ANNUAL REPORT 2016

HEAT PUMPING TECHNOLOGIES

Technology Collaboration Programme on
Heat Pumping Technologies - HPT TCP

International Energy Agency

Technology Collaboration Programme
on Heat Pumping Technologies

Image sources

Front page

- On the way to the ExCo meeting in Sophia Antipolis, France, November 2016 (Christoph Reichl).
- ExCo meeting in Jeju Island, South Korea, June 2016 (Heat Pump Centre, HPC).
- National Teams meeting Nürnberg, October 2016 (HPC).

HPT TCP (p.7)

- iStock Photo

Highlights (p. 8)

- ExCo meeting in Sophia Antipolis, France, November 2016 (HPC).
- CERT Workshop, February 2016 (HPC).

12th IEA Heat Pump Conference (p. 9-10)

- All images are provided by the National Organizing Committee (NOC) for the 12th IEA Heat Pump Conference in Rotterdam, the Netherlands, 2016.

HPT TCP Research Projects

- p.20 - Based on Sartori et. al., 2012.
- p.21 - Institute of Energy Technologies, Univ. Appl. Sciences HSR Rapperswil.
- p.30 - DHPA, BDH.
- p.38 - B. Atanasiu and I. Kouloumpi. 2013. Building Performance Institute Europe - BPIE.
- p.39 - Technical University Nuremberg.
- p.42 - RISE Research Institutes of Sweden.
- p.43 - AIT Austrian Institute of Technology for both of the images.

Back page

- ExCo meeting in Jeju Island, South Korea, June 2016 (HPC).
- Logotype from 12th IEA Heat Pump Conference.

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HPT TCP Annual Report 2016

www.heatpumpingtechnologies.org

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Content

Technology Collaboration Programme on
Heat Pumping Technologies (HPT TCP)

Message from the Chairman

Heat pumps are acknowledged as a highly efficient technology that uses renewable energy. Therefore, they are destined to reduce greenhouse gas emissions and increase energy efficiency by replacing conventional heating systems in the building sector as well as in industrial processes. They will play a major role in achieving the International Energy Agency's (IEA) target to limit the global temperature rise to well below 2 °C (WB2DS). Furthermore, heat pumping technologies, including air-conditioning and refrigeration, are important in developing countries. Many of these are located in warm climate zones and suffer from health problems caused by the lack of, or perished, nutrition. Highly efficient, easy to install and cheap air-cooling devices and refrigeration units are needed.

Research, development, demonstration and dissemination as well as knowledge transfer of efficient and renewable heat pumping technologies form the scope of our Technology Collaboration Programme (TCP). Since the launch of our TCP in 1978, we have accomplished 40 Annexes (projects realised with the collaboration of many experts from different countries participating in the TCP). In addition to this, we have eleven ongoing annexes. In 2016, we approved the final reports from three annexes and have launched four new ones. 16 countries are collaborating in the TCP. This shows that the TCP is very active as the topic of heat pumping technologies becomes more and more important and is developed by experts from many countries in North America, Asia and Europe.

In 2016, the Executive Committee (ExCo) of the TCP met at the spring ExCo Meeting, which was organised by Korea, and a well-attended workshop was held jointly with the Korean Heat Pump Association. In November, the host of the next ExCo-Meeting was France and we met in Sophia Antipolis. The ExCo held a one-day workshop dedicated to the development of the future strategy for the TCP. The outcome will contribute to the strategic plan that we have to establish prior to the request for an extension of the TCP in 2017.

An important role in disseminating the outcomes of our work is played by our website. In 2016, the website was redesigned and equipped with the latest technology in order to be suitable for different devices, such as PCs, tablets, and smart phones. A new database has been elaborated to improve the search function and the accessibility of our documents. In autumn 2016, we launched a completely redesigned 'Magazine'. It replaces the former 'Newsletter'. News is published on our website and can be updated as often as needed. Many of those activities are performed by our "Operating System" – the Heat Pump Centre.

An important, challenging and time-consuming effort has been undertaken by the International and the National Organising Committees (IOC and NOC) and the Regional Coordinators (RC) in order to organise our International Heat Pump Conference in Rotterdam in 2017. More than 300 abstracts were submitted; these had to be selected and most of them were submitted as a full paper that had to be checked by many experts. The result is a four-day conference with a workshop at the beginning and three days with presentations and poster sessions in four tracks.

All this work can only be done thanks to the highly motivated and experienced people collaborating in the different fields and levels of our TCP. Therefore, it is my pleasure to thank the operating agents and their experts in the Annexes, the staff of the Heat Pump Centre, and my colleagues, the delegates in the ExCo. Not to forget our Desk Officer, John Dulac at IEA Executive Office, with whom the collaboration and exchange of information is very fruitful. Many thanks go to the participating countries and their funding agencies. Without the financial support via the membership fee, and all the different projects contributing to the Annex-work, our activities would not be possible. As I mentioned at the beginning, the money spent is used for the important work needed to improve energy efficiency and limit global warming.

Stephan Renz, Chairman of the Executive Committee

International Energy Agency

About the International Energy Agency (IEA)
The IEA is an autonomous organisation which works to ensure reliable, affordable and clean energy for its 29 member countries and beyond. Founded in 1974, the IEA was initially designed to help countries co-ordinate a collective response to major disruptions in the supply of oil such as the crisis of 1973/4. While this remains a key aspect of its work, the IEA has evolved and expanded. It is at the heart of global dialogue on energy, providing authoritative statistics and analysis.

An autonomous organisation, the IEA examines the full spectrum of energy issues and advocates policies that will enhance the reliability, affordability and sustainability of energy. Main areas of focus are:

- energy security: Promoting diversity, efficiency and flexibility within all energy sectors;
- economic development: Ensuring the stable supply of energy to IEA member countries and promoting free markets to foster economic growth and eliminate energy poverty;
- environmental awareness: Enhancing international knowledge of options for climate change;
- engagement worldwide: Working closely with non-member countries, especially major producers and consumers, to find solutions to shared energy and environmental concerns.

For more information on the IEA, see the Frequently Asked Questions: *www.iea.org/about/faqs*

About the IEA Energy Technology Collaboration Programmes (TCPs)
The IEA TCPs are independent, international groups of experts that enable governments and industries from around the world to lead programmes and projects on a wide range of energy issues. The current portfolio of TCPs comprises:

- efficient end-use (buildings, electricity, industry, transport)
- cleaner fossil fuels (greenhouse-gas mitigation, extraction, supply, transformation)
- renewable energy and hydrogen (technologies and policies for deployment)
- cross-cutting issues (modelling, technology transfer, project financing)
- fusion power (safety, physics, materials, technologies)

The 6,000 experts in the TCPs work to advance development and commercialisation of energy technologies. The scope and strategy of each TCP is in keeping with the IEA shared goals of energy security, environmental protection and economic growth, as well as engagement worldwide. Depending on the TCP, activities may include basic and applied research, feasibility studies, environmental impact studies, policy implications; information exchange of research results and programmes, scientist exchanges, modelling analysis, experts' networks.

The TCPs are at the core of a network of senior experts consisting of the Committee on Energy Research and Technology (CERT), four working parties and three expert groups – the IEA Energy Technology Network.

The four expert Working Parties (end-use, fossil fuels, fusion and renewables) oversee activities of the TCPs and evaluate their outcomes at the end of each term. The Working Parties provide leadership by guiding the HPT TCP to shape work programmes to address current energy issues, by reviewing their accomplishments and suggesting reinforced efforts. For more info, see *CERT and Working Parties.*

Each TCP is organised under the auspices of an Implementing Agreement. The IEA Framework for International Technology Co-operation specifies the minimum legal and management requirements for TCPs. The activities of each TCP are governed by an Executive Committee comprised of representatives from each entity that becomes a signatory. For more information on TCPs, see the *Frequently Asked Questions* brochure.

Technology Collaboration Programme on Heat Pumping Technologies



Organised under the umbrella of the International Energy Agency since 1978, the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) 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. In connection with the development of a request for extension of the Programme, and as a part of our ever-continuing efforts for improvement, we are currently reviewing the Programme strategy.

HPT TCP MEMBER COUNTRIES
Austria, Belgium, 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 significantly improve the visibility and status of the Programme, and to be an outstanding Technology Collaboration Programme within the IEA.

Activities

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

Highlights 2016

Executive Committee Meetings
Two meetings of the HPT TCP Executive Committee (ExCo) were held in 2016:

- June 7-8, on Jeju Island, South Korea
- November 8-10, in Sophia Antipolis, France

Workshop and Study Visit in South Korea
An international workshop was organized together with the Korean Heat Pump Association at the Ramada Plaza Jeju Hotel in Jeju on the 9th of June 2016 in conjunction with the IEA HPT Executive Committee meeting. This provided a unique opportunity to receive the latest information on the activities in the host country related to heat pumping technologies and the Korean audience to be informed about the activities within the HPT TCP.

The ExCo delegates and the Operating Agents of the IEA TCP on Heat Pumping Technologies and the Heat Pump Centre also visited the Smart Grid Information Centre on Jeju Island in South Korea. In an electrical Smart Grid, heat pumping technology can play a key role. South Korea, the world's tenth largest energy consumer, has ambitions to complete the establishment of the national Smart Grid Unit in 2030. During the visit the representatives from the HPT TCP were informed about the Smart Grid Test-bed on Jeju Island and what the Test-bed management will do to reach their objective.

Strategy Workshop
During the end of the year, the preparation work to submit a request for extension of the Technology Collaboration Programme to the IEA CERT during 2017 was initiated, including compiling an end-of-term report and strategy work plan for the forth-coming five-year period. A strategy workshop for the ExCo delegates was held in connection to the fall ExCo meeting in France. During the workshop, the expectations from the different stakeholders were shared, an internal and external situation analysis conducted and the vision, mission and strategic goals of the TCP were discussed.

Building Coordination Group Meeting
The IEA Building Coordination Group (BCG) consists of representatives from all building-related Technology Collaboration Programmes (TCPs), and holds annual meetings. A meeting was held in January in Paris, with participation from the HPT TCP.

CERT workshop
In February CERT, the Committee on Energy Research and Technology, organized a workshop entitled "Maximising the impact of IEA's Technology Collaboration Programmes through enhanced cooperation in the Energy Technology Network". Since September 2015, IEA has a new executive director, Dr. Fatih Birol, who wants to expand and enhance the activities of the Technology Collaboration Programmes. The workshop was the first of a series of workshops aiming at increasing the cooperation between different TCPs and increasing the visibility and impact of IEA by increased outreach activities. The aim is also to make the results from the TCPs reach a wider audience. The HPT TCP participated and presented the activities and aim of the programme. It was a very successful event, and the organizers announced that they plan to continue with more similar workshops in the future.

12th IEA Heat Pump Conference

The 12th IEA Heat Pump Conference will be held on 15-18th of May 2017 in the World Trade Centre in the bustling city of Rotterdam, praised for its great architecture by many. That many of these buildings, among them the WTC, are heated and cooled with large ground source heat pumps is unknown to many people.

The theme of the Conference is: '**Rethink Energy, Act NOW!**'. This is a time of rethinking or a paradigm change. The era of heat pumps and other renewables is inevitable. The main solutions and choices will not be made purely on economics, but more on expectations on future energy systems, infrastructures becoming dependent on insecure suppliers and on electricity from renewable sources. Ecological concerns become key drivers for policy makers and consumers alike, and their choices are fundamentally altering the energy business landscape.

Renewable energy is inevitable because we still use more and more energy based on fossil fuels that is not sustainable. Thus, from an environmental point of view, it is necessary for us to increase our use of renewable energy, in order to stop 'the race to the cliff', as evidenced by "World Overshoot Day". The message of the conference goes beyond the standard slogans such as energy efficiency, renewables and environment.

In the area of heating and cooling systems, there is a great urgency to act now. Almost all current investments made in this sector will have a long-term effect on overall energy use. The renovation of a heating system will impact energy usage for the next 15 to 20 years. At the same time, almost all these measures to reduce energy emissions, whether implemented within the industrial, commercial or residential market, can be categorized as "no-regret options" and should be prioritized in a systematic policy approach.

