They all have been instrumental in the conference success.

Two Executive Committee meetings were held in 2014; one in Montreal in May in conjunction with the conference, and one in Germany in November. In conjunction with this meeting, a workshop was arranged by Germany to present their national heat pump activities and organize a visit to the Fraunhofer Institute for Solar Energy Systems in Freiburg. A National Teams' meeting to discuss future activities and proposals was held in October at SP's offices in Gothenburg. HPP was also present at international events, such as the IEA Building Coordination Group meeting in Paris in January. HPP also held regular meetings with the European Heat Pump Association.

Sophie Hosatte-Ducassy, ExCo Chairman

It was all the way back in November 2004 in Paris, when Sophie Hosatte was elected Chairman of the IEA HPP Executive Committee, and an excellent choice it was that the delegates made. Sophie Hosatte led this international group of experts in heat pumping technologies and representatives from government and industry with a great vision, committed and consistent, and always maintaining a good atmosphere. During the ten years of her commitment as Chairman, sixteen new annexes have been started, reviewed, and many of them are still ongoing. Relevant topics of heat pumping technology have been addressed, international cooperation has been promoted and the dissemination of knowledge increased. In addition, during her time as a Chairman, four International Heat Pump Conferences have taken place. 2005 in Las Vegas, 2008 in Zurich, 2011 in Tokyo (virtual conference) and finally 2014 in her country in Montreal.

Sophie Hosatte deserves our heartfelt thanks for her extraordinary engagement over the last ten years for IEA HPP. We are grateful that she remains a member of the Executive Committee, bringing her valuable experience and expertise to its service, and continuing to support our work overall.

Stephan Renz, ExCo Chairman elected

11th IEA Heat Pump Conference

Global Advances in Heat Pump Technology, Applications & Markets

Denis Tanguay, conference director

The 2014 conference was the eleventh in a series of triennial conferences sponsored by the International Energy Agency (IEA) Heat Pump Programme. The conference was organised as 18 sessions in three tracks, plus an opening plenary session. It attracted 295 attendees from 31 different countries. Experts from research institutions, governments, energy companies and manufacturers provided 93 oral presentations and 84 poster presentations. 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 host committee (National Organizing Committee) comprised the staff of the Canadian GeoExchange Coalition under the chairmanship of Denis Tanguay, Director. The International Organizing Committee (IOC) comprised those IEA Heat Pump Program executive committee delegates from countries that provided financial sponsorship for the conference: Takeshi Hikawa (Japan), Emina Pacic (Sweden), Sophie Hosatte (Canada), Claus Börner (Germany), Stephan Renz (Switzerland), Hermann Halozan (Austria), Penny Dunbabin (UK) and Antonio Bouza (the U.S.). Antonio Bouza served as IOC Chairman.

The IOC provided overall review and guidance to the NOC, especially regarding financial matters, the technical programme and other key elements. The three Regional Coordinators for the Conference, Takeshi Hikawa (Asia –Pacific), Gerald Groff (North America) and Monica Axell (Europe and Africa), were also members of the IOC.

Programme

The oral programme consisted of 93 presentations, within the following 14 topics:

- Regional reports
- Heat Pumps for a Sustainable Society
- Technology Advances – Components
- Ground Source Heat Pump Applications
- Heat Pump Applications in Residential and Commercial Buildings
- Ground and Water Source Heat Pumps
- Applications – General
- Heat Pump Applications in Manufacturing and Industrial Processes
- Global Markets Perspective for Heat Pumps
- Heat Pump Applications for Low Energy Buildings
- Innovative Technologies and General Applications
- Technology Advances – Systems
- Research Reports – Emerging Technologies
- Thermally driven heat pumps in building and industrial applications

The poster session consisted of a total of 84 posters, presented in six sessions. Each poster session followed right after an oral session, and covered the same topics. The conference participants showed a high level of interest in the posters.

Five awardees recognized in the 2014 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 2014 awardees were announced in a ceremony held at the conference banquet.

Mr. Frédy Burkhalter, CEO of the Swiss Friotherm company, Switzerland, was acknowledged for his contributions in market development and applications of large heat pumps. His activities on the large capacity heat pump market, with various heat sources and high hot water production temperatures, have made a considerable impact on development of the Sulzer Friotherm centrifugal compressor. His work has led to many developments, such as high-temperature heat pump technology in district heating applications.

Mr. Daniel Ellis, the President of ClimateMaster Inc., USA,was recognised for his product innovation and market development activity for geothermal heat pumps. He is recognised as one of the industry pioneers, and led the industry efforts that resulted in U.S. federal tax incentives for GSHPs. Mr. Ellis has been a strong supporter of international technical collaboration. His technical contributions include residential energy analysis software, development of advanced technology heat pumps and design procedures for commercial systems.

