# ANNUAL REPORT 2017

## HEAT PUMPING TECHNOLOGIES

Technology Collaboration Programme on
Heat Pumping Technologies - HPT TCP


International Energy Agency

Technology Collaboration Programme
on Heat Pumping Technologies

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**HPT TCP Annual Report 2017**

*www.heatpumpingtechnologies.org*

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# Content

Technology Collaboration Programme on
Heat Pumping Technologies (HPT TCP)

# Message from the Chairman

More than half of the primary energy in the world is used for heating and cooling in buildings and other processes. In the future, heating demand for multiple applications will remain significant, and global demand for cooling and refrigeration is growing quickly, especially in rapidly emerging economies and developing countries.

At the *21st Conference of the Parties (COP21)* in Paris, 197 countries signed an agreement on climate change. The overarching goal is to limit global average temperature rise to "well below 2 °C". In the energy sector, a transformative change will be necessary in order to reach this goal.

*The IEA Energy Technology Perspectives 2017* shows that heat pumping technologies are a critical enabler to reach these climatic ambitions. By 2060 heat pumps should attain a share of almost 50 % of the total worldwide heating equipment in buildings. Furthermore, heat pumps are one of the prioritized areas within the international *Mission Innovation Challenge No 7 "Affordable Heating and Cooling in Buildings"*. It should also be borne in mind that the technology can improve energy efficiency and the use of renewable energy in other sectors as well, such as in industry and transport, and assume a significant role in smart grids.

These trends guided us in the development of the HPT TCP's Strategic Workplan for 2018 – 2023. The Workplan was a part of the Request for Extension (RfE) documents we had to submit to the IEA End Use Working Party in 2017. We are happy to report that our Technology Collaboration Programme (TCP) was confirmed for another five years.

Our new vision states that "*heat pumping technologies play a vital role in achieving the ambitions for a secure, affordable, high-efficiency and low-carbon energy system for heating, cooling and refrigeration across multiple applications and contexts. The Programme is a key worldwide player in this process by communicating and generating independent information, expertise and knowledge related to this technology as well as enhancing international collaboration*". The full Strategic Workplan can be downloaded from our website.

We are aware that it is a challenge to fulfil this vision and that we have to widen our scope of activities, and improve communication and collaboration with other groups. But we are optimistic that we will be successful. The basic conditions are beneficial for heat pumps. In 2017 we observed increasing worldwide activities as well as a broader acceptance of heat pumping technologies as clean, efficient and renewable heating devices. We accomplished 43 Annexes (projects), 9 ongoing Annexes and a number of Annex proposals and ideas. Many of them are already well aligned with the direction of the new strategy. An example is the proposal "Advanced Cooling / Refrigeration Technologies Development", that will be launched in 2018. As many of our member countries support Mission Innovation, we started a new cooperation and identified opportunities to collaborate with other IEA TCPs.

2017 was the year of the 12th edition of our tri-annual international IEA Heat Pump Conference. More than 550 people from industry, government, research institutes and universities attended the four-day event in Rotterdam in May. Never before have we had so many attendees, using the conference as a platform to gather and exchange information about recent developments in heat pumping technologies. It was a further sign of the increasing interest in this technology.

The success is only possible with highly motivated and experienced people collaborating in the different fields and levels of our TCP. Therefore I would like 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. Special thanks go to the IEA Secretariat and IEA Energy Technology Network staff who supported us in the elaboration of our "RfE" and in our outreach activities. Many thanks go to our member countries and their funding agencies. Without the financial support from the membership fee, and all the different projects contributing to the Annex-work, our activities would not be possible.

Stephan Renz, Chairman of the Executive Committee

# International Energy Agency

**About the International Energy Agency (IEA)**
Established in 1974, the International Energy Agency (IEA) carries out a comprehensive programme of energy co-operation for its 30 member countries and beyond by examining the full spectrum of energy issues and advocating policies that will enhance energy security, economic development, environmental awareness and engagement worldwide. For more information, visit *www.iea.org*.

**IEA Energy Technology Network**
The IEA Energy Technology Network (ETN) is comprised of the Committee on Energy Research and Technology (CERT), its Working Parties (WPs) and Expert Groups, as well as the Technology Collaboration Programmes (TCPs). At the direction of the Governing Board, the CERT oversees the implementation of the IEA Medium-Term Strategy for Energy Research and Technology, and it provides strategic guidance to the energy technology work undertaken by the IEA Secretariat and the wider ETN. The CERT is supported by four Working Parties:

- Working Party on Energy End-use Technologies (EUWP): technologies and processes to improve efficiency in the buildings, electricity, industry, and transport sectors;
- Working Party on Fossil Fuels (WPFF): cleaner use of coal, improvements in gas/oil exploration, and carbon capture and storage;
- Fusion Power Co-ordinating Committee (FPCC): fusion devices, technologies, materials, and physics phenomena;
- Working Party on Renewable Energy Technology (REWP): technologies, socio-economic issues and deployment policies.

Each Working Party coordinates the research activities of relevant TCPs. The CERT directly oversees TCPs of a cross-cutting nature.

**IEA Technology Collaboration Programmes**
The IEA Technology Collaboration Programmes (TCPs) are international groups of experts from government and private sector to lead programmes and projects on a wide range of energy technologies and related issues. The first TCP was created in 1975. Today there are 38 TCPs in operation with over 6 000 experts from around 300 public and private-sector organisations from over 50 countries. The term TCP indicates the collaborative programmes under the IEA Framework for International Technology Co-operation. Each TCP is formally organised under the mechanism of an “Implementing Agreement”, which is also the term used to describe the legal text of a TCP. TCP activities and programmes are managed and financed by the participants. To learn more about TCPs, please consult the short promotional film, the Frequently Asked Questions brochure or the IEA website *www.iea.org/tcp*.

# 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.

## Strategy Work Plan 2013 - February 2018

***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 2017

**Request for Extension of the HPT TCP**
The duration of the programme usually is five years. As the term of the HPT TCP ends in February 2018 a request for extension for the period 2018-2023 had to be elaborated and submitted to the IEA Committee on Energy Research and Technology (CERT). The main documentation required were a Strategy Work Plan, an End of Term Report, and a Questionnaire.

These documents were prepared as a group effort coordinated by the HPC, initiated in 2016 with a strategy workshop of the ExCo.

The core of this process has been to develop the new Strategy, which has a wider scope than the previous one, and also includes increased cooperation with other TCPs. A comprehensive work had to be performed by HPC in collaboration with the HPT Chair, the Executive Committee (ExCo) and the Annex Operating Agents (OAs) The documents were finally submitted to the IEA in August, and were presented in September to the IEA Working Party On Energy End-Use Technologies (EUWP). This presentation was given by the HPT Chair Stephan Renz supported by HPC's manager Monica Axell. The response from EUWP has been positive, and the extension was approved by CERT in February 2018.

**Executive Committee Meetings**
Two meetings of the HPT TCP Executive Committee (ExCo) were held in 2017:

» May 19, Rotterdam, the Netherlands
» November 15-16, Vienna, Austria.

**Workshop in Vienna, Austria**
In connection with the IEA HPT Executive Committee meeting in Vienna, an international workshop entitled "IEA Heat Pumping Technologies Workshop – An Austrian Perspective" was held, together with the Austrian Heat Pump Association. This gave a unique opportunity to receive the latest information on the activities in Austria related to heat pumping technologies, and the Austrian audience to be informed about activities within the HPT TCP.

**Mission Innovation**
The Mission Innovation (MI) is a very significant global initiative of twenty-two countries and the European Union to dramatically accelerate global clean energy innovation. As part of the initiative, participating countries have committed to double their governments' clean energy research and development investments over five years to 2021, while also encouraging greater levels of private sector investment in transformative clean energy technologies.