Policy makers worldwide must give primary consideration to heating and cooling usage and look at the best available options. Here heat pumps play a key role as an already available and proven technology.

Conference program

The first day of the conference will start with a number of challenging workshops organized together HPT Annex participants and other IEA TCPSs. Each workshop will be introduced by speakers from all continents, giving an overview of the state of the art in the market, experiences and on current research topics with challenging questions for discussion. The topics are:

- Heat pumps for nearly Zero Energy Buildings (nZEB), retrofit and energy flexibility
- Rethink Energy: Community energy supply systems
- Smart communities
- Industrial heat pumps, the next phase
- Future of Air Conditioning
- Ground source heat pumps and thermal energy storage systems
- Heat Pumps and Solar Energy, a win-win combination.

Interesting speakers will introduce the topics. Amongst these are Prof. Stephen Harrison from Queens University in Canada on Solar; Dr. Xiaobing Liu, Principal Investigator at Oak Ridge National Laboratories on Ground Sources; Prof. Carsten Wemhoener from HSR University of Applied Sciences, Rapperswil, Switzerland on nZEB; Antonio Bouza from Department of Energy, USA; and Helmut Strasser from the Salzburg Institute for Regional planning and housing (SIR) on the role of Smart Cities.

12th IEA HEAT PUMP CONFERENCE 2017 | ROTTERDAM

In the plenary opening session on the second day, invited speakers from all continents will give their vision:

- Mr. Jean-François Gagné, head of the Energy Technology Policy Division of the International Energy Agency, leading the strategic design of the Agency's analytical work on energy technologies, policies and strategies to promote innovation, and supporting the IEA international collaborative work on energy technology research and development;
- Mr Michael Taylor from the International Renewable Energy Agency (IRENA) will focus on the 'Act Now' question;
- Prof. Dr. Hans-Martin Henning, head of the Institute for Solar Energy systems ISE at Fraunhofer in Germany. In his presentation entitled 'Pathways to transform the Energy System until 2050', Prof. Henning sketches, from the German Example, Perspectives for Europe and the position of heat pumps as key technology already on short term in the energy infrastructure;
- Prof. Kensuke Fukushi from University of Tokyo. In his presentation 'Stimulating social application of energy efficient technology for climate change mitigation', prof. Fukushi discusses the effect of climate change on technologies needed;
- Dr. Karim Amrane, Ph.D. Senior Vice President, Air-Conditioning, Heating, and Refrigeration Institute (AHRI, USA). Dr. Amrane focuses in his presentation 'Effectively Managing the Transition to Lower GWP Refrigerants' on the importance of the management of refrigerants to reduce leak and service emissions, and the promotion of the recycling, recovery, reclaiming, and end of life destruction of refrigerants.

After the plenary opening session the conference will continue for three days in four parallel tracks of presentations. The final program can be found on the website for the conference *www.hpc2017.org*

Papers
The very successful call for papers has generated more than 250 high quality papers. In four main conference tracks, the conference has the unique opportunity to present topics directly related to the work under the IEA Technology Collaboration Program on Heat Pumping Technologies, in the now eleven running international collaboration projects (annexes) and two new ones under development.

Organization
The conference is organized by the National Organizing Committee (NOC) in collaboration with the International Organizing Committee (IOC). The IOC has as chairman Mr Per Jonasson (Sweden) and two vice chairs, being Mrs Sophie Hosatte (Canada) and Mr Hiroshi Okumura (Japan). The NOC has a chairman, Mr Onno Kleefkens, and vice chair, Ms Marion Bakker.

Heat Pump Centre

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

As for new members, contacts and discussions regarding membership are under way with several countries, including China, South Africa, Mexico and Poland, as well as with the European Union. Chinese observers attended the spring ExCo meeting in South Korea.

During 2016, the HPC has put major efforts in developing a new website, a new database and transforming the HPC Newsletter into the HPT Magazine.

HPC Newsletter/HPT Magazine

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.

During 2016, the newsletter was redesigned to an online magazine. The redesign included a name change from HPC Newsletter to Heat Pumping Technologies Magazine. The HPT Magazine is published on the digital publishing platform *issuu* and linked from the HPT website.

Newsletters/Magazines 2016

The two 2016 newsletters/magazines are available on the Heat Pumping Technologies website. The topics were:

1. Refrigerants
2. Smart Grids - Heat Pumps

* which changed name to RISE Research Institutes of Sweden during March 2017

The magazine is free of charge and also free to read for everyone, regardless of whether the reader lives in an HPT member country or not.

The change from newsletter to magazine also included some minor changes of the content. The information from the annexes is now more result-oriented and the news section has been removed, since it often gave the reader yesterday's news. Instead, the website is now updated with news more frequently.

Two issues were published during the year: HPC Newsletter no 1, 2016 with the topic "Refrigerants", and HPT Magazine no 2, 2016 with the topic "Smart Grids – Heat Pumps". The number of issues, two instead of four as previous years, is due to the resource-demanding work with the update of both newsletter/magazine and the website.

Website

Another activity that HPC has put a lot of effort into during 2016 is the development of a new website. The website has moved from the domain *www.heatpumpcentre.org* to *www.heatpumpingtechnologies.org* to reflect the entire TCP instead of just the HPC. It has also undergone a complete refurbishment: the HPT website now hosts the annexes' websites, is much easier to navigate and has a layout that is more up to date. The database, with over 1300 publications from HPT, has been updated, and because of the new function with an introduction page to every publication, the publications can now be found with a search engine such as Google.

Because of the removal of the News section in the HPT Magazine, HPC has updated the website with news more frequently than before. To reach out even more to different audiences, HPC has started the Twitter account *@HeatPumpingTech* and publishes news in a LinkedIn group. The website is also continuously updated with events, press releases and contact information for the new annexes.

Updates during 2016 include the addition of Final reports and two-page summaries for three finalized annexes (Annexes 37, 39 and 40), as well as three annex executive summaries.

60 seconds

During 2016, 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 those involved in annexes and national teams.

Activity Generation

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

The National Teams’ meeting was held in Nuremberg, Germany, in October, with high attendance. The main focus of the meeting was to generate new activities in the form of annexes and annex ideas, discuss annex proposals but also research needs and trends in the member countries. At the meeting, several annex ideas were discussed, of which two were decided to be taken further: "Long-term performance measurement of GSHP Systems serving commercial and institutional buildings" and "Alternative technologies for space cooling, including free cooling".

Two new annexes were started in 2016: "Industrial Heat Pumps, Second Phase" (Annex 48) and "Design and Integration of Heat Pumps for nZEB" (Annex 49). Two Annexes were approved: "Heat Pumps in Multi-Family Buildings for Space Heating and DHW" (Annex 50) and "Acoustic Signatures of Heat Pumps" (Annex 51). Both annexes will start during early 2017.

Contributions/Support for IEA Publications and Activities

The IEA continues its series of publications Energy Technology Perspectives (ETP). The HPT TCP reviewed and commented on a data set to be used as input data to the simulations for the ETP 2017.

HPC attended a workshop organized by the IEA CERT “Maximising the impact of IEA’s Technology Collaboration Programmes through enhanced cooperation in the Energy Technology Network”, presented the TCP and discussed possible collaboration.

Request for Extension of the Technology Collaboration Programme

During the end of the year the preparation work to submit a request for extension of the Technology Collaboration Programme to IEA CERT during 2017 was initiated, including compiling an end-of-term report and strategy work plan. HPC has assisted the HPT chair with this work , e.g. the organization of a strategy workshop for the ExCo delegates in connection to the fall ExCo meeting.

International Collaboration and Promotion

The HPT TCP and the HPC have good relations with national and international organisations, including EHPA, IIR, ASHRAE, AHRI/AHRTI, and China Energy Conservation Association (CECA).

Examples of interactions during 2016 include participation, by invitation, and presentations at the 2016 China Heat Pump Alliance Annual Conference and the 5th Asia Air Source Heat Pump Forum (both in Beijing, China); participation in a workshop entitled "Finding and crossing Heat Pump Barriers" organized by the European Heat Pump Association (EHPA) and the heat pump panel of the renewable heating and cooling platform; participation at the National Heat Pump Conference organized by the Danish Heat Pump Association (Denmark). The HPC also hosted a one-day visit by a group of Japanese colleagues, in order to discuss further collaboration.

Member Country Reports

Using the template that has been developed, and material received from the countries, member country reports or draft reports have been compiled for seven countries and published on the ExCo team website.

Heat Pump Centre
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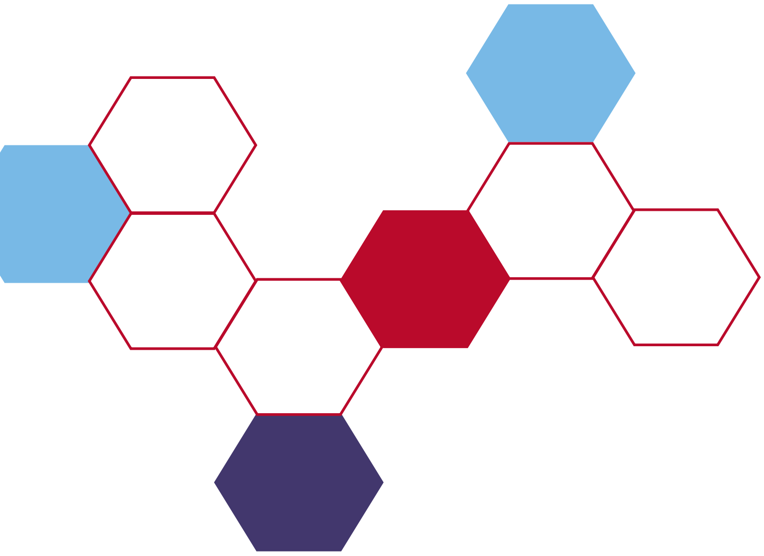
HPT TCP
Research Projects

The projects within the HPT TCP 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.



HPT TCP Annexes

The Technology Collaboration Programme on Heat Pumping Technologies participating countries are: Austria (AT), Belgium (BE), 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).

Bold, red text indicates Operating Agent (Project Leader).

DEMONSTRATION OF FIELD MEASUREMENTS OF HEAT PUMP SYSTEMS IN BUILDINGS	37	CH, **SE**, UK
A COMMON METHOD FOR TESTING AND RATING OF RESIDENTIAL HP AND AC ANNUAL/SEASONAL PERFORMANCE	39	AT, CH, DE, FI, FR, JP, KR, NL, **SE**, US
HEAT PUMP CONCEPTS FOR NEARLY ZERO-ENERGY BUILDINGS	40	CA, **CH**, DE, FI, JP, NL, NO, SE, US
COLD CLIMATE HEAT PUMPS	41	AT, CA, JP, **US**
HEAT PUMPS IN SMART GRIDS	42	AT, CH, DE, DK, FR, KR, **NL**, UK, US
FUEL-DRIVEN SORPTION HEAT PUMPS	43	AT, **DE**, FR, IT, KR, SE, UK, US
PERFORMANCE INDICATORS FOR ENERGY EFFICIENT SUPERMARKET BUILDINGS	44	DK, **NL**, SE
HYBRID HEAT PUMPS	45	CA, DE, FR, **NL**, UK
DOMESTIC HOT WATER HEAT PUMPS	46	CA, CH, FR, JP, **NL**, KR, UK
HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS	47	AT, CH, **DK**, SE, UK
INDUSTRIAL HEAT PUMPS, SECOND PHASE	48	AT, CH, **DE**, FR, JP, UK
DESIGN AND INTEGRATION OF HEAT PUMPS FOR NZEB	49	BE, **CH**, DE, NO, SE, US
HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW	50	AT, **DE**, FR
ACOUSTIC SIGNATURES OF HEAT PUMPS	51	**AT**, FR, SE

FINALIZED 2016

NEW

Publications 2016

Annex 37

- Nordman, R. et al. *Demonstration of Field Measurements of Heat Pump Systems in Buildings – Good Examples with Modern Technology: Executive Summary.*
- Nordman, R. et al. *Demonstration of Field Measurements of Heat Pump Systems in Buildings – Good Examples with Modern Technology: Final Report.*

Annex 39

- Nordman, R. et al. *A Common Method for Testing and Rating of Residential HP and AC Annual/Seasonal Performance: Executive Summary.*
- Nordman, R. et al. *A Common Method for Testing and Rating of Residential HP and AC Annual/Seasonal Performance: Final Report.*

Annex 40

- Wemhoener, C., Schweizer, R., Schwarz., R. *Results of IEA HPT Annex 40 on Heat Pumps in Nearly Zero Energy Buildings*, 12th REHVA Clima World Congress 2016, Aalborg.