Dr. Andrew Pearson from Star Refrigeration Ltd, Scotland, was awarded for his contributions in research and industrial refrigeration systems engineering. Dr. Pearson is well-known internationally through his IIR and ASHRAE activities and his work with more efficient refrigeration systems and troubleshooting of faulty, inefficient or unreliable equipment. He is very active in many associations and is chairman of the Institute of Refrigeration's Technical Committee and past-president of the institute.

The 2014 Ritter von Rittinger Awardees at the conference banquet. From left: Frédy Burkhalter, Daniel Ellis, Koichi Watanabe, Michel Bernier and Andrew Pearson.

Dr. Koichi Watanabe, Professor Emeritus of Keio University, Japan was highlighted for his research and publications in the field of thermo-physical properties. He has published more than 350 scientific and technical papers and books, and is an internationally recognized expert in the field of thermophysical properties of fluids. He has been Visiting Professor at the Polytechnical University of Marche at Ancona, Italy and at the Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University, China.

Dr. Michel Bernier, Professor, at Polytechnique Montréal, Canada, was given the award for his research and teaching contributions with particular reference to geothermal heat pump systems. He has made significant contributions to the advancement of heat pump technology through his research activities. With his graduate students, he has contributed to better understanding of dynamic processes in water-to-air heat pumps, and made numerous contributions to the improvement of modelling and design tools for ground-source heat pump systems.

Technical tours and site visits

Several technical tours and site visits were arranged, all well attended and appreciated by conference attendees. These included visits to the Montreal Biodome and Center for Sustainable Development, as well as to Canmet ENERGY Laboratory, the École de Technologie Supérieure Center for Thermal Technology, and the Fritz Kaiser Cheese Factory.

Workshop program

Seven workshops were organised in connection with the conference. The following workshops and meetings were held:

- Application of Industrial Heat Pumps (HPP Annex 35)
- Quality Installation/Quality Maintenance Sensitivity Studies (HPP Annex 36)
- Systems using solar thermal energy in combination with heat pumps (HPP Annex 38)
- A common method for testing and rating of residential HP and AC annual/seasonal performance (HPP Annex 39)
- Heat pump concepts for Nearly Zero-Energy Buildings (HPP Annex 40)
- Cold Climate Heat Pumps (HPP Annex 41)
- Heat Pumps in Smart Grids (HPP Annex 42)

Conference proceedings

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

Hope to see you at the 12th IEA Heat Pump Conference in 2017, in Rotterdam, the Netherlands!

Highlights 2014

Executive Committee meetings
Two meetings of the HPP Executive Committee (ExCo) were held in 2014:
- May 16-17, in Montreal, Canada;
- November 3-4, in Freiburg, Germany.

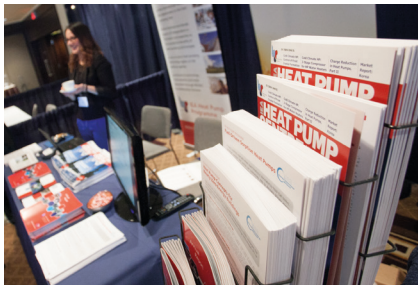
ExCo-meeting in Freiburg, Germany

Workshop in Freiburg
A workshop was held in Freiburg on November 5 in connection with the Executive Committee meeting. The objective of the workshop was to provide an overview of heat pump-related activities in the host country, together with an international overview of policy, market, and innovative applications, as well as of more specific research and development. The workshop also included a visit to the Fraunhofer ISE "Q-Tec - Competence Centre for Heat Conversion - Heat Pumps and Chillers".

Building Coordination Group meeting
The IEA Building Coordination Group (BCG) consists of representatives from all building-related IEA Implementing Agreements (IAs), and holds annual meetings. A meeting was held in January in Paris, with participation from the HPP.

As at previous meetings, the meeting highlighted work and achievements by the different BCG participants, including ongoing and upcoming activities by the IEA.

Another meeting focus was on improving co-operation. Improvements of the IAs' communication with the IEA Secretariat was discussed: for example, in order to allow the IAs actively to contribute to the Energy Technology Perspectives (ETP) series publications. Starting from its recent collaboration experience, the HPP made several suggestions, including a longer review time period, and a one–day workshop to engage the HPP and other IAs in providing contributions from a very early stage. The IEA Secretariat welcomed the idea of workshops.



Publication of articles in REHVA Journal
The REHVA European HVAC Journal had a special issue on heat pumps, to which authors from the HPP were invited to contribute. As a result, three articles were published in the September issue of the Journal, covering heat pumps for cold climates, heat pumps for nearly Zero Energy Buildings, and efficiency of heat pumps in real operating conditions.

Programme Achievements 2014

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Heat Pump Centre

The Heat Pump Centre (HPC) plays a central role in the IEA Heat Pump Programme (HPP), disseminating factual and balanced information on heat pumping technologies and promoting HPP activities. SP Technical Research Institute of Sweden has been appointed to manage the HPC.