The MI countries have established seven Innovation Challenges. Of particular interest to the HPT, MI has identified heat pumps and storage as one of the technologies to focus on under its Innovation Challenge #7, "Affordable Heating and Cooling". The Strategy Work Plan described above is in line with this innovation.

The HPT has participated in two MI workshops during 2017. The first one was a general MI workshop, covering all aspects of Mission innovation, with participation of the HPT Chair and HPC. Challenge #7 was the subject of another Mission Innovation Workshop in which HPC participated. The main insight from the group that discussed heat pumps was to think radically about heat pumps; no longer simply as a box on the wall but instead as a market enabler, merging energy vectors and delivering new services, such as balancing supply and demand.

**Cooperation with groups within the IEA**
Recently, the IEA has increased its efforts to coordinate work between different TCPs. The Building Coordination Group has had annual meetings for a number of years, and now there are also joint meetings within other important groups, as described below:

**IEA Future Building Forum**
IEA Future Buildings Forum is a Think Tank to check, to develop and to agree every five years on strategic R&D priorities for the IEA buildings-related Technology Collaboration Programmes. In 2017 the workshops were convened in Singapore under the theme «Transforming cities in hot and humid climates towards more efficient and sustainable energy use». The IEA HPT was represented by the chairman Stephan Renz. Internationally renowned experts and creative thinkers were invited to these workshops, and they shared their knowledge and anticipated which new technologies and business models will be needed to achieve the challenging goals for clean energy supply and massive demand reduction.

Increasing demand of air-conditioning in the tropics will cause a growth of energy demand at a rate of more than 10 % per year. There is an urgent need to rethink the approach towards passive design, thermal comfort and the need for disruptive technologies for the tropics as a response to the increasing need for cooling. Energy-efficient technologies such as heat pumps including solar thermal driven absorption chillers will play an important role.

**Building Coordination Group meeting**
The Building Coordination Group (BCG) consists of all building-related TCPs within the IEA. The BCG meeting is held annually. At this year's meeting, in which the HPT Chair and HPC participated, the need for further R&D possibilities of common interest were discussed. Among the points that were identified as critical for building energy technology were affordability, scale-up possibilities, policy drivers such as behaviour and public awareness, and the changing occupation patterns of buildings.

**EUWP Workshop**
The HPC represented the HPT TCP at the Working Party On Energy End-Use Technologies (EUWP) workshop "Gaps and Barriers for Energy Technology Development and Deployment – a view from the Technology Collaboration Programmes (TCPs)" in March. The focus was the question whether there is a need to create joint annexes between TCPs, and if so, how this should be initiated. The first step is an accurate mapping of activities towards optimisation of resources and maximum impact to identify gaps and overlaps.

**REWP Workshop**
HPC was invited to and participated in the panel for the session Affordable heating and cooling at the IEA Renewable Energy Working Party (REWP) workshop in March with the theme "Scaling-up renewables through decentralized energy solutions". One main conclusion of the workshop was that energy efficiency plays a critical role in integration of renewable energy to meet demand for services. All the cities that presented their case studies shared this, despite very different levels of potential for distributed renewables generation. HPC also participated in an IEA joint meeting on international co-operation on Energy efficiency: gaps, overlaps and strategic opportunities, with participation from the Working Party on Energy Efficiency (EEWP), the EUWP, and the International Partnership for Energy Efficiency Cooperation (IPEEC).

# 12th IEA Heat Pump Conference

In the middle of May, the 12th IEA Heat Pump Conference was held in Rotterdam, the Netherlands. The triennial conference had an extensive program with 564 participants from 31 countries, 186 oral presentations, 88 poster presentations and 7 workshops with focus on results from the Annexes and strengthening the collaboration with other TCPs.

The journey leading to the successful delivery of the 12th IEA Heat Pump Conference was, as in previous conferences, challenging. As always, the numbers do not reveal everything. There are many qualitative aspects which cannot be measured and translated into reportable figures, but in the end, the reward of the delegates showing their appreciation for the work done by the National Organizing Committee (NOC) was priceless.

**Objectives of the Heat Pump Conference 2017**
The goal of the conference was to get broader support and interest for heat pumping technologies as one of the key technologies in existent and future energy systems. The conference theme 'Rethink energy, act NOW!' clearly signifies the paradigm change that is needed which can already now get into effect!

The Rotterdam NOC proposed a theme that highlights the urgency to act and was aimed at showing the availability of solutions. Rethink Energy focused on the fact that heating and cooling is a major topic in the energy challenge for the world, often overlooked. Act NOW focused on the fact that we have no time to lose. Especially the plenary key note speakers were asked to deliver a presentation focusing on answering these questions from their point of view related to heat pumps as one of the solutions. The clear thematic statement gave an objective reference for plenary and invited speakers.

The objectives of the 12th IEA Heat Pump Conference was to:

- Bring together the world's scientific experts to catalyse and advance scientific knowledge about heat pumps, present the most recent research findings, and promote and enhance scientific collaborations around the world.
- Bring together community leaders, scientists, and policy leaders to promote and enhance programmatic collaborations to more effectively address regional, national and local responses to heat pumps around the world.
- Engage key, new and non-traditional stakeholders throughout the world in the development of and participation throughout the Heat Pump Conference 2017 program.

The aim of the Conference was to have an event where the added value of participants in the Conference is not in gathering a bunch of papers but in meeting other experts. There were ample networking opportunities, and the most important people did attend the Conference.

**Conference Structure and Venue**

It is safe to say that the Conference is at the core of the activities held within the HPT TCP and extremely important in terms of reputation regarding knowledge development and dissemination. The triennial conference is an opportunity for the HPT TCP to showpiece the work under the HPT TCP, to attract new participants and experts, and develop new projects.

**First day: workshops and soccer celebration**

One of the largest challenges regarding the Conference was to deal with the National Soccer Champion-ship inauguration of Feyenoord (local soccer team), coinciding with the start of the 12th IEA Heat Pump Conference. This celebration took place immediately outside the congress venue with 150 000 celebrating fans! Fortunately, we were well prepared, and thanks to the collaboration with our local partners, this was an unforgettable experience for our delegates.

The Conference opened on the first day with seven workshops. The approach for the workshops differed greatly from former conferences where Annexes were offered rooms to hold their regular Annex workshops as pre-conference activity. This new approach was in line with the advice from the evaluation of the previous Conference, held in Montréal. The workshops were seen and marketed as an integral part of the Conference with an emphasis to focus on the work in the Annexes and creating support and ideas for potential new Annexes under the TCP, also attracting the involvement from other TCPs.