Annex 41

- Eslami Nejad, P.; Hakkaki Fard, A.; Aidoun, Z.; Ozzuane, M. *Assessment of Ground-Source, Air-Source, and Hybrid Heat Pumps for a Single Family Building in Cold Climates*. ASHRAE 2016 Summer Conference, St. Louis, MO, USA.
- Ramaraj, S., Braun, J.E., Groll, E.A, and Horton, W.T. *Performance analysis of liquid flooded compression with regeneration for cold climate heat pumps.* International J. Refrigeration, Vol. 68, 50–58, 2016.
- In total there were 7 refereed journal publications and 6 conference proceedings papers published in 2016 related to Annex 41 work.
-

Annex 42

- den Ouden-Berenschot, D. and Friedel, P. *Flex-potentieel hybride warmtepomp* (English: *Flex-potential of hybrid heat pumps*). BDH.

Annex 43

- Fumagalli, M., Sivieri, A., Aprile, M., Motta, M., Zanchi. M. *Monitoring of gas driven absorption heat pumps and comparing energy efficiency on primary energy*. Renewable Energy, Special Issue Sorption heating and cooling, in press.
- Henninger, S.K., Ernsta, S-J., Gordeevab, L., Bendix, P., Fröhlich, D.,Grekova, A.D., Bonaccorsi, L., Aristov, Y., Jaenchen, J. N*ew materials for adsorption heat transformation and storage*. Renewable Energy, Special Issue Sorption heating and cooling, in press.

Annex 44

- van der Sluis, S.M. *Performance indicators for energy efficient supermarket buildings*. IEA - International state of the art in urban energy. Amersfoort, the Netherlands, 2016.

Annex 45

- den Ouden-Berenschot, B. and Friedel, P. *Flex-potentieel hybride warmtepomp* (English: *Flex-potential of hybrid heat pumps*). BDH.
- den Ouden-Berenschot, B. and Friedel, P. *Actor analysis regarding hybrid heat pumps in the Netherlands' in cooperation with IthoDaalderop, Daikin, Inventum, Gasunie and other stakeholders*. BDH.

Meetings 2016

Annex 41

- *January, Orlando, FL, US.* This was the 4th and final working meeting of the Annex participants. Representatives from Japan and the US attended. Austrian and Canadian participants provided progress updates.

Annex 42

- *June, Hochschule Luzern, Switzerland.* Two-day regular project meeting with all participants. Progress was made regarding Tasks 3 (cost of suggested solutions) and 4 (road ahead).
- *October, Utrecht, The Netherlands.* Two-day regular project meeting with all participants. One-day Expert Panel meeting (structured according to the 'Open Space' method) with a variety of stakeholders.

Annex 43

- *June 16-17, Politecnico di Milano, Milano, Italy.* Experts' meeting. First results from the round robin test of a gas driven heat pump were presented.
- *October 23-26, Taormina, Sicily, Italy.* Participation in a conference with support of the annex and strong participation from its members.

Annex 44

- Meetings were conducted as teleconference meetings between the partners from the Netherlands, Sweden and Denmark.

Annex 45

- *March, Electricité de France (EDF), Fontainebleau, France.* Regular two-day project meeting with UK, Germany, The Netherlands and France.
- *September, Department for Business Energy and Industrial Strategy (BEIS; formerly DECC), London, UK.* Regular two-day project meeting with all member participants including Canada as observer participant.

Annex 46

- *February, Amersfoort, the Netherlands.* 1st Working Meeting.
- *June, Jeju Island, South Korea.* Special Working Meeting for the Asian participants and China.
- *September, Belfast, United Kingdom.* 2nd Working Meeting.

Annex 47

- *May, DTI Taastrup, Denmark.* Start-up meeting. Presentation of participants, presentation of the project, discussion of tasks and task leaders.
- *September, Skype-meeting.* Discussion of the content of task 1. Confirmation of participation from the different countries.
- *October, Skype-meeting.* Final agreement of content of task 1. Final confirmation regarding participation.

Annex 48

- *July, Darmstadt, Germany.* Kick-off meeting. Introduction to participants that were not in the previous Industrial annex (Annex 35). The work plan, the time schedule and the activities and meetings were discussed and the results summarized.
- *October, Nuremberg, Germany.* Chillventa CONGRESS. Heat Pumping Technologies for Commercial and Industrial Applications, with 10 presentations.
- *November, Darmstadt, Germany.* Expert meeting. Discussion on changes/wording and definitions in the different tasks. Adjustments of the work plan.

Annex 49

- *October 13-14, Technical University of Nürnberg.* The kick-off meeting was the official start of the IEA HPT Annex 49 and was meant to introduce the participants and respective contributions.

ANNEX 37

DEMONSTRATION OF FIELD MEASUREMENTS OF HEAT PUMP SYSTEMS IN BUILDINGS - GOOD EXAMPLES WITH MODERN TECHNOLOGY

To build confidence in the potential gains that can be achieved by switching to heat pumping technologies for heating and cooling of buildings, it is of outmost importance that the SPF values claimed by manufacturers really prove to be true, since this significantly affects how large cost savings and emissions that can be abated by using heat pumps compared to old technology (boilers). In this annex, we have studied already performed field monitoring projects using a comprehensive system boundary concept. We have also studied upcoming requirements from policy makers, in order to make it clear what could be considered a well working heat pump system. The values we propose for ASHP and GSHP have been found in the field measurements we have studied, but they are still quite demanding to achieve. They are also of the magnitude that when reaching them, cost savings and emissions reductions are quite good, even in countries where the electricity is still produced to a large extent from fossil fuels.

OBJECTIVES

The objective was to demonstrate the potential with heat pumping technology for all types of buildings from existing field measurements.

The focus was on the best available technique in order to achieve further acceptance for heat pumping technology.

ASHP systems can be considered good if they have an SPF value of 2.8–3.2. Corresponding values for GSHP systems are 3.3–3.9.

GOOD EXAMPLES

- Heat pumps can reduce CO_2 emissions. In Sweden and Switzerland, where the carbon content of electricity is low (0.04 kg CO_2/kWh, 2009 figures), using a heat pump resulted in average CO_2 savings of more than 5 tonnes annually as compared to an oil boiler for the evaluated sites. In the UK, the default fuel is gas and the carbon content of electricity is considerably higher (0.49 kg CO_2/kWh). Even so the average saving was still 1.25 tonnes CO_2/year.
- Substantial cost savings can be made with heat pumps, depending on the heat pump efficiency and the relative prices of electricity and alternative fuels. Annual cost savings were the highest in Sweden (which has cheap electricity and expensive oil) and the lowest in the UK (which has expensive electricity and relatively cheap gas).

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April 2011 – April 2016

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ANNEX 39

A COMMON METHOD FOR TESTING AND RATING OF RESIDENTIAL HP AND AC ANNUAL/SEASONAL PERFORMANCE

The Seasonal Performance Factor (SPF) or SCOP is important for a number of reasons: manufacturers use the numbers in marketing, policy makers use them in setting subsidy requirements, and end users rely on them for the correct return on investment. There are numerous methods for calculating the SPF, taking into consideration different national geographic conditions and other special conditions. Local conditions may also affect the performance to quite a large extent. Therefore, it is reasonable that SPF calculation methods for different climates may need to be local.

However, in order to simplify for manufacturers, and make the product cheaper for end users, there may be quite some gains to harmonise the test points for lab test standards, especially since not many test points differ between different national standards. A global harmonisation could define a set of test points to be used, whether it is for testing the heating or cooling mode of heat pumps. This will make it possible to use fewer tests points in order to acquire various national certificates.

In order to better compare heat pumps' benefits with other heating technologies, but also to better understand performance of heat pumps, a number of measures other than the SPF could be used. This would make it possible to understand the improvement potential of heat pumps and heat pump systems.

This annex has set a very sound basis for better understanding of different methods and it has also identified improvement potentials for harmonising lab testing.

> ***Both the end consumers and the market need reliable performance data. Calculation methods to predict performance are therefore essential.***

OBJECTIVES

- Establish common calculation methods for SPF using a generalised and transparent approach. The focus is on a fair comparison between different heat pump types, but also on comparison between different competing technologies, such as pellet boilers and gas boilers.
- Comprehensive test methods based on further development of existing test standards will be evaluated. The test standards should include test conditions needed for future SPF calculations.

GOOD EXAMPLES

Comparisons on how different calculation methods predict the seasonal performance have been performed in the Annex, showing that the calculations almost always underestimate the real performance of the heat pumps, but that they are close to real performance. There is hence a need for further improvement of calculation methods, but conversely it can be said that real performance can quite well be predicted by calculation methods!

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ANNEX

40

HEAT PUMP CONCEPTS FOR NEARLY ZERO-ENERGY BUILDINGS

With the recast of the Energy Performance of Buildings Directive (EPBD) of 2010, the introduction of nearly Zero Energy Buildings (nZEB) as the future target for high performance buildings has started in Europe. The definition of nearly zero energy refers in the main to the annual energy balance, where the energy consumption of the building will be mostly met by renewable energy production on-site on an annual basis. Also in the USA and Japan, nZEB are the strategy for future high performance buildings.

Thus, there is a strong interest in building technology concepts fulfilling the criteria for nZEB from various stakeholders, such as building companies, designers and building equipment manufacturers, as well as from policy makers. Annex 40 has investigated heat pump applications in nearly zero energy buildings across different countries regarding system performance and cost. Concepts have been investigated by simulation and new prototype technologies have been developed in the laboratory and in field monitoring. Field monitoring of already built nZEB confirms the good performance of heat pumps in nZEB as well as some remaining optimisation potential, which even may increase the performance values. Results confirm that heat pumps are a technology well-suited for the specific use in nZEB buildings, contributing to a future, highly efficient and sustainable built environment. These results support the introduction of nZEB and could boost the markets for heat pumps and and promote heat pumps as efficient building technology for the application in nZEB.

> ***Heat pumps are a highly-efficient technology that is well-suited for application in nZEB due to their unique features***

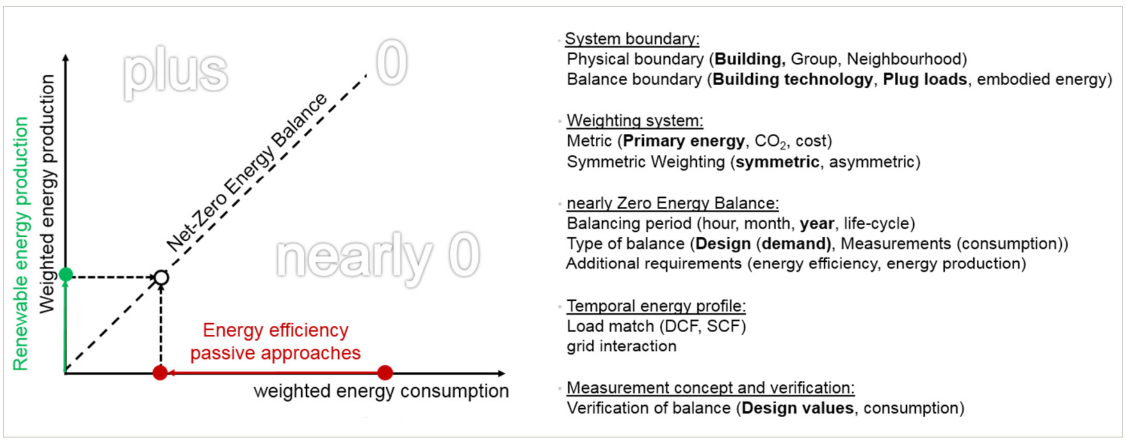

Figure 1. Criteria for the definition of nearly and nearly and net zero energy buildings. The basic principle of nZEB is shown on the left, where both efficiency measures to reduce the needs (red dots) and renewable on-site generation (green dots) contribute to the nearly zero energy balance. Even though the principle seems simple, various criteria have to be defined for the precise definition, as shown on the right (bold words correspond to the most common criteria chosen in present definitions).