Regarding new members, contacts and discussions regarding membership are under way with several countries, including (for example) China, India, and Belgium, as well as with the European Union.

During 2014, an HPC Linked-in group has been started. HPP has also become a partner in Build-up, the European Portal For Energy Efficiency In Buildings.

HPC Newsletter

One of HPC's main activities is 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. The newsletter is available free of charge to HPP member countries from the HPC website. Individuals in non-member countries can subscribe to the Newsletter. The series of national market report articles was continued in 2014, as was the Strategic Outlook article series.

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 approximately 6 % compared to 2013. In addition, the Newsletter is also disseminated through national teams in the member countries.

Website

Another important activity is the development and maintenance of the website, which is continuously updated with news, events, press releases 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 database.

Updates during 2014 include, for example, information on the Heat Pump Conference in Montreal, and the section "About heat pumps".

60 seconds

During 2014, the Heat Pump Centre has continued to distribute the "60 seconds" e-mail. This is a monthly, brief, bullet-format information page, giving an overview of HPC activities during the last month. It is distributed to the ExCo and the IEA, and those involved in annexes and national teams.

Activity generation

The Heat Pump Centre is also involved in the establishment of new activities within HPP. For example, it publishes descriptions of project proposals on the website in order to encourage initiation of new annexes. HPC also maintains regular contact with the annexes' Operating Agents, supporting them with legal text, formal participation letters, etc.

HPP publications can be downloaded from the Heat Pump Centre website.

www.heatpumpcentre.org

Although no new annexes were initiated in 2014, a number of ideas for new annexes were discussed at the working meeting and National Teams' meeting. These two meetings were held on consecutive days in Gothenburg, Sweden, in October, and were very well attended. The main focus of the meetings was to discuss and develop ideas for research projects within the programme, and the following ideas were discussed: "Domestic hot water heat pumps", "Market implementation of heat pumps", "Heat pumps in district heating systems", "Ground-source heat pumps", "Industrial heat pumps, the second phase", "Hybrid heat pumps", "Heat Pumps in multi-family buildings", "Air conditioning", as well as several ideas from the US.

Hermann Halozan and Rainer Jakobs at the National Teams' meeting in Gothenburg, Sweden

Contributions/Support for IEA publications and activities

The IEA continues its series of Energy Technology Perspectives (ETP) publications. The HPP reviewed and commented on a draft of ETP 2015, as well as an outline of ETP 2016, 'Building sustainable urban energy systems'.

International collaboration and promotion

The Heat Pump Programme and the Heat Pump Centre have excellent relations with a number of national and international organisations, including IIR, EHPA, ASHRAE, AHRI/AHRTI, REHVA and China Energy Conservation Association (CECA).

Examples of interactions during 2014 include participation at the ASHRAE Winter Conference and the US HPP national team's meeting in New York in January; participation and meeting with the Indian Ground Source Heat Pump Association at ACREX India in New Delhi in February; presentation at the "2014 China Heat Pump Annual Conference" in Beijing in August, presentation at the Flemish Heat Pump Association´s annual symposium; participation and chairing of the one-day conference at the Chillventa Congressing "Heat Pumps: Challenges Markets Technology Research Applications" in October; and presentation at the Danish heat pump conference "3rd International Symposium on Advances in Refrigeration and Heat Pump Technology" in November.

Group photo from the National Teams' meeting in Gothenburg, Sweden.

Newsletters 2014

The four 2014 newsletters and e-newsletters are available on the Heat Pump Centre website.
The topics were:
1. Policy and standards
2. Highlights from research
3. The 11th Heat Pump Conference: Market and Policy
4. Innovative Technology

Ongoing annexes*

The projects within the HPP are known as Annexes. Participation in an Annex is an efficient way of increasing national knowledge, both regarding the specific project objective, but also by international information exchange.

Annexes operate for a limited period of time, and objectives may vary from research to implementation of new technology. Market aspects are other examples of issues that can be highlighted in the projects.

35	**Annex 35** Application of Industrial Heat Pumps	AT, CA, **DE**, DK, FR, JP KR, NL, SE
36	**Annex 36** Quality Installation/Quality Maintenance Sensitivity Studies	FR, SE, UK, **US**
37	**Annex 37** Demonstration of Field Measurements of Heat Pump Systems in Buildings	CH, NO, **SE**, UK Observers: AT, DE, DK
39	**Annex 39** A Common Method for Testing and Rating of Residential HP and AC Annual/Seasonal Performance	AT, CH, DE, FI, FR, JP, KR, NL, **SE**, US
40	**Annex 40** Heat Pump Concepts for Nearly Zero-Energy Buildings	CA, **CH**, DE, FI, JP, NL, NO, SE, US
41	**Annex 41** Cold Climate Heat Pumps (Improving Low Ambient Temperature Performance of Air-Source Heat Pumps)	AT, CA, JP, **US**
42	**Annex 42** Heat Pumps in Smart Grids	AT, CH, DE, DK, FR, KR, **NL**, UK, US
43	**Annex 43** Fuel Driven Sorption Heat Pumps	AT, **DE**, FR, IT, KR, UK, US
44	**Annex 44** Performance Indicators for Energy Efficient Supermarket Buildings	**NL**, SE