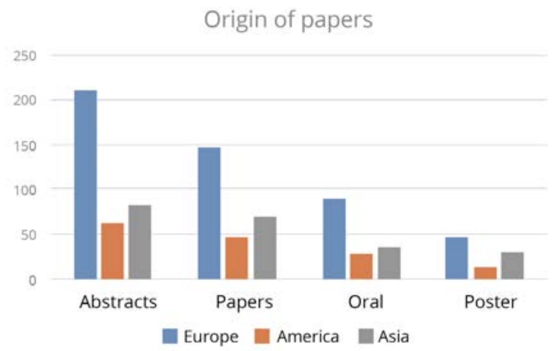
**Workshops**

- 'Heat pumps for net zero energy buildings (nZEB), retrofit and energy flexibility'
- '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'
- 'Community energy supply systems and district heating', organized by EBC Annex 63 and Annex 64

**Second day**

The second Conference day opened with a plenary opening session in the main conference hall:

- **Per Jonasson** - Chairman International Organising Committee (IOC)
- **Bert Stuij** - Manager National Programmes / Energy at the Netherlands Enterprise Agency (RVO.nl).
- **Stephan Renz** - Chairman of IEA HPT TCP
- **Eric Masanet** - Head of Energy Demand, Energy Technology Policy Division, the International Energy Agency (IEA)
- **Hans van Steen** - DG Energy, European Commission - Clean Energy for all Europeans
- **Michael Taylor** - International Renewable Energy Agency (IRENA) - Perspectives for the Energy Transition
- **Prof. Dr. Hans-Martin Henning** - Director, Fraunhofer - Institute for Solar Energy Systems (ISE) - The Role of Heat Pumps in the Transition of National Energy Systems
- **Dr. Karim Amrane** - Senior Vice President, Air-Conditioning, Heating, and Refrigeration Institute (AHRI) - Effectively Managing the Transition to Lower GWP Refrigerants
- **Prof. Kensuke Fukushi** - Tokyo University for Integrated Research System for Sustainability Science - Stimulating Social Application of Energy-Efficient Technology for Climate Change Mitigation.




The very successful call for papers generated 274 high quality papers resulting in 186 oral presentations and 88 poster presentations. This is a huge increase compared to the earlier conferences in Montréal (171), Tokyo (web conference) (191), Zürich (180), and Las Vegas (128 papers). The Conference therewith had the unique opportunity to create four main conference tracks, many of the topics directly related to the work under the HPT TCP.

As could be expected, the majority of papers were from Europe. Given the extensive programming of the Conference and a solid and varied international participation, adding a local component to the event did not dilute the quality of the program. We expect also that a great number of participants from other continents than Europe were very interested in listening to the Europeans. To increase the deployment of knowledge and innovation from the Netherlands, the NOC had set up a special event to show the Dutch innovation in the application of heat pumping technologies and even issued two Journals with articles on the various achievements in the building and industrial sector.

The main tracks of the Conference were clustered into complete comprehensive sessions, focusing on main themes:

- Track 1: Domestic and Building Applications
- Track 2: Smart Energy Communities and Ground Sources
- Track 3: Air-Conditioning & Industry
- Track 4: Sorption and Working Fluids

**Posters**

Many of the sessions had key note presentations and a large number of poster presentations. These poster presentations were all presented in the central meeting area of the Conference hall. Locating the posters near the coffee and lunch breaks and organizing an after-conference drink was experienced as a good solution, in order to provide good attention for the posters. One aspect that should be considered is that posters can be seen as a separate part of the Conference, parallel to the oral sessions. A poster can be seen as a phenomenon in itself which can attract more and focused attention and discussion.

The Conference participants were asked to vote for the Best poster. This award was awarded on behalf of the HPT TCP to Zuo Cheng, Wenxing Shi, and Baolong Wang for the poster entitled "Vapor injected heat pump using non-azeotropic mixture R32/R1234ze(E) for low temperature ambient". The authors represent Beijing Key Laboratory of Indoor Air Quality Evaluation and Control, Department of Building Science, Tsinghua University in Beijing, China.

**Third day – awards and exhibition**

On Wednesday there was a session on the 'Daikin Best Student Award'. In this session a number of students gave presentations on their heat pump related projects. The awardee was Yaodong Tu, Shanghai Jiao Tong University, China. The 'Dutch Innovation Award', as sponsored by the Dutch energy company Eneco, was presented at the Wednesday lunch break. The winner of this award was the company TripleAqua. Exhibition and information booths were also present in the main hall of the World Trade Centre. There were exhibitors from three local companies and organizations, eight European companies and organizations and six from companies and organizations outside of Europe, although from the latter group three of the contacts were through their Dutch representatives.

**Conference Dinner**

The Conference dinner was staged in the Laurens Church with 435 participants. During the dinner there were presentations of The Ritter von Rittinger Award (awardees: Professor Eckhard A Groll, USA; Professor Alberto Cavallini, Italy; the ORNL Building Equipment Team, USA; and Professor Per Lundqvist, Sweden), Daikin Best Student Award and the Eneco Dutch Innovation Award.

**A conference to remember**

In addition to the country sponsors, the host committee recruited fourteen corporate sponsors and exhibitors. Corporate sponsors contributed to the financial support of the Conference, where two of the main sponsors, Daikin and Eneco, both were given place and time for presenting a special award. Besides the commercial sponsors the host country took huge effort by facilitating the Conference dinner. Support was further given by sixteen supporting media partners, publicizing and promoting the conference within their respective constituencies. The NOC thanks these exhibitors, sponsors and media partners. Without them it would not have been possible to organize this great event!

All in all, the 12th IEA Heat Pump Conference in Rotterdam was a conference never to be forgotten – also thanks to the Dutch soccer champion Feyenoord!

# 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. RISE Research Institutes of Sweden (previously SP) has been appointed to manage the HPC.

During 2017, there has been a focus on activities that communicate what the HPT TCP does, and achievements within the Annexes. Also, significant effort has been put into the Request of Extension of the HPT TCP, the 12th IEA Heat Pump Conference, and collaboration with other important organisations, all of which are described elsewhere in this Annual Report.

As for new member countries within the HPT, contacts and discussions regarding membership are under way with several countries.

**HPT Magazine**
One of HPC's main activities is the publication of the Heat Pumping Technologies Magazine. Each issue covers a particular topic and contains articles, news and events, together with a contribution from a guest columnist.

During 2017, the HPT Magazine has continued to be published as an online magazine, on the digital publishing platform *issuu*, and linked to via the HPT website. 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.

Three issues were published during the year: HPT Magazine No. 1/2017 with the topic "Heat Pumping Technologies in Special Applications and New Markets", No. 2/2017, "Report from the 12th IEA Heat Pump Conference", and No. 3/2017, "Heat Pumping Technologies in near Zero Emission Buildings (nZEB)".

In a survey conducted at the HP Conference in Rotterdam, it was found that a majority of the respondents were aware of the HPT Magazine, and that the content was well appreciated.

**Website and social media**
2017 has been an active year for the HPT on the web and in social media. The development of the website has continued, with a News section that is frequently updated. A Twitter account, *@HeatPumpingTech*, has been created, and News have also been published on LinkedIn. The HPC has supported Operating Agents to use Annex subsites on the HPT website, to promote their Annexes.

Updates during 2017 include the addition of several Annex reports, executive summaries and two-page summaries of Annexes 41 and 42. Further, a film has been produced and released on the website, "Why heat pumps are a technology for the future". The proceedings from the Conference can be purchased from the HPC.

**The 12th IEA Heat Pump Conference**
HPC participated very actively in the 12th IEA Heat Pump Conference. Caroline Haglund Stignor, HPC, chaired one of the sessions. The HPC had a booth, promoting the HPT TCP. An information meeting about the HPT TCP was held for conference participants from non-member countries. A survey with conference participants was performed, regarding awareness of the HPT TCP and satisfaction with products of the HPC.

**Activity Generation**
The Heat Pump Centre is involved in initiation of new activities within the HPT TCP. The HPC also maintains regular contact with the annexes' Operating Agents, supporting them with legal text, formal participation letters, etc.

The National Experts' meeting (previously, National Teams' meeting), organized by HPC, was held in Nuremberg, Germany, in October, with good attendance. As usual, the main focus of the meeting was to generate new activities in the form of Annexes and Annex ideas and to discuss Annex proposals, in particular in connection to the proposed new strategy. At the meeting, several Annex ideas were discussed, of which three were decided to be taken further within the HPT: "How to improve the channel between manufacturer and end-user, to extend the good use of heat pumps", "Internet of Things for Heat Pumps", and "HP systems with low GWP refrigerants".