OBJECTIVES

The objectives of Annex 40 are:

- Characterisation of the state-of-the-art of realised nZEB and heat pump application in these buildings;
- Assessment and improvement of different building concepts and technology options regarding the performance and cost of heat pump application in nZEB;
- Technology development of new heat pump prototypes suited to fulfil nZEB requirements in lab and field testing;
- Evaluation of results from field monitoring of heat pumps in nZEB regarding performance and optimisation potentials in real operation.

HIGHLIGHTS

- Case studies and technology comparisons of HVAC systems in nZEB across different countries and region in Europe, Canada, and Japan have been performed. The results regarding system performance and cost show that heat pumps are among the most energy-efficient and cost-effective system solutions in this type of buildings. These findings confirm that heat pumps are a key technology for the future.
- Integrated heat pump developments in the USA have led to different ground-source and air-source prototypes, for which simulations and field monitorings have shown that they will reach the DOE targets of 50 % reduced energy consumption for the equipment. The ground-coupled integrated heat pump is already on the market, while the air-source prototype showed an average summer performance above 5 in combined cooling operation and 4.4 in DHW production in field monitoring. Different variants of the air-source prototype will be investigated further in field monitoring.
- Technology developments of an HVAC system in Japan have resulted in a highly efficient VRF technology by decoupling temperature and humidity loads. The system consists of a heat pump desiccant system and a capacity enhanced VRF heat pump. Humidity loads are covered by desiccant technology, while the VRF heat pump can work at higher evaporation temperature and lower pressure differences to cover temperature loads effectively. By using new heat exchanger and compressor developments, the system performance has been increased significantly. Field monitoring results have confirmed a 70 % reduction in energy consumption with improved comfort values compared to a conventional reference system.

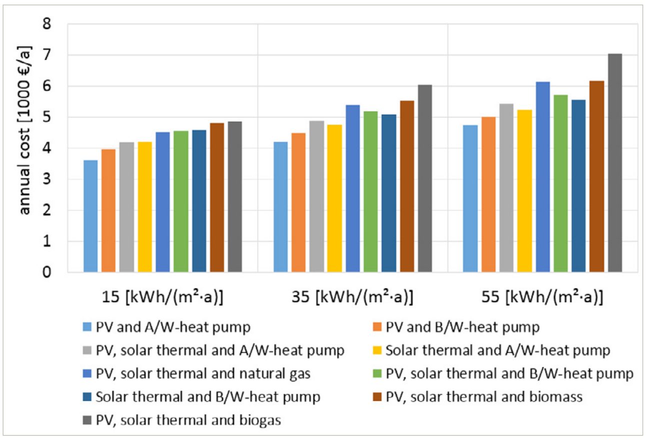

Figure 2. Cost-comparison of different heating systems as case study for a single family nZEB in Switzerland. In the single family buildings with different space heating demands heat pumps are the most cost-effective building technology regarding 20-year life-cycle cost. Also in multi-family building and office application, heat pumps are among the best systems with respect to performance and life-cycle cost.

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July 2012 – August 2016

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ANNEX 41

COLD CLIMATE HEAT PUMPS
Improving Low Ambient Temperature Performance of Air-Source Heat Pumps

> ***Analyses and experimental work by the annex 41 parties have shown the technical feasibility for ASHPs to achieve heating seasonal COPs in cold locations well in excess of the 2.63 target.***

Annex 41 aims to identify and evaluate technology solutions to improve performance of heat pumps for cold climate locations. Its primary focus is on electrically driven air-source heat pumps (ASHP) but novel ground-source heat pump (GSHP) and solar assisted heat pump (SAHP) approaches are being investigated as well. The main near-term outcome of this annex is information-sharing for use by designers/manufacturers to develop ASHPs with much better cold climate performance. In the longer term, availability of ASHPs with better low-temperature heating performance should help bring about a much stronger heat pump market presence in cold climates (loosely defined as having a significant number of hours with ambient temperatures <-7 °C). Such areas today rely predominantly on fossil fuel heating systems or, where natural gas is not readily available, on conventional electric ASHPs or even electric resistance heating systems.

Electric ASHPs generally have the lowest installation cost of all heat pump alternatives, but also the greatest performance challenges at cold outdoor temperatures. One of these is loss of heating capacity. Traditional ASHPs lose 80 % of their heating capacity at outdoor temperatures of -25 °C compared to the rated performance at 8.3 °C. This means that traditional ASHPs must use low-efficiency backup heat at lower temperatures, as noted in Figure 1. The other major issue is the loss of capacity due to frosting and defrosting of the outdoor heat exchanger (OHX) at moderate outdoor temperatures between about -5 °C to 5 °C (noted in Figure 1).

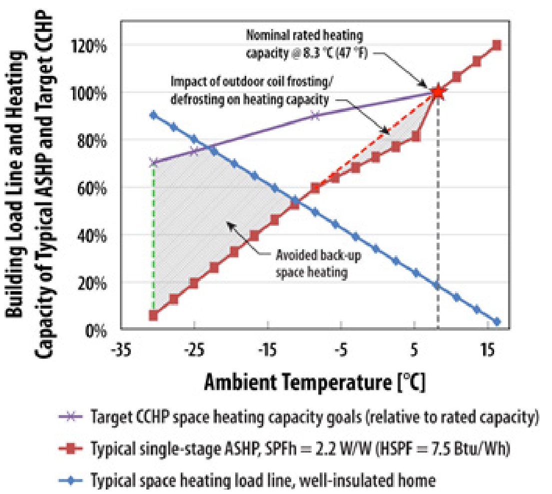

Figure 1. Space heating capacity for target CCHP vs. typical single-stage ASHP.

Annex members have focused on two primary areas to address the cold climate performance problems noted above. First, advanced Cold Climate Heat Pumps (CCHPs) with low-temperature capacity-enhancement approaches have been developed. Second, detailed investigations on OHX frosting have been conducted.

OBJECTIVES

» General: produce/share technical data/results for use by designers & manufacturers in producing ASHPs with significantly improved cold climate heating performance, achieved through technical publications and annex presentation materials.

» Achieve ASHP solutions with heating capacity at -25 °C that is ≥75 % of nominal rated capacity at 8.3 °C; several advanced prototypes have been developed, including some on the market.

» Prototype cold climate ASHPs “in field” measured heating SPF > 2.63 W/W; achieved.

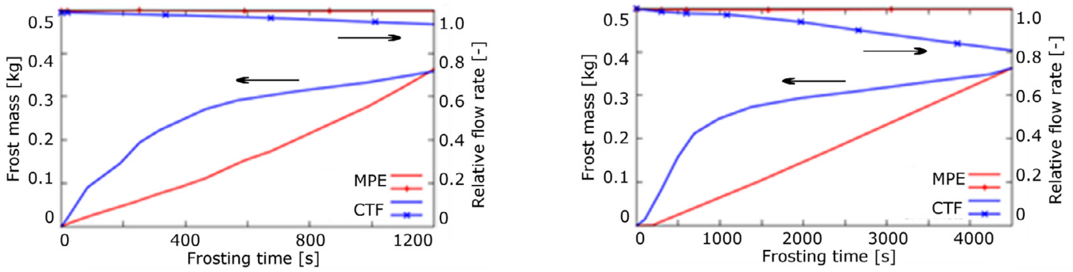

Figure 2. Frost mass growth and relative flow rate for advanced (MPE) and standard (CTF) heat exchanger configurations, at ambient temperatures 10 °C (left) and -25 °C (right).

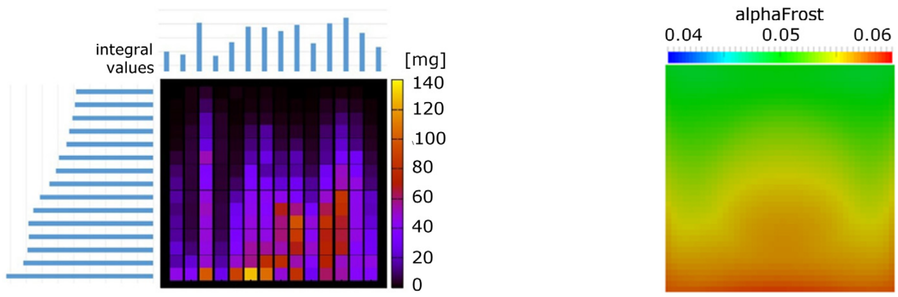

Figure 3. Measured (left) vs. predicted (right) frost distribution on MPE evaporator from CCHP system tests.

PROGRESS

- The research activities of the Austrian Institute of Technology (AIT) team were focused on the investigation of evaporator frosting in cold climates. Wind tunnel tests determined that advanced compact multi-port extrusion (MPE) heat exchangers have better frosting characteristics than conventional tube-and-fin (CTF) heat exchangers. This can be seen in Figure 2, which depicts evaporator frost accumulation vs. time, and the resulting reduction of air flow through the evaporator (relative to the maximum flow rate). The MPE evaporator has been included in research toward developing an innovative CCHP system prototype. Shown in Figure 3 is a comparison of measured frost distribution (left side) to simulated frost distribution (right side) resulting from the refrigerant temperature variation inside the evaporator. The view is looking from above onto the horizontally mounted heat-exchanger. The heat exchanger fluid enters from the bottom of the figure. The blue bars indicate horizontal sums and vertical sums. The horizontal bars to the left show that frost builds up predominantly at the refrigerant entrance while the vertical bars indicate the extent of refrigerant fluid maldistribution. The simulation results on the right-hand side of Figure 3 are are based on the boundary conditions extracted from the experiments shown on the left-hand-side.
- A number of ASHP products with improved cold climate performance have been introduced to the market by Japanese and US manufacturers (Mitsubishi Electric, Toshiba, Hitachi, Daikin, and others). They employ a number of heat pump cycle innovations including variable speed compressor technology, vapor injected compressors, liquid injected compressors, etc. Rated performance characteristics show the capability to maintain heating capacity at 70 % to 90 % of rated capacity down to -20 °C to -25 °C outdoor temperatures. Most meet the requirements of recently released cold climate heat pump specifications by the U.S. Northeast Energy Efficiency Partnership (NEEP).

Van Baxter

Project duration:
July 2012 – June 2017

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ANNEX

42

HEAT PUMPS IN SMART GRIDS

Smart heat pumps offer a unique bridge between power and heating, by converting renewable power to heat.

Heat pumps offer a grid management potential with huge possibilities for interaction with novel technologies, such as solar PV and electric vehicles.

In our modern energy system, flexibility and smartness in the electric power grid is essential for sustainability. Here, flexibility means the degree to which producers, consumers and prosumers are able to react to the fluctuating supply on the electricity market. Particularly, if electricity from intermittent sustainable sources continues to increase, the demand will have to be geared to the supply, in some way.

Heat pumps are important components of a smart grid. They are perfect for demand management in smart grids, since they convert electrical energy into thermal energy. By combining heat pumps with thermal storage, the heat pump can be applied as a regulatory instrument. In addition, they are flexible in the sense that they can start up relatively quickly.

However, if heat pumps are installed on a large scale in existing buildings, there is a potential grid load peak that needs to be managed, especially in countries that rely on natural gas as the sole energy carrier. Furthermore, these heat pumps have to be managed in a smart way, since they otherwise have a large simultaneity factor: when it is cold, they all switch on at the same time.

Although smart-grid pilot projects and studies have demonstrated the advantage of smart-driven heat pumps, commercially available heat pumps are not provided with communication as a standard. Neither can the grid communicate with heat pumps. The Internet of Things is rapidly becoming the solution expected to bridge this dilemma, enabling smart heat pumps to interact with a standard grid.