The IEA Heat Pump Programme participating countries are: Austria (AT), Canada (CA), Denmark (DK) Finland (FI), France (FR), Germany (DE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), South Korea (KR), Sweden (SE), Switzerland (CH), the United Kingdom (UK), and the United States (US). All countries are members of the Heat Pump Centre (HPC). Sweden is the host country for the Heat Pump Centre.

* Bold text indicates operating agent.

Annex 35
Application of Industrial Heat Pumps

Participating countries: Austria, Canada, Denmark, France, **Germany**, Japan, the Netherlands, South Korea, Sweden
and from IETS Implementing Agreement: Denmark, the Netherlands, Sweden

The IEA HPP-IETS Annex 35/13 "Application of Industrial Heat Pumps", a joint venture of the International Energy Agency (IEA) "Industrial Energy-Related Technologies and Systems" Implementing Agreement (IETS) and "Heat Pump Programme" (HPP), was initiated in order actively to contribute to the reduction of energy consumption and emissions of greenhouse gases by increased implementation of heat pumps in industry.

Annex 35/13 started on April 1, 2010 and was concluded on April 30, 2014, with 15 participating organizations from Austria, Canada, Denmark, France, Germany (Operating Agent), Japan, the Netherlands, South Korea and Sweden.

The work programme has been mainly concentrated on collection of statistical energy and environmental data and information related to industry, as well as the present status of R&D and the application of heat pumps in industry. A total of 39 R&D projects and 115 applications of heat pumps in industry - in particular the use of waste process heat as the heat source - have been presented and analysed by the participating countries.

It has been shown that in many companies, and especially in SMEs, only very little and aggregated information on the actual thermal energy consumption is available, and disaggregated data such as consumption of individual processes and sub-processes therefore either have to be estimated or determined by costly and time-consuming measurements, which often requires the integration of several processes at different temperature levels and with different operating time schedules.

Modelling calculations and economic models activities have been carried out. The basis has been the update of the Industrial Heat Pump screening program, to determine how industrial heat pumps could be used in different applications, developed and presented in "Annex 21 - Global Environmental Benefits of Industrial Heat Pumps (1992 -1996)".

The IHP screening program has been analysed and converted from an outdated Visual Basic version to the latest Visual Basic version employing the .NET framework. This new, converted version would in principle be ready for any modifications, updates of data and models as well as for extensions.

Taking into account the results of Annex 35 with detailed information on statistical data, R&D results and case studies, a possible follow-up annex should be concentrated on:

- Collected case studies of industrial sectors with a large potential, analysed through firmly founded energy audits focused on waste heat recovery, and the creation of an international information data base
- Development of a web-based information platform for heat pumps in industry
- Creating information material for IHP training courses
- Preparing information for policy-makers on the IHP potential for more efficient use of energy and reduction of GHG emissions
- Development of a simplified model for integration of heat pumps into processes.

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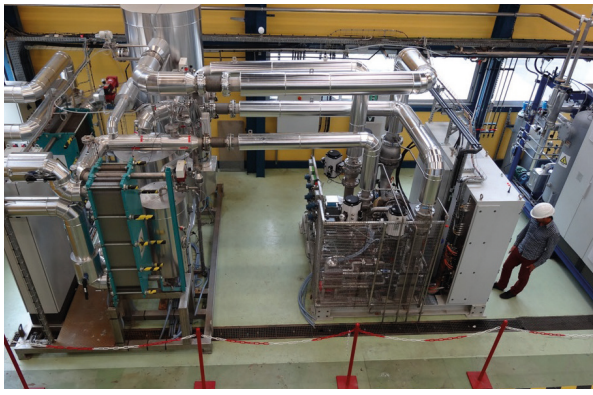
Annex 35 publications can be downloaded from the Heat Pump Centre website.



Heat Pump up to 140°C with water as working fluid.

Annex 36
Quality Installation/Quality Maintenance Sensitivity Studies

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Annex 36 publications can be downloaded from the Heat Pump Centre website.

Participating countries: France, Sweden, the United Kingdom, **the United States**

Annex 36 evaluated how installation and/or maintenance deficiencies cause heat pumps to perform inefficiently (i.e., decreased efficiency and/or capacity). The investigations showed that operational deviations (or faults) are significant; that multiple deviations – when combined – can have an additive effect on heat pump performance degradation; and that some deviations (among various country-specific equipment types and locations) have greater performance impact than others. The focus and work undertaken by each participating country is presented in Table 1.