Two new Annexes were started in 2017: “Heat Pumps in Multi-Family Buildings for Space Heating and DHW” (Annex 50) and “Acoustic Signatures of Heat Pumps” (Annex 51), and one will start in early 2018, “Long term performance measurement of GSHP Systems serving commercial, institutional and multi-family buildings” (Annex 52; see further the Outlook for the future section).

**60 seconds**

During 2017, 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.

**Support for IEA Publications and Activities**

The IEA continues its series of publications Energy Technology Perspectives (ETP), which will now return to be published once every two years. The HPC has provided input to the ETP 2017, both regarding data for heat pumps and regarding review of a draft version. Further, the HPC has reviewed the content of the draft for the IEA publication Tracking Clean Energy Progress 2017.

The HPC and the HPT Chair has answered a questionnaire from the IEA secretariat. The responses from the survey will better enable the IEA to help improve the HPT’s impact.

**International Collaboration and promotion**

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

Caroline Haglund Stignor, HPC, attended the ASHRAE Winter meeting in Las Vegas in order to be better informed about what is going on related to the technology in different parts of the world, to promote the HPT programme, the upcoming IEA HPT conference, and for networking purposes. She also attended the US National Team meeting and gave a presentation about the latest activities within the programme and the Heat Pump Centre.

HPC participated in the EHPA General Assembly and the ensuing conference on the DeCarb Heat initiative. This initiative has the aim to turn the vision of a 100 % carbon-free, efficient renewable heating and cooling sector in Europe by 2050 into reality. The initiative consists of an Industry Pledge and a Declaration of support open to all.

HPC participated in European Heat Pump Summit and had a stand for the HPT there.

Monica Axell of HPC was invited speaker at the Asian Heat Pump & Thermal Storage Technologies Network (AHPNW) Workshop in Tokyo, presenting the HPT and its activities.

Monica Axell was also invited as speaker at the 2017 China Aerothermal Energy Conference – China Heat Pump Alliance Annual Conference & 6th Asian Air-Source Heat Pump Conference Heat Pump Forum in Suzhou, in August. The main focus of the conference was clean heating planning and market development in China, and the latest technology trends in the field of air source heat pumps.

Colleagues from the New Energy and Industrial Technology Development Organization (NEDO), Japan, visited the HPC in March and November, in order to discuss future cooperation.

As was the case in 2016, an article from the HPT Magazine was translated into Chinese and reprinted in the Chinese reputable magazine “HVAC SPECIAL”, after permission from the HPC and the authors. In this way the article, and the HPT, becomes more well-known also in China.

**Heat Pump Centre**
*www.heatpumpingtechnologies.org*

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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).

| | | |
|---|---|---|
| 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, US |
| HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS | 47 | AT, CH, **DK**, SE |
| INDUSTRIAL HEAT PUMPS, SECOND PHASE | 48 | AT, CH, FR, JP, UK [**DE**] |
| DESIGN AND INTEGRATION OF HEAT PUMPS FOR NZEB | 49 | AT, BE, **CH**, DE, NO, SE, UK, US |
| HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW | 50 | AT, **DE**, FR, NL |
| ACOUSTIC SIGNATURES OF HEAT PUMPS | 51 | **AT**, FR, IT, SE |
| LONG TERM PERFORMANCE MEASUREMENT OF GSHP SYSTEMS SERVING COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS | 52 | NL, **SE**, US |

FINALIZED 2017

NEW

# Meetings 2017

**Annex 42**
- *April, Freiburg, Germany.* Final report definition and completion.
- *May, Rotterdam, the Netherlands.* Workshop in connection with the IEA Heat Pump Conference.

**Annex 43**
- *January, Las Vegas, USA.* An experts' meeting. Decision to integrate new working pairs in Software SorpSim. Brainstorming event for work to be done in last year of the annex.
- *January, Las Vegas, USA.* ASHRAE 2017 Winter Conference. Conference session with four speakers from the annex about sorption heat pumps.
- *December, Brussels, Belgium.* An experts' meeting back to back with EHPA working group "thermally driven heat pumps", to identify common goals and unify work plan.

**Annex 45**
- *May, Oostende, Belgium.* Regular two-day project meeting.
- *October, Utrecht, the Netherlands.* One-day expert panel meeting with a variety of stakeholders within and from outside the Annex project.

**Annex 46**
- *May, Rotterdam, the Netherlands.* 3rd Working Meeting.
- *October, Fontainebleau, France.* 4th Working Meeting.
- *October, Nuremberg, Germany.* Extended 4th Working Meeting.

**Annex 47**
- *January, Skype.* Decision on content and structure of Task 1, Market and energy reduction potential.
- *March, Skype.* Discussion on content, structure and timeline of Task 2, Description of existing DHC systems and demonstration and R&D projects with Heat Pumps.
- *July, Hamburg, Germany.* Content and progression of Task 1 was discussed; structure and layout of Task 2 was decided. A proposal for the Task 3 setup was presented.
- *September, Skype.* Discussion about task 2 progression.
- *November, Vienna, Austria.* Presentation of results in Task 1 and Task 2. Discussion regarding plans for 2018.

**Annex 48**
- *May, Rotterdam, the Netherlands.* 3rd expert meeting. The data sheet for the case studies and application examples was discussed and adopted.
- *October, Nuremberg, Germany.* 4th expert meeting.

**Annex 49**
- *February, Rapperswil, Switzerland.* Presentation of the state-of-the-art of nZEB in the different participating countries.
- *May, Rotterdam, the Netherlands.* Short information exchange. Update on evaluation of national definitions and criteria for a common definition in Annex 49 was discussed, also an update on national contributions.
- *October, Nuremberg, Germany.* A definition of nZEB in Annex 49 was established, and a simulation framework for the comparison of system concepts was set up.

**Annex 50**
- *January, Freiburg, Germany.* Kick-Off-meeting.
- *May, Rotterdam, the Netherlands.* Workshop in connection with the IEA Heat Pump Conference.
- *June, France.* The market situation in each country was presented. A list of influencing factors (market, regulation, economic, knowledge, etc.) was generated.
- *November, Graz, Austria.* Final structures and a no-go-list were edited, heat-pump-systems were classified, existing simulation-models discussed, topics for the HPT Magazine suggested, and administrative issues were clarified.

**Annex 51**
- *June, Vienna, Austria.* Kickoff-Meeting. Setup of the Annex structure (task- and subtask-leads) and communication, definition of roadmap for Task 1 and Task 2.

# Selected Publications 2017

**Annex 41**

- *HPT TCP Annex 41 Cold Climate Heat Pumps: Two-page Summary.*
- *HPT TCP Annex 41 Cold Climate Heat Pumps: Executive Summary.*
- *HPT TCP Annex 41 Cold Climate Heat Pumps: Final Report.*

**Annex 42**

- *HPT TCP Annex 42 Heat Pumps in Smart Grids: Two-page Summary.*
- *HPT TCP Annex 42 Heat Pumps in Smart Grids: Executive Summary.*
- *HPT TCP Annex 42 Heat Pumps in Smart Grids: Final Report.*

**Annex 43**

- Bendix, P. et al. *Optimization of power density and metal-to-adsorbent weight ratio in coated adsorbers for adsorptive heat transformation applications.* Appl. Therm. Eng. 124, 83-90, 2017.