The approach of this annex is to have each participating country consider some key questions, and then compile and discuss the answers. Key questions include the size and urgency of the country's grid problem, possible scenarios including heat pumps to solve these problems, the cost for each of these solutions, and conclusions regarding the road ahead.

The results from this annex will make it easier to plan and implement smart grids, drawing on the advantages of heat pumps. In this way, the advantages of smart grids will be optimized: balance in the energy system, decreased energy use and greenhouse gas emissions.

OBJECTIVES

The objectives of this annex are to:

- gather information for governmental and non-governmental policy makers and decision makers on energy systems in urban areas concerning the possibilities and barriers related to the implementation of heat pumps in smart grids;
- develop strategic information for the heat pump industry, including its supply and consulting chain.

Further, in the long run, to contribute to the implementation of smart grids, for:

- balance between supply and demand in the energy system;
- reductions in energy use;
- reductions in emissions of greenhouse gases.

RESULTS

The business model behind heat pumps in smart grids was assumed to be in flexible tariffs, which would tempt users to adjust the on/off switching of their heat pump device. One of the results from Annex 42 was that flexible tariffs may not be as effective as was anticipated, since they have limited potential to influence the end user.

The generally accepted perception in 2012 of a smart managed grid that rules and serves 'dumb' heat pumps has proven to be outdated in just four years' time. On the other hand, smart heat pumps, with their flexibility and versatility (based on the Internet of Things) aggregated by a totally new type of companies, will form an entirely new perspective on the start-up of 'heat pumps in smart grids'. This is a potentially strong instrument for managing 'smart cities'.

Figure 1. Integral approach of energy in smart grids

Project duration:
May 2013 – April 2017

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ANNEX 43

FUEL-DRIVEN SORPTION HEAT PUMPS

The heat pump market is dominated by electrically driven compression technology. After a period of stagnation, thermally driven sorption technology was “rediscovered” at the end of the 20th century, mainly for thermally driven cooling. In recent years, gas fired sorption heat pumps have been identified as an efficient solution for space heating and sanitary hot water preparation, mainly in existing buildings. Consequently, a number of products have already entered the market. They are seen as a complementary technology to electrically driven heat pumps with a potential to reduce the requirements on the electric grid and to balance the overall energy consumption in the future energy mix by using different sources (e.g., biogas, power-to-gas) and existing infrastructure. The technology is efficient, especially as retrofit in existing buildings, and is often seen as the next generation of efficient condensing gas boilers with a significant usage of renewable energy. This annex has the aim to support the technology at this early stage through cooperation between experts from industry and academia.

As the end user on the demand side, city councils and housing corporations owning large housing estates are important target groups. On the supply side, heat pump manufacturers, power companies, technical consultants as well as planners/installers will be addressed. Furthermore, political decision makers are of interest since governments set the boundary conditions for future development for a carbon emission-free society.

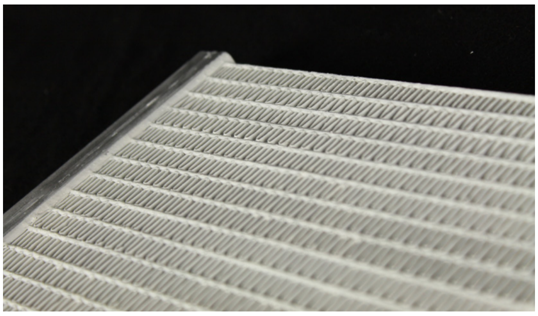

Figure 1. Heat exchangers coated with sorption materials improve heat and mass transfer and lead to significant improved power densities and thus smaller appliances and reduced costs.

> ***Annex 43 supports fuel driven heat pumps on their way to larger market shares by identifying most promising solutions and by generating trust in this technology with best examples.***

The annex has produced a state of the art report on fuel driven heat pumps, and cooperates on projects to develop new technologies such as adsorbers using new composite materials, e.g., coated metal fibers, to increase power density (Figure 1). Further, the annex is developing recommendations for lab-based performance measurement standards (Figure 2). Finally, best case examples will be compared to these results and used to generate trust in this technology (Figure 3).

OBJECTIVES

- Widen the market acceptance of fuel driven heat pumps, increasing the market awareness for this technology;
- identify market barriers and opportunities to allow smooth and sustainable market entrance and deployment of the technology;
- quantify the economic, environmental and energy performance of integrated fuel driven sorption heat pumps in heating systems in a range of climates, countries and building standards;

Figure 2. Different standards for performance evaluation of gas driven heat pumps are compared in a round robin test between several labs.

Figure 3. Gas driven heat pumps are tested with different climates and building types to find optimal configurations and system layouts.

- identify the most suited system layouts and which type of fuel driven heat pump fits best to a specific building type or climate;
- propose technical procedures to be included in future standards for determination of the performance of fuel driven heat pumps and methods to evaluate primary energy consumption of the systems within this annex.

PROGRESS

The annex has made significant efforts to increase the awareness of fuel driven heat pumps, organizing several national workshops for installers and planners as well as organizing a large international conference about sorption heat pumps with more than a hundred attendees from science and industry. The best papers from this conference are published in a special issue "Sorption systems for energy efficient heating and cooling" of the renowned journal "Renewable Energy".

A second highlight is the round robin test of a hybrid sorption heat pump among four partners of the annex, comparing the performance results among the labs as well as comparing two different performance evaluation methods (VDI 4650-2 and CEN 12309) and setting up recommendations for the normative bodies.

Additionally, the cooperation between the members of the annex have led to several joint papers in reviewed journals and increased the knowledge transfer for new developments from research to industry, both new materials and new component developments.

Project duration:
October 2013 – November 2017

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Further information:
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ANNEX 44

PERFORMANCE INDICATORS FOR ENERGY EFFICIENT SUPERMARKET BUILDINGS

In our "information society" there is an abundance of data, but this data remains meaningless if it is not transformed into knowledge. You may have collected fuel station bills for years and years, but as long as you don't know the car's mileage you have no knowledge about the car's fuel efficiency. And even then, only you would know if this efficiency mostly reflected urban driving or long distance fuel efficiency.

The same is true in a supermarket environment. There is a clear trend for more and more monitoring systems to be installed in supermarkets, measuring, for example, temperature (typically to secure and validate food quality) and other relevant data. Measurements are taken and stored, and overall energy consumption data is available, but in many cases there is still no knowledge about the supermarket's energy efficiency compared to other supermarkets in the same chain, or to competing supermarkets.

Performance indicators are needed to transform available data into knowledge about the energy efficiency of a supermarket building. Such indicators, for example, are the size of the supermarket, the opening hours, the outdoor climate, etc. In this annex, performance indicators will be defined that will allow evaluation of the energy efficiency of existing single supermarkets, supermarkets within one chain, supermarkets across different chains and even supermarkets in different regions or countries. Within a chain of supermarkets, it then becomes possible to identify the "weakest links in the chain" from an energy efficiency viewpoint, and investments in energy efficiency can be directed towards these (Figure 1).

> ***Non-conventional parameters, such as motivation of personnel and system dynamics, may play a significant role in energy efficiency.***

The work in the annex relies on measured data from the field, and not very much on theoretical and/or computer models. The results are intended for practical use in the field, and should be useful even when only a small number of performance indicators are known. Nevertheless, when more performance indicators are known, the resulting evaluation will of course be more precise.

OBJECTIVES

- To create key performance indicators for energy efficient supermarket buildings, so that measurements and monitored data

Figure 1. When the objectives of this annex have ben fulfilled, it will become possible to identify the "weakest links in the chain" within a chain of supermarkets, from an energy efficiency viewpoint. Investments in energy efficiency can then be directed towards these weak links.

can be converted into knowledge about the energy performance of supermarket buildings;

- to create knowledge about the energy efficiency of supermarket buildings from measurements and monitored data, which is useful for decision making, benchmarking and development of energy efficiency strategies for supermarket buildings.

Supermarkets, and the supermarket sector, are the main target for the annex. However, the methodology created in this annex, when modified accordingly, may also be applied to other food retail establishments (e.g. hypermarkets).

PROGRESS

- Energy consumption data (for both electricity and gas) has been collected for 150 Dutch supermarkets for the years 2013 and 2014. This data contains a considerable amount of detail regarding performance indicators, such as supermarket area and the amount of refrigerating equipment, as well as the presence or absence of some 70 energy saving options.
- The supermarket sales area is the most relevant performance indicator for electrical energy consumption. The associated average energy intensity is 407 kWh/m² per year for the Dutch data (Figure 2). The conventional technical performance indicators (such as size, opening hours and energy saving options) are not sufficient by themselves to give a complete view of the energy efficiency; non-conventional parameters such as motivation of personnel and system dynamics may play a significant role in energy efficiency.
- Management policy can have an effect on energy efficiency. A choice to focus refurbishment and construction on the largest supermarkets in a chain, with an emphasis on energy efficiency, was clearly visible in the resulting data set (Figure 3), with an average energy intensity of 430 kWh/m² per year for existing shops and 364 kWh/m² per year for new and refurbished shops.

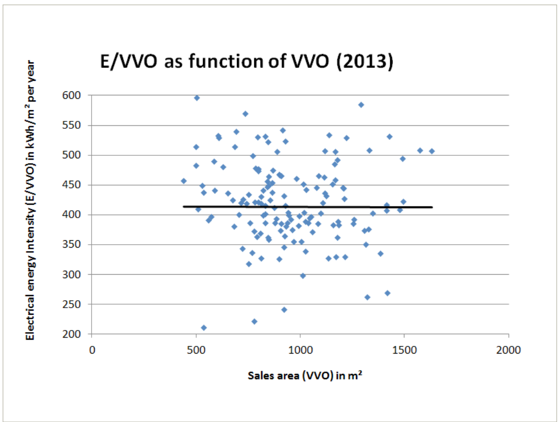

Figure 2. Electrical energy intensity versus sales area for 2013, with regression line.

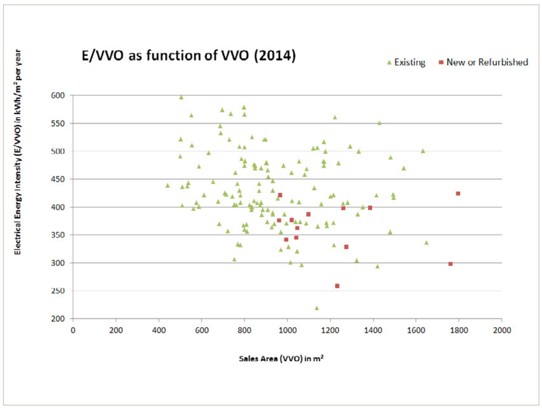

Figure 3. Electrical energy intensity versus sales area for 2014, highlighting the new and refurbished supermarkets against the existing ones.

Project duration:
July 2013 – June 2017

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ANNEX

45

HYBRID HEAT PUMPS
Heat Pump and Fossil Fired Boiler as Hybrid Heat Pumps

Boiler replacement markets are the most important markets for heating and domestic hot water production in residential housing in Europe, since the technical lifespan of heating devices runs up to 15-20 years. Due to insulation measures when retrofitting buildings, a decrease in the heating supply temperature is possible. This makes such buildings interesting for an efficient implementation of heat pump technology for a substantial part of the heating season, since heat pumps function optimally at low supply temperatures. In this context, heat pump and gas boiler hybrid systems can, beside solar thermal and PV, introduce and quickly increase the usage of renewable energy in strongly conservative markets. An example of how the penetration of heat pumps, including hybrid heat pumps, may develop in a country such as the Netherlands is shown in Figure 1.

Accordingly, this offers a chance for more rapid CO_2 emission reductions, for instance by 'hybridizing' existing installations by adding a heat pump to an existing boiler. This can help

The potential for congestion management by means of hybrid heat pumps is in principle available whenever grid load reaches its maximum value.

open up hidden opportunities for a far more significant usage of renewable energy in the short term. As a result of this 'hybridizing', there is currently a need for action on issues such as testing standards, definition of quality requirements, system configurations and control strategies.