Annex 36 activity led to a number of developments in the participating countries:
France A CO_2 heat pump water heater aimed for the French market; resultant system was of modular design, ½ day installation time, with annual COP of ~3.0.
Sweden An information manual – aimed at owners of small multi-family buildings – that provides guidance on purchasing, commissioning, operation & maintenance, and system monitoring for various heat pump systems. Additionally, a 'smart fault detection & diagnostic system' is currently under development.
The United Kingdom Revisions to the heat pump system design/installation standard (i.e., Microgeneration Certification Standard MIS 3005 issue 3.1) with improved guidance to designers, installers, and maintenance personnel.
The United States Quantification of the efficiency degradation experienced by air source heat pumps typically installed in the U.S. Federal, State, and local entities are assessing their energy efficiency programs and considering changes based on this information.

The four-year effort concluded in mid-2014 with results presented at the Annex 36 workshop held in conjunction with the 11th IEA Heat Pump Conference 2014. The Annex 36 Final Report has been accepted by the ExCo at its October 2014 meeting and its publication will occur in early 2015.

Table 1: Annex 36 Focus Areas and Effort

Annex 36 participants	Focus Area	Work Emphasis
France	EdF – Space heating and water heating applications.	Field: Customer feedback survey on HP system installations, maintenance, and after-sales service. Lab: Water heating performance tests on sensitivity parameters and analysis.
Sweden	SP – Large heat pumps for multi-family and commercial buildings KTH – Fault detection and diagnoses in heat pump systems	Field: SP – Literature review of operation and maintenance for larger heat pumps. Interviews with real estate companies owning heat pumps. KTH - investigations and statistical analysis of 68,000 heat pump failures. Modeling/Lab: KTH – Determination of failure modes and analysis of found failures and failure statistics based on analysis of most common and costly faults reported to insurance companies and equipment manufacturers.
the United Kingdom	DECC – Home heating with ground-to-water, water-to-water and air-to-water systems.	Field: Monitored 83 domestic heat pumps and made modifications to improve performance. Lab: Investigated the impact of thermostatic radiator valves on heat pump system performance.
the United States (OA)	NIST – Air-to-air residential heat pumps installed in residential applications (cooling and heating).	Lab: Cooling and heating tests, with imposed faults, to develop correlations for heat pump performance degradations due to those faults. Modeling: Seasonal analyses modeling to evaluate the effect of installation faults on heat pump annual energy consumption. Includes effect of different building type (slab vs. basement foundation) and climates in the assessment of impact on fault-imposed heat pump performance.

Annex 37

Demonstration of Field Measurements of Heat Pump Systems in Buildings - Good Examples with Modern Technology

Participating countries: CH, NO, **SE**, UK. Observers: AT, DE, DK.
Start date: Spring 2011

The aim of this project has been to demonstrate and disseminate the economic, environmental and energy-saving potentials of heat pumping technology in buildings. The focus is on modern technology, using results from existing field measurements in order to calculate energy savings and CO_2 reduction potentials. It should be possible to predict the most suitable heat source and heat pump system for particular applications in particular geographic regions. It has been shown that the quality of the measurements is assured, and so criteria for good and assured quality have been defined in the project.

As an additional task, evaluations of field monitoring campaigns in the UK, in Germany and in Denmark have been conducted and compared with the monitoring originally performed in this project.

The final report for this Annex is under preparation, and is expected to be published in 2015.

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Annex 39

A Common Method for Testing and Rating of Residential HP and AC Annual/Seasonal Performance

Participating countries: AT, CH, FI, FR, DE, JP, KR, NL, **SE**, US.
Start date: September 2010

Annex 39 has published proposals for harmonisation of SPF calculation methods for domestic heat pumps (including heating, cooling and domestic hot water production), as well as proposals for global harmonisation of test points, to minimise testing efforts. The idea is that pre-normative research that has been carried out in this annex can later be incorporated in standardisation documents (ISO, CEN etc.), or in national and/or regional standards for estimating annual performance.

The following task-sharing activities have been carried out (in some cases, with some exceptions):

Task 1 Review and evaluation of existing test and calculation methods for SPF. A template for reporting has been developed and national methods have been summarised.
Task 2 Development of a matrix defining needs for testing and calculation methods.
Task 3 New calculation methods for SPF/commonly accepted definitions on how SPF is calculated. In this task, a review of current methods has been performed, with recommendations for future work.
Task 4 Identification of improvements to existing test procedures.
Task 5 Validation of SPF method. No specific SPF method was validated, but instead some methods were compared and discussed.
Task 6 Proposal of an alternative method to evaluate heat pump performance.
Task 7 Communication to stakeholders.