**Annex 44**

- van der Sluis, S. et al. *Performance indicators for energy efficient supermarket buildings.* 12th IEA Heat Pump Conference, Rotterdam, the Netherlands, 2017.
- *HPT TCP Annex 44 Performance indicators for energy efficient supermarket buildings: Two-page Summary.*
- *HPT TCP Annex 44 Performance indicators for energy efficient supermarket buildings: Executive Summary.*
- *HPT TCP Annex 44 Performance indicators for energy efficient supermarket buildings: Final Report.*

**Annex 45**

- Friedel, P. *Smart control for hybrid heat pumps may solve grid congestion*. Business Development Holland, 2017.

**Annex 46**

- Nawaz, K. et al. *R290 (propane) and R600a (isobutane) as natural refrigerants for residential heat pump water heaters*. Appl. Therm. Eng. 127, 2017.
- Garrabrant, M. et al. *Residential and Commercial Capacity Absorption Heat Pumps for Space and Domestic Water Heating Applications*. 12th IEA Heat Pump Conference, Rotterdam 2017.
- Kleefkens, O. et al. *Booster Heat Pump, development of test procedure and calculation methodology in order to estimate the energy performance in various domestic applications*. 12th IEA Heat Pump Conference, Rotterdam 2017.

**Annex 47**

- Pedersen, S. *Annex 47, Heat Pumps in District Heating Systems*. European Heat Pump Summit. Nuremberg, Germany, 2017.
- Schmidt, R. R. *Sustainable heat supply strategies for district heating networks – tools and methodologies.* 3rd International Conference on Smart Energy Systems and 4th Generation District Heating. Copenhagen, Denmark, 2017.

**Annex 48**

- Watanabe, C. *Application of Heat Pumps to Cutting and Washing Processes*. European Heat Pump Summit, Nuremberg, Germany 2017.
- Nampoothiri, M. *Industrial Heat Pumps in India - Unlocking the potential.* European Heat Pump Summit, Nuremberg, Germany 2017
- Jakobs, R. M. *IEA HPT TCP Annex 35 + 48: Heat Pump Application in Commercial and Industrial Processes.* International Workshop: High Temperature Heat Pumps, Copenhagen, Denmark 2017

**Annex 49**

- Wemhoener, C. et al. *IEA HPT Annex 49 - Design and integration of heat pumps in nZEB.* Energy Procedia 122, 661-666, 2017.
- Clauß, J. et al. *Investigations of different control strategies in a residential nZEB in Nordic climate.* 12th IEA Heat Pump Conference, Rotterdam, 2017.
- Munk, J. et al. *Air-source integrated heat pumps field evaluation results.* 12th IEA Heat Pump Conference, Rotterdam, 2017.

**Annex 51**

- Hellgren, H. et al. *Improved measurement method for heat pump noise*. 12th IEA Heat Pump Conference, Rotterdam 2017.
- Reichl,. C. et al. *Transient Acoustic Signatures of the GreenHP with special focus on icing and defrosting*. 12th IEA Heat Pump Conference, Rotterdam 2017.
- Reichl,. C. et al. *Experimental and numerical methods for the fluid dynamic and acoustic characterization of heat exchanger icing*. 67. Jahrestagung der Österreichischen Physikalischen Gesellschaft, Geneva, Switzerland 2017.

# ANNEX 41

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

The primary aim of Annex 41 has been to identify and evaluate technology solutions to improve performance of heat pumps for cold climate locations (Cold Climate Heat Pumps, CCHP). The primary focus is electrically driven air-source heat pumps (ASHP) but novel ground-source heat pump (GSHP) and solar assisted heat pump (SAHP) approaches have been investigated as well. The main near-term outcome of this Annex is information-sharing for use by designers/manufacturers to develop ASHPs with significantly improved cold climate performance. In the longer term, the technology advancements made under the Annex should help facilitate development of future ASHPs with better low-temperature heating performance and bring about a much stronger heat pump market presence in cold climates (loosely defined as having a significant number of hours with ambient temperatures below -7 °C).

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 at low outdoor temperatures. The other major issue is the loss of capacity due to frosting and defrosting of the outdoor heat exchanger (OHX). Traditional ASHPs must use low-efficiency backup heat at lower temperatures and suffer loss of performance at moderate outdoor temperatures, as noted in Figure 1.

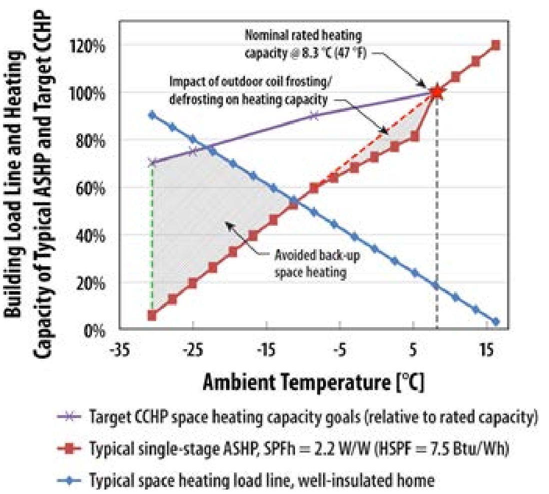


Figure 1. Space heating capacity for target CCHP vs. typical single-stage ASHP.

> ***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.***

### OBJECTIVES

- General: produce/share technical data/results for use by designers and 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 developed including some on the market.
- Prototype cold climate ASHPs "in field" measured heating SPF > 2.63 W/W; achieved.

### RESULTS

- Annex 41 was completed in 2017 and the final reports have been published. Table 1 below, extracted from the final report, summarizes the principal outcomes resulting from the activities of each Annex participant to address the two principal performance challenges noted above.