The annex will give a perspective on the possibilities for implementation of hybrid heat pumps in potential markets. It will focus on combinations between the (electrical or gas driven) heat pump and fossil fuel driven boilers (oil or gas) in the residential and light commercial sectors, packaged in a configuration or as an integral unit.

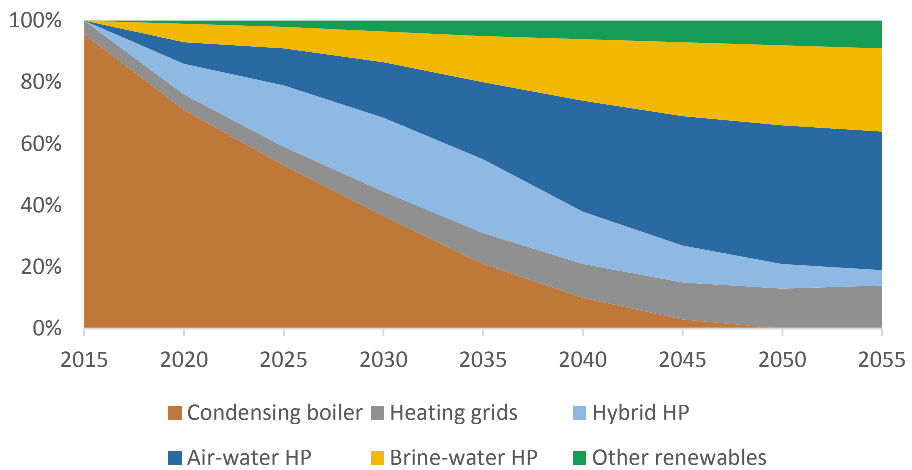

Figure 1. Spread of technologies - Annual numbers installed. Development scenario for heating devices in the Netherlands.

OBJECTIVES

The main objective of this annex is to investigate the potential of emission reductions of greenhouse gases by the increased implementation of hybrid heat pumps, both through replacement of boilers by hybrid systems, and by means of upgrading the systems' efficiency in existing running installations. This objective will be achieved by:

- market overview and system classification;
- identification of market barriers and opportunities to allow sustainable market development;
- quantification of economic, environmental and energy performance of hybrid heat pumps in heating systems in a range of climates, countries and building types and building standards;
- identification of best practice cases in various applications.

RESULTS

One of the first results obtained was the matrix assembled by Fraunhofer ISE (see Figure 2, data for Germany) which sheds light on the switching point for hybrid heat pumps when optimizing for low primary energy use, greenhouse gas emissions, or costs.

At each moment, the hybrid system must make a choice whether to use the heat pump part or the boiler part to supply the necessary heat. Several operating strategies can be chosen. A simple strategy may, for instance, be to always use the subsystem with the lowest marginal operating cost. The COP of the heat pump part drops (and the cost per kWh heat production rises) as the outside temperature gets lower, and ultimately a temperature level is reached below which running the boiler part is cheaper than running the heat pump part.

Depending on the choice of operating strategy, the switching point occurs at a certain heat pump COP. This COP is directly determined by the outside temperature. Above the switching temperature, the heat pump part will be supplying heat, below the switching temperature, the boiler part will be supplying heat.

In the figure below, the switching point is shown in relation to the temperature distribution, giving direct visual insight into the contribution of the boiler and heat pump part. One of the annex' main output goals is a comparison of hybrid systems' suitability using this type of graphs.

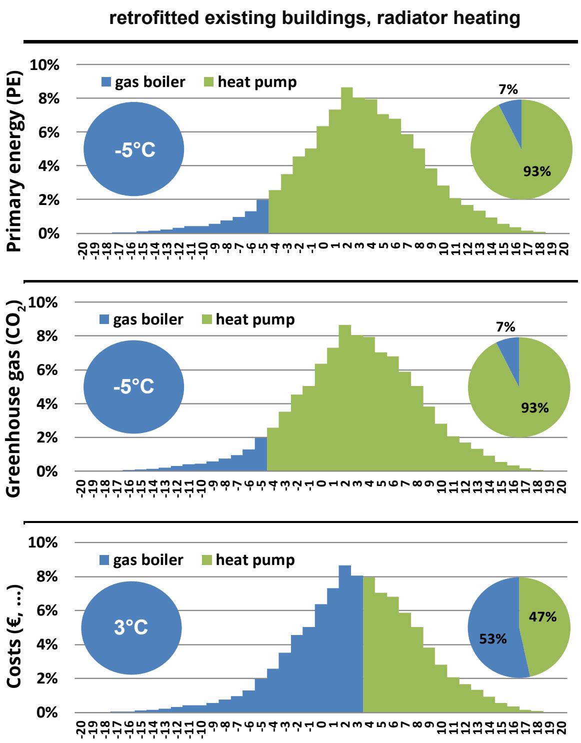

Figure 2. Switching points for hybrid heat pumps for three different control strategies.

Project duration:
September 2015 – July 2018

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ANNEX 46

DOMESTIC HOT WATER HEAT PUMPS

Heat pump markets and the policy in many countries have focused mainly on residential heat pumps for space heating, resulting in standardized products and installations. This is not the case for Domestic Hot Water: there is still a large potential for energy optimization and thus reduction of CO_2 emissions.

Domestic Hot Water Heat Pumps (DHW HPs) deliver hot water only, for bath, shower and kitchen. Driven by the market for electric water heater replacements and boiler upgrades, the use of DHW HPs is growing strongly and a doubling of the European market is predicted by 2017. The same market trends can be seen in the US, Canada, Japan and China.

Other interesting applications are the replacement of collective DHW systems in apartment blocks and multifamily buildings by individual DHW HPs (Europe), combination with air-conditioning systems, where the condenser heat is used for water heating (US, Asia, Southern Europe), and combination with solar thermal systems in nZEB.

Due to strict legislation on energy performance, inherently better insulation, and higher comfort demands (e.g. rain-shower shower heads) from the end user, DHW is going to dominate the overall energy use in houses.

An efficient DHW system is based on a high performance heat pump. However, the overall system efficiency depends on more than the efficiency of the heat generator alone, and energy policy is concerned with the complete chain from primary (fossil) energy to the end user. The benefits of a highly efficient generation device can be nullified by poor system integration and large storage or distribution losses. Overall efficiency is a crucial point in the development of an energy neutral society with a smart energy infrastructure.

"Great opportunities for Domestic Hot Water Heat Pumps: sustainable DHW production will become more and more important"

This annex is being carried through by developing and sharing knowledge on performance optimization, high-efficiency construction and proper implementation of this specific type of heat pump.

The main actors targeted in the annex are heat pump manufacturers, consultants, housing corporations, installers and building companies committed to the technical concept and design of equipment for high performance buildings.

OBJECTIVES

The main objective is to provide deeper insight into the possibilities for implementation and potential reduction of CO_2 emissions and energy costs using various DHW heat pump concepts and systems for new as well as existing buildings. This will be achieved by:

» Reviewing system concepts and available DHW heat pumps;
» Gaining deeper insight into the use of DHW to create a solid basis for test and standardization procedures;
» Developing and validating a model for objective comparison of DHW heat pumping technologies and systems;
» Databasing with showcases for concepts and monitoring results;
» Creating a web-based information platform to serve participating countries by publishing information on their market approach and training courses;
» An overview of R&D on DHW heat pumps, along with the R&D still missing.

OVERVIEW OF TASKS

Task 1: Market overview, barriers for application

Combined country reports about the market situation, future expectations and specific DHW issues per country.

Task 2: Systems and concepts in comparison to alternatives

Overview of systems and concepts: what combinations of technologies are feasible in combination with DHW heat pumps? Where are these located in the energy infrastructure, at the building level or regional level?

Task 3: Modelling calculation and economic models

Finding or creating a model to calculate and compare system efficiencies in an objective way.

Task 4: R&D

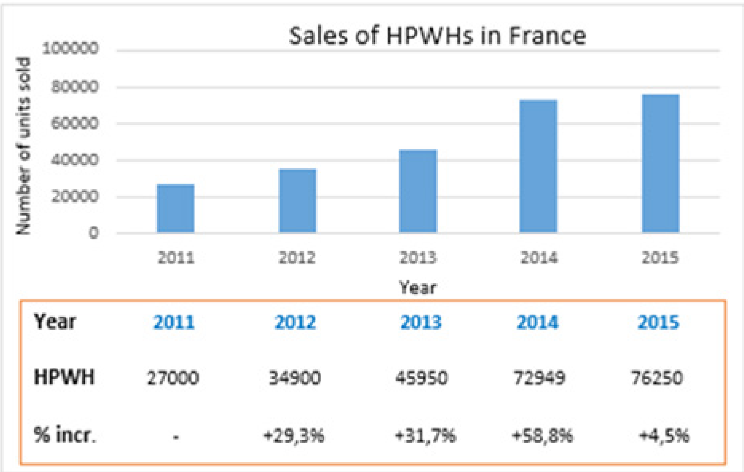
Overview of running projects and R&D still missing.

Task 5: Example projects and monitoring

Database with showcases and monitoring results of existing projects.

Task 6: Communication and training

Production of a reference guide with available



Year	2011	2012	2013	2014	2015
HPWH	27000	34900	45950	72949	76250
% incr.	-	+29,3%	+31,7%	+58,8%	+4,5%

Figure 1. Sales of DHW Heat Pumps in France.

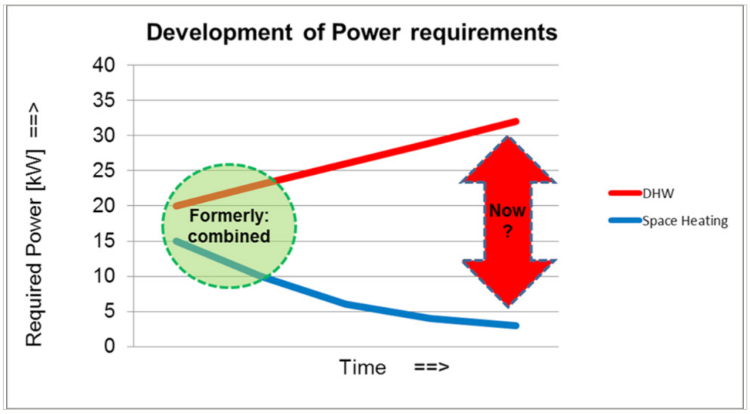


Figure 2. Trends in direct capacity demands of DHW and space heating.

Project duration:
January 2016 – April 2019

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ANNEX
47

HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS

> ***Interesting annex with large perspectives, and fine synergy with the IEA DHC TCP***

All over the world, the energy system needs to be decarbonised. As an example, the European Council has set the objective for the EU to decarbonise its energy system by 2050 to at least 80 % below the 1990 level.

Decarbonising heating and cooling of buildings requires that the use of energy becomes more efficient on both the demand and the supply side. District Heating can capture excess heat which is currently wasted, and replace the natural gas for heating in cities. Heat savings can reduce the total heat demand in Europe by 30-50 %.

District Heating will grow in the future as heating supply in the cities, and is expected to increase from today's level of 10 % to 50 % by 2050.

Heat pumps is a technology which is expanding in district heating systems at the moment as more district heating systems are making use of excess heat and renewable energy as sources. Another reason why heat pumping technologies are interesting in combination with district heating and cooling systems is that low temperature district heating, the so-called 4th generation district heating, is being implemented at the moment, and heat pumps then will be necessary for the production of Domestic Hot Water.

The goal of this annex is to show how heat pumps can be implemented in both old and new district heating systems, but also in different sizes of district heating systems, and with different sources.

OBJECTIVES

The objective of this annex is to gather information and ideas for policy makers, decision makers and planners of energy systems in urban areas concerning the possibilities and barriers related to the implementation of heat pumps in DHC systems.

One objective will be to suggest how heat pumps can be implemented in both new and old district heating systems in the best way. The different types of integration will be described. The differences and possibilities in integration in both central and local systems will be described.

The possibilities of increasing a larger share of renewable energy or using excess heat in the different systems by using heat pumps will be a focus area. Minimizing the system losses by using heat pumps will also be an objective.