A workshop was organised during 2014, together with the IEA HPP Conference in Montreal. Work has started on preparing the final report of the annex, to be published in 2015. The project website, www.heatpumpcentre.org/Annex 39, contains material from meetings and conferences.

Annex 40

Heat Pump Concepts for Nearly Zero-Energy Buildings

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Participating countries: Canada, Finland, Japan, the Netherlands, Norway, Sweden, **Switzerland**, the United States. Start date: July 2012

Political targets indicate that nearly Zero Energy Buildings (nZEB) are the next step of high performance buildings. In Europe, a broad introduction of nZEB in the new building sector will start by 2020. In Japan, the projected target for a broad introduction of nZEB is 2030. A consistent definition of nZEB, though, is still missing. The European standardization organization, CEN, has drafted a rating procedure for nZEB, which is currently going through the approval procedure.

Heat pumps are already well established as HVAC systems in nZEB that have been built. However, many current nZEB are effectively prototypes aimed at approving the zero energy balance. The objective of this Annex is therefore to investigate and further develop tailored heat pump system solutions for particular nZEB requirements. Potentials are seen in building and system integration, since the nZEB concepts comprise renewable energy sources on-site.

The principal objectives are:

- to improve and further develop heat pump systems for nZEB
- to gather more field experience from operation of novel and existing heat pumps in nZEB
- to derive recommendations and best practice systems for heat pumps in nZEB.

The Annex has been structured into four tasks:
Task 1 State-of-the-art survey of nZEB and applied technologies in nZEB
Task 2 Improvement of heat pump systems in terms of performance and cost
Task 3 Technology development and field testing of systems (in parallel with Task 2)
Task 4 Integration of nZEB into the energy system.

Activities in 2014

In 2014, Canada and Finland started work on Annex 40, and Germany joined the Annex. Focus of work in 2014 was both on Task 2, dealing with system comparison and improvement, and on Task 3, technology development and field monitoring. Regarding Task 2, several countries performed system comparisons. In Switzerland, it was confirmed that heat pumps are among the most efficient and cost-effective systems in both single- and multi-family buildings. Currently, integrated solutions are being assessed. In Sweden, it was evaluated that ground-source heat pumps are an efficient and economical way to supply residential nZEB. Norway is developing a design tool for heat pumps in nZEB, and the US has a software development for comfort evaluation. Japan has performed case studies for nZEB office buildings. Finland is evaluating the best system solutions for Finnish boundary conditions in residential buildings.

Several Task 3 monitoring projects started in 2014. In Norway, monitoring of the first nZEBs is ongoing. The US runs field tests of the residential testing facility for nZEB systems and different highly integrated heat pumps. The Netherlands is performing a large field test, Energy Leap, which is investigating different heating technologies. Germany is performing long-term monitoring of office buildings with heat pumps and thermally-activated building systems, evaluating performance and load matching.

Interim results were presented at two workshops in 2014, in the frame of the IEA Heat Pump Conference in Montreal in May 2014, and in connection with the 5th Annex 40 working meeting at Nagoya University in November 2014.

Workshop presentations can be downloaded from the Annex 40 website

www.annex40.net

Annex 41

Cold Climate Heat Pumps (Improving Low Ambient Temperature Performance of Air-Source Heat Pumps)

Participating countries: Austria, Canada, Japan, **the United States**.
Start date: June 2012

Heat pump technology provides a significant potential for CO_2 emissions reduction. Annex 41 will revisit research and development work in different countries to examine technology improvements leading to successful heat pump experience in cold regions. The primary focus is on electrically driven air-source heat pumps (ASHP) with air (air-to-air HP) or hydronic (air-to-water HP) heating systems, since these products suffer severe loss of heating capacity and efficiency at lower outdoor temperatures. Thermally activated (engine-driven, absorption, etc.) ASHPs and ground-source heat pumps (GSHP) may also be included in individual country contributions, if desired. The main technical objective is to identify solutions leading to ASHPs with heating SPF ≥ 2.63 W/W, recognized as a renewable technology. The main outcome of this Annex is expected to be information-sharing on viable means to improve ASHP performance under cold (≤ -7°C) ambient temperatures.

The 2nd working meeting and 1st workshop of the Annex were held during the 11th IEA Heat Pump Conference in Montréal on May 12, 2014. Presentations were provided by all four participating countries and posted to the member page of the Annex web site. A summary Annex interim report was completed in December 2014 and will be posted to the Annex web site in 2015. A common characteristic to note about all the various system configurations being investigated (analytically and experimentally) by the Annex Participants is the added complexity required in order to achieve significant improvement in low ambient temperature heating capacity (and efficiency) for an ASHP. Additional compressor capacity or novel compressor approaches, cycle enhancements (ejectors or vapor injection), or incorporation of supplemental renewable energy sources will be necessary. These capacity and efficiency enhancement measures will lead to more complex (and costly) systems compared to standard single-compressor ASHPs.