| Annex Participants | CCHP Investigated Techniques | Resulting Performance Improvements |
|---|---|---|
| Austria, Austrian Institute of Technology, AIT | Coil frost measurements and analyses | Wind tunnel tests of OHXs show that multiport extrusion compact heat exchangers experience less air flow reduction due to frost growth than conventional tube-and-fin heat exchangers at both 10 °C and -25 °C air temperature (80 % RH in both cases); therefore, they can maintain better air flow. |
| Austria, Technical University, Graz | Evaluation of compressor liquid injection (LI) for cold climate performance improvement | • Lab tests show liquid injection (LI) cycle capability to extend compressor performance envelope for air-water heat pumps down to -20 °C or lower with high water supply temperatures<br>• System analyses for several cold climate locations show seasonal COP improvements of up to 12 % |
| Canada, CanmetENERGY | Novel SAHP (solar-assisted HP) using ice-based thermal storage | • Lab tests/simulations estimate > 60 % space and water heating energy savings potential<br>• Potential cost-effective alternative to GSHPs in Canadian climates, especially for retrofit applications |
| | Zeotropic refrigerant mixtures | • Evaluations of potential for zeotropic mixture of R32 and CO2 to improve system efficiency and low temperature capacity<br>• Results show possibility of ~30 % seasonal COP improvement with variable mixture composition control components included in heat pump system<br>• Future plans to build and test lab prototype |
| Canada, Hydro Québec, Laboratoire des technologies de l'énergie (LTE) | Revisions to seasonal efficiency rating standard to better represent heat pump performance in cold climates | • Field testing of ASHP systems pointed out inadequacies in seasonal efficiency rating metrics per Canadian Heat Pump rating standard CAN/CSA-C656-05 for cold climate applications.<br>• Office of Energy Efficiency issued bulletin requiring changes in ASHP heating performance ratings and reporting; specifically required adding capacity and COP ratings for -17.8 °C outdoor temperatures by 2014. |
| Japan | Coil surface frosting R&D (Waseda University) | • Innovative frost growth measurement and visualization technique (resolution to 0.02 mm)<br>• Frost growth model developed; comparison with measurements for different surface geometries<br>• Applied frost model to heat pump system model; coil frost growth measured vs. simulated |
| | Novel frost-free air source heat pump water heater system (Central Research Institute of the Electric Power Industry, CRIEPI) | • System retards frosting by dehumidifying air using a desiccant-coated heat exchanger<br>• Potential for 20-30 % boost in COP at a temperature of -7 °C and relative humidity of 60-80 %. |
| United States | Two- (parallel, equal-sized) compressor field test CCHP prototype (ORNL, Emerson) | • Achieved field-measured $SCOP_h$ ~3.0 over two winters (2015 and 2016)<br>• 40 % energy savings during coldest month; possible to eliminate backup electric heat<br>• Heating COP at – 25 °C was >2.0; ~3.8 at 8.3 °C (including cycling losses) |
| | Novel oil-flooded HP cycle development and evaluation (Purdue University Herrick Labs) | • Approaches isothermal vapor compression process<br>• High oil circulation rates remove heat of compression and significantly reduce discharge temperature, which expanded compressor operation envelope to much lower ambient temperatures<br>• Improvements in heating capacity range up to 19 % at the lowest ambient temperature tested (-17.8 °C) |
| Complementary market promotion activities*<br><br>[*These efforts were conducted independently of the Annex but took place during the Annex working period and will continue for the foreseeable future] | U.S. Northeast Energy Efficiency Partnership (NEEP) | • Established voluntary CCHP specification; latest version (2017) posted on NEEP web site<br>• For variable speed (VS) ASHPs only; requires rated $SCOP_h$ ≥2.93 per ANSI/AHRI Standard 210/240<br>• Web site contains list of nearly 300 ASHPs that meet the requirements; 80 % are ductless minisplit or multisplit (VRF) types |
| | U.S. Electric Power Research Institute (EPRI), Next Generation (NextGen) Heat Pump specifications | • ASHPs only but VS compressor not required; other capacity control approaches acceptable<br>• Two levels of NextGen specification requirements, Tier 1 and Tier 2<br>• Tier 1 requires the same rated SCOPh as NEEP CCHP specification above; rated heating capacity at -8.3°C to be ≥80 % of rated capacity at 8.3 °C; requires control scheme to limit backup heat use; must have demand response capability<br>• Tier 2 requires rated SCOPh ≥3.81; rated heating capacity at -15 °C to be ≥80 % of rated capacity at 8.3 °C; requires control scheme to limit backup heat use; must have demand response capability |


Van Baxter

**Project duration:**
July 2012 – August 2017

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ANNEX

# 42

## HEAT PUMPS IN SMART GRIDS

Climate change enforces unprecedented growth in power from intermittent origin, so flexibility and smartness in the electric power grid is essential for sustainability. Flexibility means the degree to which producers, consumers and prosumers are able to react to the fluctuating supply and pricing on the electricity market. Particularly, if electricity from intermittent sources continues to increase, the demand will have to be geared to the supply, in some way. Otherwise the cost for end consumers will soar.

Heat pumps are the heart of a smart grid in domestic housing, perfect for demand management since they efficiently convert electrical energy into thermal energy. By combining heat pumps with thermal and/or electrical 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, heat pumps installed on a large scale in existing buildings may create grid load peaks that need to be managed, especially in countries that so far rely on natural gas as the sole energy carrier. Furthermore, heat pumps have to be managed in a smart way, since they have a large simultaneity factor: at lower temperatures, they all switch on at the same time.

Although smart-grid pilot projects and studies have demonstrated the advantage of smartly-driven heat pumps, available heat pumps are not provided with such connectivity 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.

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

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 simpler 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.

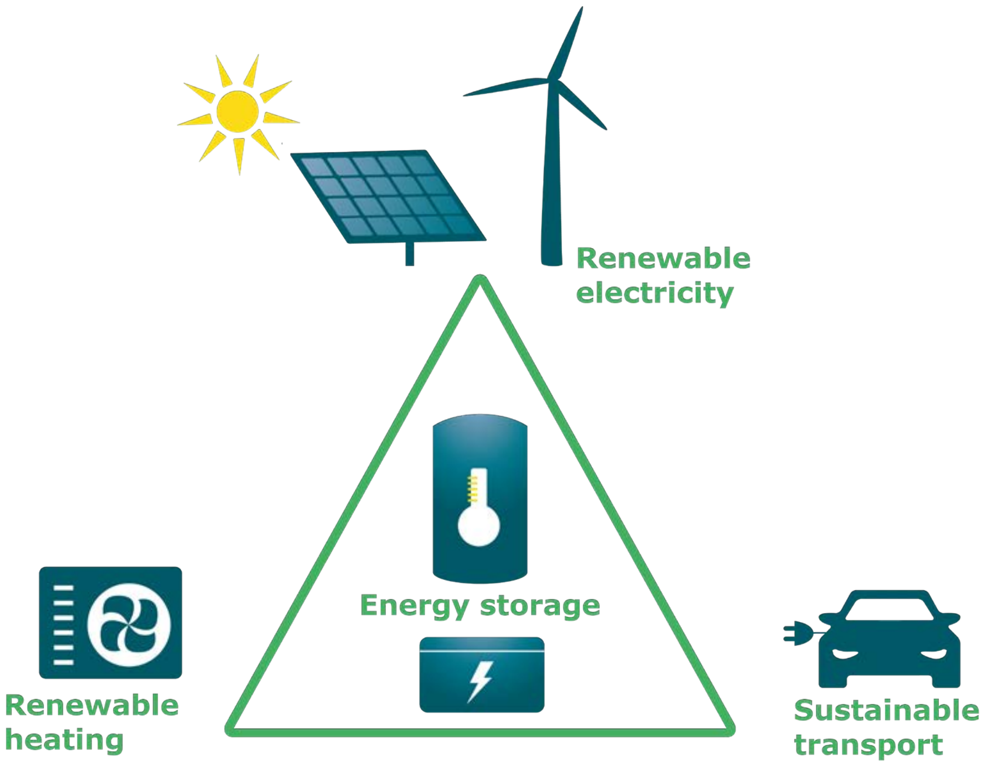


Figure 1. Integral approach of energy in smart grids

**OBJECTIVES**

- 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 the purpose of:

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

**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'.

**Project duration:**
June 2013 – June 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 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.

> ***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.***

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.

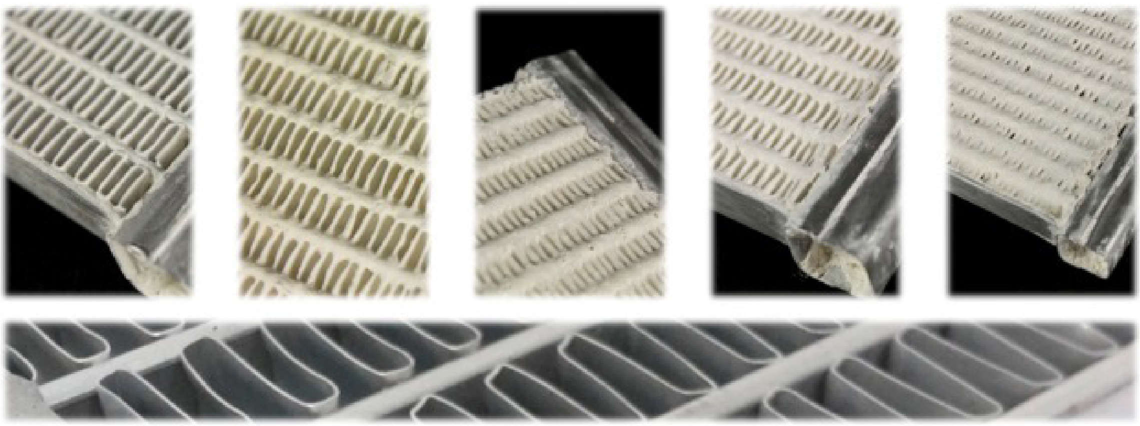

Figure 1. Coated adsorber heat exchangers for adsorption heat pumps. Binder-based coatings allow a flexible use of various adsorbents. Due to enhanced heat and mass transfer, both power density and COP can be increased significantly compared to adsorbers with adsorbent pellet beds.