Existing projects where heat pumps are integrated in district heating systems will be described and evaluated for each participating country. Further, the market potential and economic opportunities will be evaluated and described for each participating country.

OVERVIEW OF TASKS

Task 1: Market and energy reduction potential

The primary objective is that each participating country draws an overview of the market potential for heat pumps district heating and district cooling and describes the potential for implementing heat pumps in these thermal grids.

Task 2: Description of existing DHC systems and demonstration and R&D projects with Heat Pumps

Here, existing DHC systems and demonstration projects are presented, where heat pumps are used for heating or cooling in DHC systems described on a country basis. The projects will be described and presented as an idea and inspiration catalogue.

Task 3: Review of the different concepts/solutions

Based on the work done in task 1 and 2, the different concepts will be described. The concepts will be divided between central and decentralized systems, and between options for existing DHC grids and options for new DHC grids.

Task 4: Market and energy reduction potential

Description of typical barriers regarding implementation. Different business models for different systems.

Task 5: Dissemination

Summary report of the project. Presentations at workshops and conferences.

Project duration:
January 2016 – June 2018

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ANNEX

48

INDUSTRIAL HEAT PUMPS, SECOND PHASE

Securing a reliable, economic and sustainable energy supply as well as environmental and climate protection are significant global challenges of the 21st century. Using renewable energy and improving energy efficiency are the most important steps to achieve these goals of energy policy. While impressive efficiency gains have already been achieved in the past two decades, energy use and CO_2 emissions in manufacturing industries could be reduced further, if best available technologies were to be applied worldwide. In the previously completed Annex 35 “Application of Industrial Heat Pumps” a total of 39 examples of R & D projects and 115 case studies were collected.

The results show the successful integration of heat pumps in the industry and how to overcome barriers: short payback periods are possible (less than 2 years), high reduction of CO_2 emissions (in some cases more than 50 %), and temperatures higher than 100 °C are possible. Supply temperatures below 100 °C are standard.

Based on these results, collected information, and experiences, the main goal of the Annex 48 is to overcome difficulties and barriers for the market introduction of industrial heat pumps.

> ***Overcome still existing difficulties and barriers for the larger scale market introduction of industrial heat pumps***

The collected case studies of industrial branches with a large potential will be analysed and elaborated for a clear understanding of the benefit and advantage of the application. This will be shown in a simple table form. The goal is to develop a web-based information platform for heat pumps in industrial and commercial applications. Interested users should have the possibility to find their application with meaningful data of existing case studies from global sources.

We will arrange the information on heat pumping technologies for industry, for policymakers, industrial planners and designers, stake holders as well as heat pump manufacturers in a way that will lead to a better understanding of the opportunities. It will also lead to the use of this information for the reduction of primary energy consumption, CO_2 emissions, and energy costs of industrial processes.

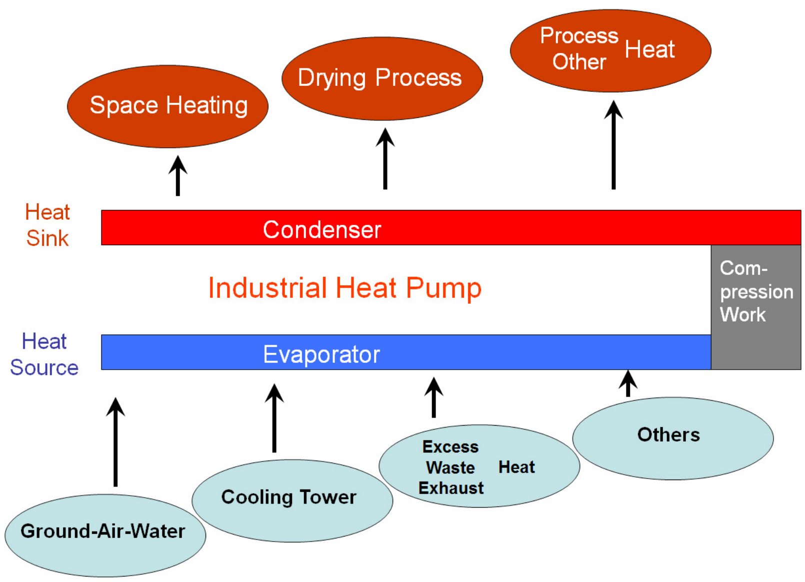

Figure 1. Possible heat sources and heat sinks for industrial heat pumps.

OBJECTIVES

The annex defines Industrial Heat Pumps (IHP) as heat pumps in the medium and high power range and temperatures up to 200 °C which can be used for heat recovery and heat upgrading in industrial processes, but also for heating, cooling and air-conditioning in commercial and industrial buildings. The objectives of the annex are:

» Development of a framework which structures information on IHP applications, using existing and new case studies. Best available technologies and best practices should be selected based on the matrix (sorted by type of installation, of technology and system).
» Creating information material for IHP training courses.
» The material describing the IHP potential for more efficient use of energy and reduction of greenhouse gas emission should be accessible for policy makers.

OVERVIEW OF TASKS

Task 1: Analysis of Case Studies

» Selecting excellent application opportunities and approved examples.
» Selecting a limited number of industries with large potential, focused on special areas with high product quality.

Task 2: Structuring information on industrial heat pumps and preparation of guidelines

» Developing a heat pump data base to be used for the structuring of information of task 1 for each industry, with best available technologies.

Task 3: Application of existing models

» Evaluate and describe the existing models for a consistent integration of a heat pump into an industrial or commercial process.

Task 4: Communication

» Arrange the information on heat pumping technologies for the industry, for policymakers, industrial planners and designers, stakeholders and users as well as heat pump manufacturers.
» Create information material, guidelines and tools for IHP training sessions.
» Provide a better understanding of the opportunities for the reduction of primary energy consumption, CO_2 emissions and improved economy of industrial processes.
» Develop marketing and communication instruments and potentially support and advise on legislative issues.

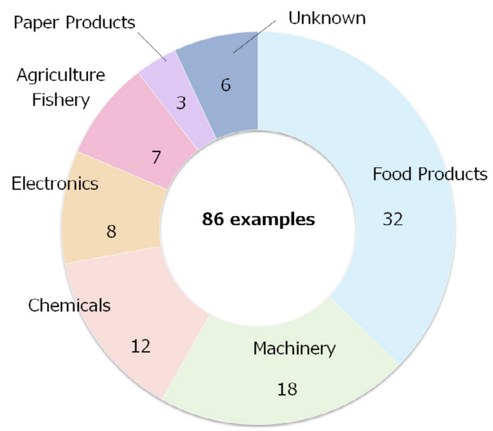

Figure 2. Japanese applications of Heat Pumps in different industries.

Project duration:
April 2016 – April 2019

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ANNEX 49

DESIGN AND INTEGRATION OF HEAT PUMPS FOR nZEB

Nearly Zero Energy Buildings (nZEB) are to be introduced by the beginning of 2019 for all new public buildings and, by the beginning of 2021, for all new buildings in Europe. Heat pumps are already a wide-spread technology in built nZEB due to their high performance, which is attained in efficient buildings with low supply temperature requirements.

However, many of the currently realized buildings are showcase and demonstration projects, and cost-effective nZEB still remain a challenge. Building companies and designers will have to fulfil new requirements for reaching a nearly zero energy balance according to the national definitions in the EU member countries. Building system manufacturers will have to provide highly efficient and adapted equipment. Besides performance and cost, the energy flexibility may also become an important criterion in the future, in order to integrate nZEB in the connected energy infrastructure and to operate renewable energy systems for on-site generation more economically. Flexibility and demand response capability are linked to the enhanced control of the building technology.

> ***Heat pumps are the key technology for the realization of cost-effective and energy flexible nZEB as the future standard for a sustainable built environment.***

Annex 49 will therefore investigate the design and integration of heat pumps with other building technology, such as renewable energy systems in the building envelope, ground and other heat sources, and thermal and electric storage systems. The work is carried out by simulating the system integration as well as by developing new technologies and the field monitoring of new and existing heat pump systems for different building uses in nZEB. Investigations will also be extended to groups of buildings connected by thermal or electrical micro-grids and smart neighbourhoods.

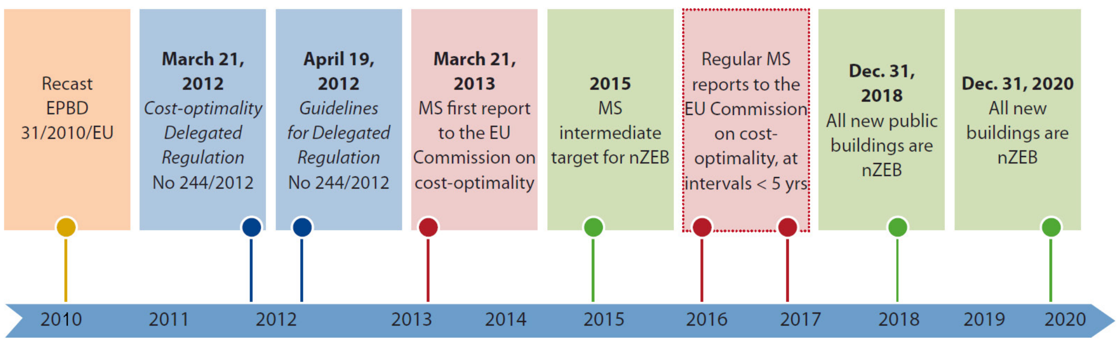

Figure 1. Timetable for the introduction of nZEB according to the EPBD recast of 2010.

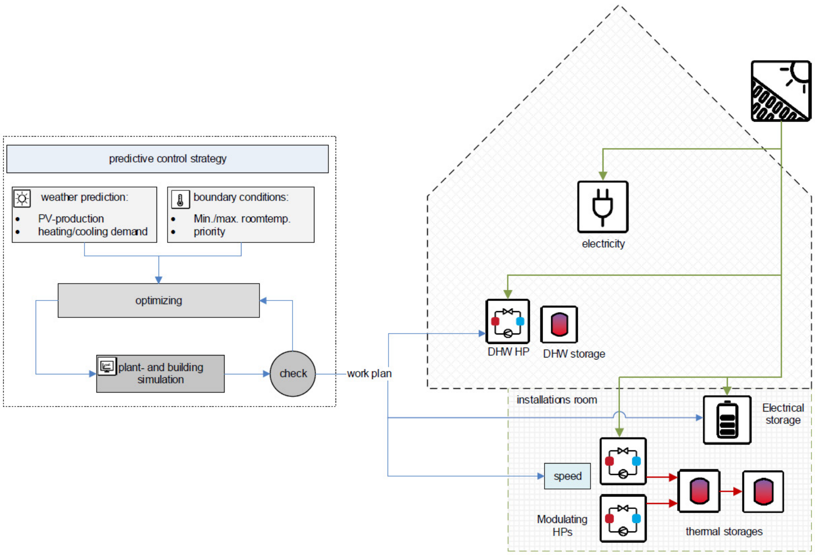

Figure 2. Building technology and control concept of project Herzo-Base as one German contribution to Annex 49.

OBJECTIVES

- » Evaluate and compare definitions of nZEB across the participating countries regarding the impact on building technologies with heat pumps.
- » Evaluate the design of heat pump systems for different applications in residential or office buildings regarding performance, cost and demand response.
- » Refine integration options for building technology with heat pumps in terms of multi-functional operation and the needs of integrated systems.
- » Field monitoring of buildings across different participating countries and evaluation of different concepts and technologies under different climate and market conditions.
- » Derive recommendations for integrated heat pump systems as well as heat pump design and control in single nZEB and groups of buildings.

OVERVIEW OF TASKS

Task 1: State-of-the-art of definitions and nZEB concepts
Task 1 will update the state of the art regarding definitions and technologies used in nZEB as a basis for the evaluation of building technologies.

Task 2: System integration options of heat pumps
Task 2 will investigate in more detail the integration options for heat pumps with other building technologies, such as the building envelope, ground and both thermal and electric storage systems, e.g. by simulation studies.