The Annex 41 web site is located at http://web.ornl.gov/sci/ees/etsd/btric/usnt/QiQmAnnex/indexAnnex41.shtml.

The next planned meetings of the Annex are a working meeting in Vienna (May 2015) and the 2nd workshop planned for August 2015 in Yokohama, Japan during the 2015 International Congress of Refrigeration. The Annex officially began in July 2012 and is expected to run until July 2016.

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Annex 41 workshop attendees, Montreal Conference

Annex 42
Heat Pumps in Smart Grids

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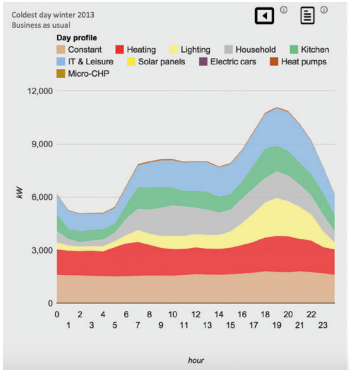
Participating countries: Austria, Denmark, France, Germany, **the Netherlands**, South Korea, Switzerland, the United Kingdom, the United States. Start date: May 2013

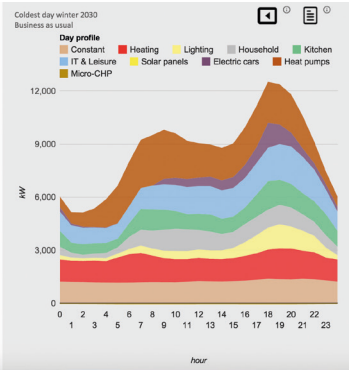
Just like wind power, photovoltaic, solar heating, and other renewable energy sources, heat pumps will become increasingly widespread in future energy systems in the buildings. Thus, there will be a greater need to match user demand to production from the varying energy sources. Energy use will become more attuned to the moment of availability, instead of today's near-random demand by the consumer/user. Today, in addition to investigating the potential of heat pumps for reducing peak load demand in smart grids, there is also a need to investigate how to use domestic demand to absorb the production of electricity from intermittent sources.

The graphs show the differences between grid loads for the coldest day in 2013 and the coldest day in 2030 in an average Dutch city of 40 000 inhabitants. The growth in penetration of heat pumps and electric vehicles alone already justifies the development of smart grids (source: www.scenariotool.nl). The increase in electricity use by both technologies is an opportunity to absorb renewable electricity from intermittent sources.

Objectives and scope

The objective of Annex 42 is to contribute to reduction of the use of energy and emissions of greenhouse gases through increased implementation of heat pumps (ground source, water source, air-to-water and hybrid types) in smart grids. This will also help to manage the increasing contribution of solar PV and wind power.





Deliverables

A summary report has been prepared for policy-makers, summing up the results from Tasks 1-3, including input from discussions in the working group. The ExCo and national policy-makers will be advised regarding the needs for further projects or annexes on heat pump implementation in smart grids.

Progress of the Annex

The Annex 42 group held a meeting in May 2014 during the conference in Montreal, attended by Annex members from UK, the Netherlands, Germany, South Korea and Denmark. Details of the project structure were finalised at the meeting. This project structure forms the backbone of the annex, and also formed the main structure for the meeting in Freiburg in October 2014. In the end, diversity offers more insights and learning potential than do similarities. The enormous diversity in the energy systems in the participating countries has already provided a wealth of probable knowledge within this annex.

During the Freiburg meeting, progress was made on gradually consolidating the annex into a more defined shape. Case scenarios per country are the methodology to investigate the possibilities in various energy systems, and make the output quantifiable for the participants. Confirmed participants in the Annex are the United Kingdom, the Netherlands, South Korea, USA, Switzerland, France, Denmark, Austria and Germany. The annex runs for three years.

Task structure

Task 1: Market overview, barriers for application;
Task 2: System aspects and opportunities;
Task 3: Modelling and technology;
Task 4: System technology and application;
Task 5: Communications.

Annex 43
Fuel Driven Sorption Heat Pumps

Participating countries: Austria, France, **Germany**, Italy, South Korea, the United Kingdom, the United States. Start date: October 2013

While Annex 34, "Thermally Driven Heat Pumps for Heating and Cooling", was in progress, interest in the area of fuel-driven sorption heat pumps was increasing, as a result of more products coming closer to market. A new annex, "Fuel-driven sorption heat pumps", was therefore proposed to the ExCo in March 2012. After an Annex Definition Meeting, a legal text was compiled and accepted by the ExCo as a draft. Annex 43 started officially in July 2013, with a planned duration of four years. Seven countries have joined the annex, others have expressed their interest in doing so (Poland, China).