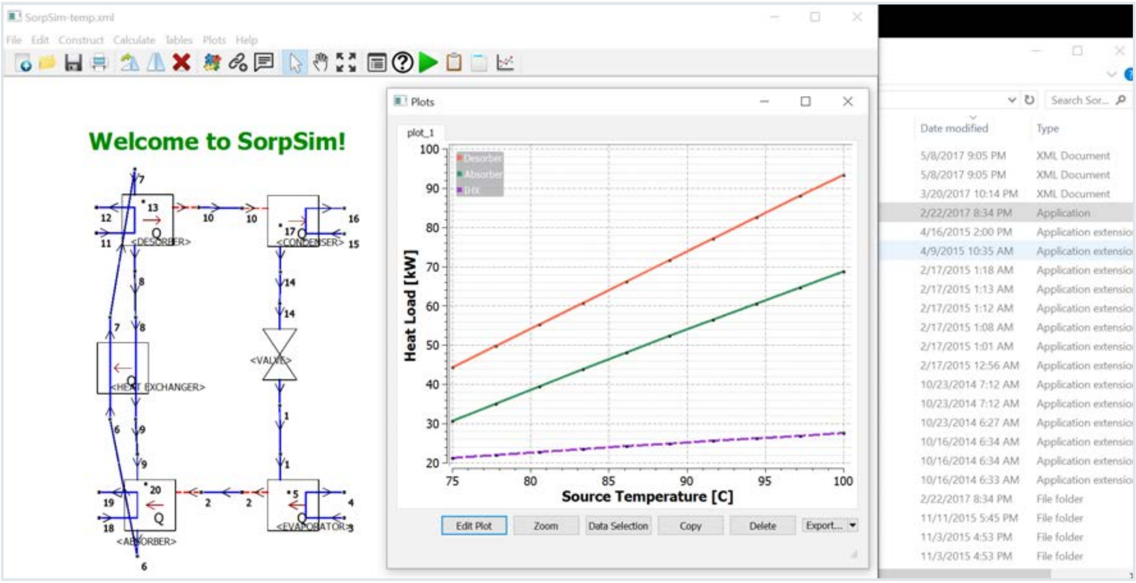


Figure 2. Screenshot of Sorption system Simulation program (SorpSim) developed by ORNL and Purdue University for flexible steady-state simulation and analysis of a wide range of sorption cycles with user-friendly features and parametric analysis functions. The isotherm database SorpPropLib, developed with input from Annex 43 participants, will be dynamically linked as an external library to SorpSim, supporting simulation and isotherm inquiry function in the SorpSim Graphical User Interface (GUI).

## 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 for a range of climates, countries and building standards;
- identify the most suitable 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.

## RESULTS

Several new adsorber concepts have been developed by the partners in the annex, such as a new active carbon type by the University of Warwick and a new zeolite coating by Fraunhofer ISE shown in Figure 1, and described in detail in the paper under "Publications".

Another outcome of the annex is the integration of several new working pairs for sorption heat pumps in the open source software SorpSim. This is developed by ORNL and Purdue University, and allows users to evaluate the effects of new materials for sorption heat pumps. See Figure 2. In addition, several types of gas driven heat pumps or water heaters are undergoing field tests to prove their performance and reliability. Examples are the equipment from Bosch and Stone mountain Inc.

**Project duration:**
October 2013 – December 2018


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ANNEX

# 44

# PERFORMANCE INDICATORS FOR ENERGY EFFICIENT SUPERMARKET BUILDINGS

In the supermarket environment there is a clear trend that more and more monitoring systems are installed, typically to secure and validate food quality, for example to measure temperatures 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.

> ***A supermarket is energy efficient when its total energy consumption is below 400 kWh/m² per year.***

Performance indicators are needed to transform available data into knowledge on the energy efficiency of a supermarket building. Such indicators are, for instance, supermarket size, opening hours, outdoor climate, etc. In this Annex, performance indicators have been defined that make it possible to evaluate 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 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. The work in the Annex has relied on measured data from the field, and not so much on theoretical and/or computer models. The results are intended for practical use in the field, and are useful even when only the most fundamental performance indicator – the supermarket size - is known.

Figure 1. Refrigeration accounts for close to 50 % of the electrical energy consumption of a supermarket.

Figure 2. The refrigeration system of a supermarket is often used as a heat pump, also providing hot water and space heating for the sales area.

## OBJECTIVES

- To create key performance indicators for energy efficient supermarket buildings, so that measurements and monitored data can be converted into knowledge concerning the energy performance of supermarket buildings;
- to create knowledge about the energy efficiency of supermarket buildings from measurements and monitored data. This knowledge is useful for decision making, benchmarking and development of energy efficiency strategies for supermarket buildings;
- to provide an estimate for the energy consumption of a supermarket, based on a number of performance indicators. With only one performance indicator used, the energy consumption will be a first, gross estimate, but with more performance indicators used, the estimated energy consumption will be more precise.

## RESULTS

- An average energy intensity of 400 kWh/m$^2$ per year is found for supermarkets in Denmark, Sweden and The Netherlands, with an average total area of 1360 m$^2$ and 73 opening hours per week, see Figure 3. Corrections are available for differences in size and opening hours.
- A supermarket is energy efficient, compared to supermarkets from Denmark, Sweden and the Netherlands, when its total energy consumption is below 400 kWh/m$^2$ per year.
- Based on the available measured data, no relation could be found between the total energy consumption (heat and electricity) and the geographic region of the supermarkets; nor did additional computer modelling reveal such a relation for this case.
- The original idea was that when more performance indicators are known, the resulting evaluation would be more precise, but it was found to be more difficult than expected to extract "secondary" performance indicators from field data. To obtain more secondary performance indicators, an approach based on modelling in addition to verification measurements is recommended.
- Developments, especially in refrigeration systems and lighting, lead to an increase of energy efficiency in new or refurbished supermarkets ranging from 1-10 % per year. Thus, refurbishment is effective in order to increase energy efficiency.

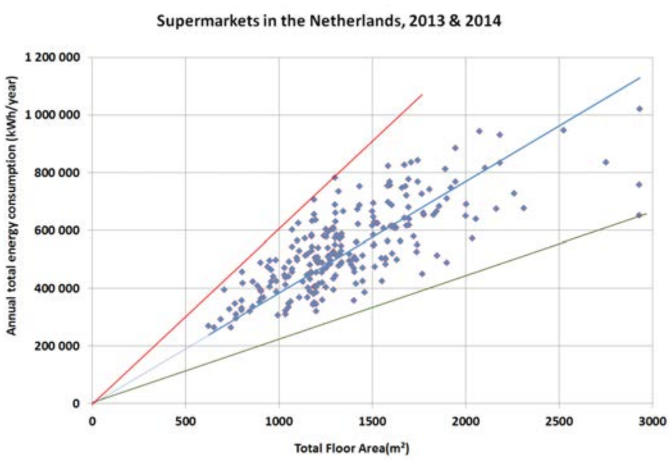


Figure 3. The distribution of the total energy consumption of a collection of supermarkets from the Netherlands shows that the total annual energy consumption can vary considerably for supermarkets of the same size. The red line denotes the least efficient supermarket (56 % above average energy consumption), the green line denotes the most efficient supermarket (42 % below average energy consumption).