Task 3: Technology evaluation and development/ Continued field evaluation
In Task 3, technology developments started in Annex 40 and new developments will be investigated by prototyping, lab-testing and field monitoring, which will also include built nZEB in operation.

Task 4: Design and control of nZEB technologies
Task 4 deals with the design and control of heat pumps integrated into the building technology in nZEB in terms of performance, cost and demand response capability for self-consumption optimisation.

Project duration:
October 2016 – September 2019

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ANNEX

50

HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW

The building sector plays a significant role for the energy consumption in every country. Apart from the power generation and transport sector, it is the most important sector regarding the emission of greenhouse gases. Accordingly, the radical reduction of CO_2 emissions from buildings is crucial for achieving climate neutrality in the building sector.

For multi-family buildings, the challenge to apply heat pump technologies and renewable energy is more complex than it is for single-family dwellings. The type of ownership varies among member countries of the IEA HPT TCP. While in some countries multi-family houses are often owned by municipalities, communities or housing corporations, in other countries ownership is private and divided into separate flats.

Multi-family houses are associated with a range of heat demand characteristics. Firstly, the share of domestic hot water in the overall heat demand varies due to varying building standards as well as different climates. Secondly, the temperature level of the heating system is influenced by these aspects as well as by the installed heat transfer system. Thus, dealing with the variety of heat demand characteristics is the challenge on the way to a broader spread of heat pumps in multi-family buildings.

Annex 50 focuses on solutions for multi-family buildings with the aim of identifying barriers for heat pumps on these markets and solutions for how to overcome them.

Annex 50 focuses on solutions for multi-family buildings with the aim of identifying barriers for heat pumps on these markets and solutions for how to overcome them. With respect to the demand from the participating countries, new buildings and retrofit will be considered, together with buildings with higher specific heating demand.

As the end user on the demand side, city councils and housing corporations owning large housing estates are important target groups. On the supply side, heat pump manufacturers, power companies, technical consultants as well as planners/installers will be addressed. Furthermore, political decision makers are of interest since governments are setting the boundary conditions for future development for Energy Zero in 2050.

OBJECTIVES

- Enhancement of heat pump systems and/or heat pump components for their adaptation to multi-family buildings;
- Development and demonstration of concepts for application of heat pumps in buildings renovated in terms of energy and in buildings without improved building envelope;
- Finding the optimal bivalence temperature for bivalent or hybrid systems;
- Identification of the characteristics of heat pump components and identifying the characteristics that are neither fulfilled by market-available products nor a scope in ongoing research and development projects;
- Present recommendations for the optimal (multi) heat source and operating mode (fuel driven, electric driven, hybrid) solutions depending on building type and ecologic-economic situation and climatic zone.

OVERVIEW OF TASKS

Task 1: Market overview, barriers for application, system classification

Task 1 focuses, among other things, on the analysis and classification of products with regard to different types of multi-family buildings, legislation, energy supply scenarios etc.

Task 2: Modelling and simulation of systems, economic models

The focus of Task 2 will be on the simulation of various systems in a wide range of operating conditions (type of buildings/insulation, climates, applications, energy scenarios, heat sources etc.).

Task 3: Technology development, evaluation and system assessment

Among other things, heat pumps with better modulation or cascaded systems, as well as hybrid systems will be investigated within Task 3.

Task 4: Demonstration and monitoring

The first step of Task 4 will be a definition of the system boundaries and performance evaluation figures. After a period of monitoring, the measured data will be analysed.

Task 5: Dissemination and communication

Within Task 5, the results of the annex will be provided for a broad audience spectrum.

Project duration:
January 2017 – December 2020

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ANNEX

51

ACOUSTIC SIGNATURES OF HEAT PUMPS

Reduction of acoustic emissions is important to further increase the acceptance of heat pumps as air-to-water, water-to-air, air-to-air and brine-to-water (ground source) units. To increase this acceptance and minimize noise annoyance, more focus has to be put on the acoustic emissions at steady state and on the transient behaviour of acoustic signatures during different operating conditions (e.g., icing, defrosting, capacity control, and cooling mode). Depending on the end user, or the end-user's neighbours, the noise emissions under investigations are an indoor and/or outdoor issue, requiring appropriate treatment.

Air to water heat pumps provide a convenient and effective way to exploit potential energy savings and are often used in retrofit installations. Thus, acoustic improvements are important for both the new and the retrofit market.

Acoustic emissions will be accessed in a hierarchical approach considering the following

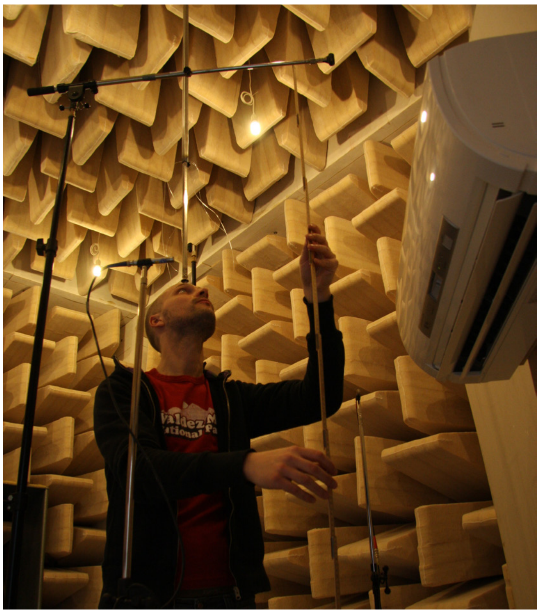

Figure 1. Noise measurement of an air-to-air heat pump in the hemi-anechoic room at RISE in Sweden.

Acoustic training ensures that optimal installation complements good acoustic design - further increasing the acceptance of heat pumps.

levels: Component level - Low noise components (e.g. fans and compressors); Unit level - System approach of combining the components, unit control, transient acoustic features; Application level – Building and neighbourhood including smart grid, psychoacoustic effects and acoustic propagation.

Options for noise measurement techniques (see Figure 1-3) for improved understanding, measuring and description of the acoustic performance will be an important focus of the annex. Seen from a global perspective, the current legislation – serving the needs of the different locations and countries – is very diverse. The annex will contribute to guidance and future standards in this field in the short and long term to help in harmonizing the different local approaches, for the benefit of all involved stakeholders.

Education and training are very important aspects in heat pump acoustics (placement, noise reduction measures, modes of control and operation) so that bad installations will not go against good acoustic design and construction of the units. Guidelines will be prepared for component and heat pump manufacturers, heat pump testing laboratories, engineering consultants, installers and designers.

Participants of the annex will contribute through presenting and discussing the results of their corresponding ongoing and starting acoustic research projects. Furthermore, national guidelines that are already in place will be improved and prepared for broader use.

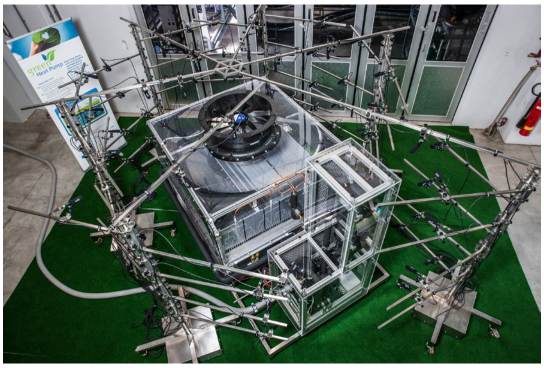

Figure 2. Demonstration setup of a 64 microphone Acoustic Dome around the GreenHP Heat Pump.

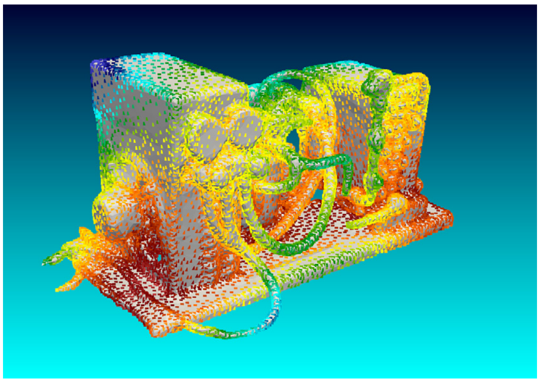

Figure 3. Three-dimensional visualization of the sound source distribution of an educational heat pump at a frequency of 1250 Hz.

OBJECTIVES

- Further increase the acceptance of heat pumps for comfort purpose with respect to noise and vibration emissions;
- Increasing knowledge and expertise at different levels (manufacturers, acoustic consultants, installers, legislators);
- Input to national and international standardization;
- Preparation of six annex meetings on acoustics in the participating countries;
- Organization of a concluding international workshop and compilation of proceedings;
- Worldwide dissemination to heat pump manufacturers via already available dissemination media and additionally a special annex newsletter which can be subscribed to;
- Acoustic Guidelines for the different levels (Component Level, Unit Level, Application Level).

OVERVIEW OF TASKS

Task 1: Legislation and standards

Gathering and comparison of acoustic regulations and standards, measurement techniques and certification schemes.

Task 2: Definition of heat pump units to be covered by the study

Compilation of a list of representative products used in the annex.

Task 3: Identification of noise at component and unit levels and noise control techniques

Generation of an overview on component and unit noise as well as design and control strategies.

Task 4: Analysis of the effect of operating conditions of heat pumps on acoustic behaviour

Task 5: Heat pump installation and effects on surrounding environment

Focusing on acoustic perception, heat pump installation and its environmental effects.

Task 6: Improved measuring and description of the acoustic performance

Discussion on future options for more detailed and significant acoustic performance figures.

Task 7: Diffusion, dissemination

Preparation of Guidelines, recommendations and educational material on heat pump acoustics.

Project duration:
April 2017 – March 2020

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Outlook into the Future

During 2016 two new annexes within the programme were approved, **"Heat Pumps in Multi-Family Buildings for Space Heating and DHW"** (Annex 50) and **"Acoustic Signatures of Heat Pumps"** (Annex 51). Both annexes will start early 2017 (see page 40-43).

One annex proposal that is under preparation is about **"Long-term Performance Measurements of GSHP Systems Serving Commercial and Institutional Buildings"**. Measured long-term performance data for ground source heat pump systems serving commercial and institutional buildings are rarely reported in the literature. Energy use intensity figures are occasionally published, but as they necessarily lump the building loads and the system performance together, they are of limited usefulness in understanding real-world system performance. The proposed annex aims to survey and create a library of quality long-term measurements of ground source heat pump (GSHP) system performance for commercial and institutional buildings with an emphasis on recent and current measurements. Outcomes will be guidelines for instrumentation, monitoring and analysis of long-term performance.

Another idea for the TCP is to establish an annex about **"Air Conditioning, Including Non-Vapor-Compression Technologies"**. The background to this is that in a warmer, richer world, the demand for air conditioning will skyrocket. From 900 million room air conditioners in 2015, the global stock is expected to grow to 2.5 billion units in 2050. In many parts of the developing world, cool dehumidified air is not only a matter of comfort but also one of public health and safety. The challenge we have before us is how to deliver that cooling sustainably to more people. Most of the cooling equipment that will be in place in 2030 has yet to be manufactured, sold, and installed. The next step in developing a proposal for such an annex is a workshop – regarding **"Future Non-Traditional Air-Conditioning (and Heating) Technologies for Buildings"** – to be held in conjunction with the IEA Heat Pump Conference in Rotterdam in May 2017.

The HPT TCP will submit a request for extension of the Technology Collaboration Programme to the IEA Committee on Energy Research and Technology (CERT) during 2017. For that request, the strategy work plan of the TCP for the next five-year period will be presented.

The technology scope for future research, development, demonstration and deployment within the TCP includes electrifying the heating market as well as combinations with other technologies such as energy storage, smart grid control, solar energy, waste heat recovery, and combinations with district heating or thermal (neutral) networks. Applications of "new" or natural refrigerants, possibly flammable, as well as application of heat pumping technologies in new or special markets and applications, should also be included in future activities in the programme.

Further, the programme will work on attracting new member countries that are key partners or associate members of the IEA, addressing new markets as well as more climates, and tailoring communication to reach and affect policy makers.

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