The scope of the work under this annex is the use of fuel-driven sorption heat pumps in domestic and small commercial or industrial buildings and applications. The additional possibility of supplying cooling may be considered. The main goal is to extend the use of fuel-driven heat pumps by accelerating technical development and market readiness of the technology, and to identify market barriers and supporting measures.

In Task A, a template for the country report was sent out to the participants. Two country reports have been submitted to the task leader, and related ongoing work from a number of countries was reported at the last meeting. All country reports should be submitted by May 2015.

In Task B, the participants reported the ongoing work on materials and on components/heat pumps. A round-robin test regarding characterisation of carbon-ethanol working pairs was proposed. A discussion on other refrigerants is ongoing.

The work in Task C is concentrating on the definition of standardised measurements and monitoring procedures. This focuses on a clear definition of system boundaries for calculation of performance figures; a definition of reference conditions and measurement minimum precision

A first draft of a standardised monitoring and evaluation procedure for FSHP (Fuel-Driven Sorption Heat Pumps) has been circulated to the participants, and has subsequently been adapted to the requirements of the European Directives for labelling of combined systems.

So far work within Task D is related to simulation studies. The general approach and the methodology to achieve the goals set has been discussed.

Task E focused on work for visibility of Annex 43 and FSHP technology in general. A logo for the Annex was designed, templates for the reports and presentations produced and a web page with general information on the Annex accessible to the public, with a restricted area reserved for active participants only, was set up and launched.

In addition, a short survey of available content on FSHPs in Wikipedia was carried out. It was concluded that the information available is not sufficient, and that the participants are willing to contribute to improve and extend the content.

One of the major outcomes of the third meeting in Freiburg in November 2014 was the common interest in starting a large field test (> 1000 systems) on fuel-driven sorption heat pumps to prove the efficiency of this technology, gather more information of ideal system layouts and to increase awareness. This idea will be discussed with interested parties from the gas industry and heating systems manufacturers.

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Annex 44

Performance Indicators for Energy Efficient Supermarket Buildings

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Participating countries: the Netherlands, Sweden. Start date: June 2013

Annex 44 started in June 2013. Two meetings with the Swedish reference group were organised in 2014, and a public workshop was held in June 2014 in London, UK. In the Netherlands, energy consumption data has been collected for 150 supermarkets. Online working meetings, of which minutes are available, have been held throughout the duration of the annex.

Objective

There is a clear trend for more and more monitoring systems, measuring parameters such as temperatures (typically to ensure and validate food quality) and energy to be installed in supermarkets. Although measurements are taken and stored, and energy cost data is available, there is still in many cases no knowledge of the supermarket's energy efficiency, whether compared to other supermarkets in the same chain or to competing supermarkets. In this annex, performance indicators will be defined that will permit evaluation of energy efficiency of existing single supermarkets, supermarkets within a particular chain, supermarkets across different chains, and even supermarkets in different regions or countries.

Target audience

The results will give supermarket organisations the ability to turn their available data into knowledge concerning the energy efficiency of their supermarket(s), and to use it for energy-related decisions and investments. Useful energy consumption data for supermarkets can also be used at a national level to map energy use and benchmark best practices for supermarket buildings.

Workplan

The following tasks are defined in the Annex work plan:
1. Mapping existing energy systems in supermarkets and collection of monitored data from selected supermarket chains and individual supermarkets
2. Definitions & inventory of resources & System boundaries
3. Suggestions of suitable key performance indicators
4. Evaluation of existing monitoring methodology
5. Selection and refinement of selected key performance indicators
6. Evaluation (and validation) of results
7. Dissemination of results

Participation

The annex was started in 2013, with Sweden and the Netherlands as participants. Other possible participants have been contacted, leading to the expectation that at least one additional participant will join. The annex has been open for new members throughout 2014.

Image Sources

11th IEA Heat Pump Conference (p. 6-8)
All photos were taken by the Conference photographer

Highlights (p. 9)
ExCo-meeting in Freiburg, Germany, Nov 2014. A. Ingemarson, HPC
Heat Pump Centre publications, 11th IEA Heat Pump Conference, Montreal, May 2014, Conference photographer

Programme achievements (p. 10-11)
Hermann Halozan and Rainer Jakobs at the National Teams' meeting in Gothenburg, Sweden, Oct 2014. J. Berg, HPC
Group photo from the National Teams' meeting in Gothenburg, Sweden, Oct 2014. J. Berg, HPC

Annex 35 (p. 13)
A heat pump with an output temperature up to 140 °C, with water as its working fluid. EdF R&D, France

Annex 41 (p. 17)
Annex 41 workshop attendees, 11th IEA Heat Pump Conference, Montreal, May 2014. Conference photographer.

Annex 42 (p. 18)
Graphs of the differences between grid loads for the coldest day in 2013 and the coldest day in 2030 in an average Dutch city of 40 000 inhabitants. Annex 42.

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