**Project duration:**
June 2013 – June 2017

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ANNEX

45

HYBRID HEAT PUMPS

Heat Pump and Fossil Fired Boiler as Hybrid Heat Pumps

The heating market is in general still dominated by gas-fired appliances, but increasingly turning to more sustainable options. Replacement markets are 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 feasible for installation of heat pumps covering 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 introduce and quickly increase the usage of renewable energy in these conservative markets.

This market has shown rapid growth in several European countries. Figure 1 shows the development of the Dutch heat pump market over the last years. The growth is mainly driven by an increase in hybrid systems output.

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

Accordingly, this offers far more rapid CO2 emission reductions, for instance by 'hybridizing' existing installations by adding a heat pump to an existing boiler. This opens up untapped opportunities for a more significant usage of renewable energy in the short term, without any 'lock-in risk' for future technologies. 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.

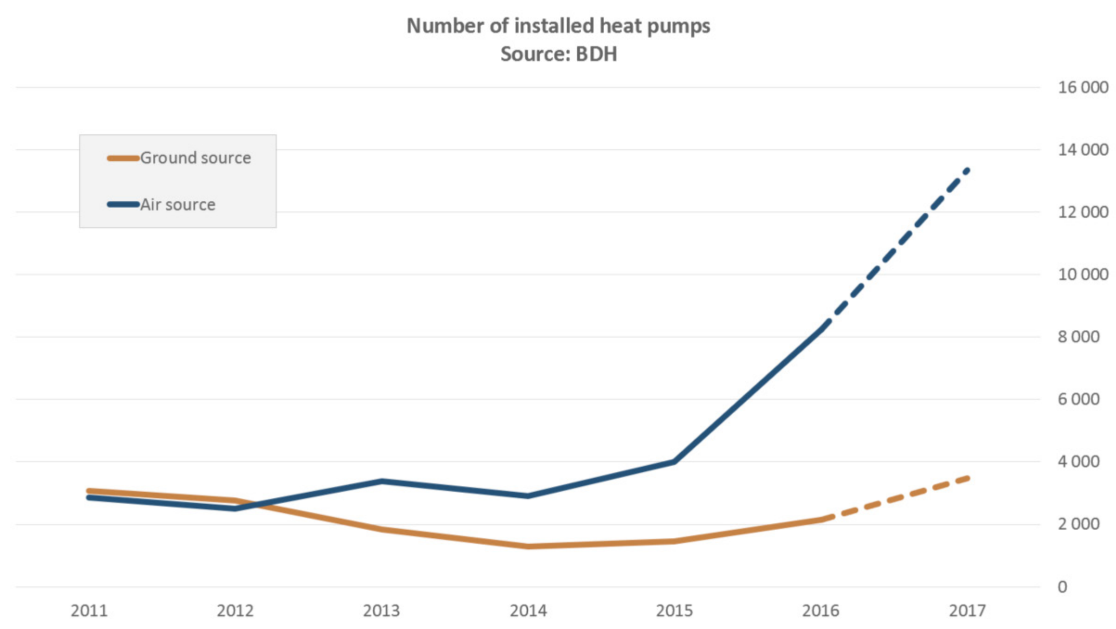


Figure 1. Development of the Dutch heat pump market.

Annex 45 gives a perspective on the possibilities for implementation of hybrid heat pumps in potential markets. Its focus is on combinations between the (electrical) heat pump and fossil fuel driven boilers (oil or natural gas) in the residential sector and light commercial sector, packaged in a configuration or as an integral unit.

**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 is 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**

A new result in 2017 was comprehensive modelling of optimal heating appliances for use in the French domestic market. EdF has convincingly shown the potential of hybrid heat pumps within the landscape of  heating options. On economic considerations, hybrid systems score better than both electric heating and oil boilers - two of the standard heating systems in France - for four regions in France.

The Island of Ameland in the Netherlands (1800 houses) goes 100 % renewable, mainly due to hybrid heat pumps in combination with locally produced green gas. The municipality of Ameland, the local housing corporation and installers on the island are supported by Liander, TNO and GasTerra to start a joint initiative to make the island independent from fossil energy in 2030.

ENECO, Dutch energy supplier, will offer very compact exhaust air heat pumps to its energy clients in a total package, with advanced controls and services. The aim is to implement a significant number of installations within a few years. These systems will cover a significant part of the users' heat demand, the rest being supplied by the already present gas boiler. Thus an 'easy-entry' hybrid system can be added to existing heating installations.

With a group of end-users in Groningen, the Netherlands, results from hybrid heat pumps are monitored based on actual energy consumption data. The outcome of these field measurements should offer a better estimate on the energy performance to be expected in the daily practice from hybrid heat pumps (exhaust air and ambient air source).

**Project duration:**
September 2015 – August 2018

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ANNEX

# 46

## DOMESTIC HOT WATER HEAT PUMPS

The domestic sector energy consumption is mainly concentrated around space heating and hot water demand. Due to new building regulations and energy efficiency measures, in the future, space-heating demands will decrease, by inherently better insulation. But domestic hot water demand will remain relatively constant or even increase as a consequence of higher comfort. Thus, due to strict legislation on energy performance, domestic hot water may dominate the overall energy use in houses. Domestic hot water will set the requirements for the dimensioning of the overall heating systems for low energy domestic houses.

Heat pump markets and policy in many countries have focused 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 reductions of $CO_2$ emissions. An efficient domestic hot water system can be based on a high performance heat pump. However, the overall system efficiency depends on more than the efficiency of the generator alone. The benefits of an efficient energy generation device such as a heat pump can be nullified by poor system integration and large storage or distribution losses. This makes the choices for the efficient heating of domestic hot water for new buildings and renovation a challenge.

***"Sustainable domestic hot water production with heat pumping technology will become a dominant energy demand in the domestic infrastructure"***

Many concepts are still based on the traditional method of installation. For Nearly Zero Energy new buildings, the placing of the heat generator can be non-traditional next to the kitchen or bathroom. For the large renovation market such a solution is less feasible, and standardized renovation packages should be developed. Some of these are already realized. For Multi-Family Buildings the solution can be more complex with existing collective systems for domestic hot water (DHW). The replacement of these collective systems by individual domestic hot water heat pumps or semi-collective booster heat pumps is one of many options under survey. Other combinations with air-conditioning-systems or solar thermal systems and solar photo-voltaic systems are a possible extension for this annex.

Annex 46 will be implemented by developing and sharing knowledge on performance optimization, high-efficiency construction and proper implementation of this specific type of heat pump.

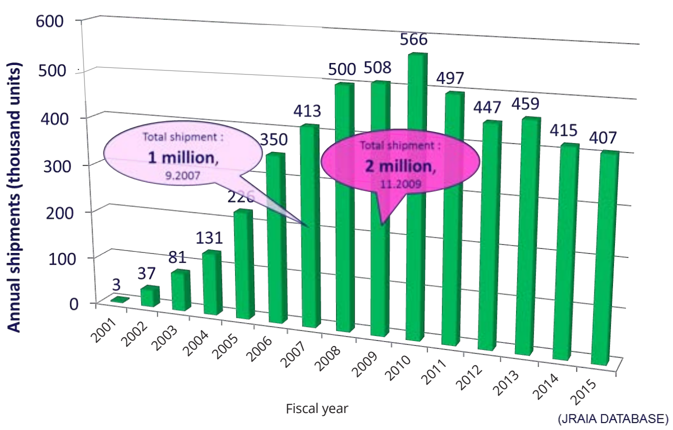


Figure 1. Task 1 report on the Market development of Eco Cute in Japan

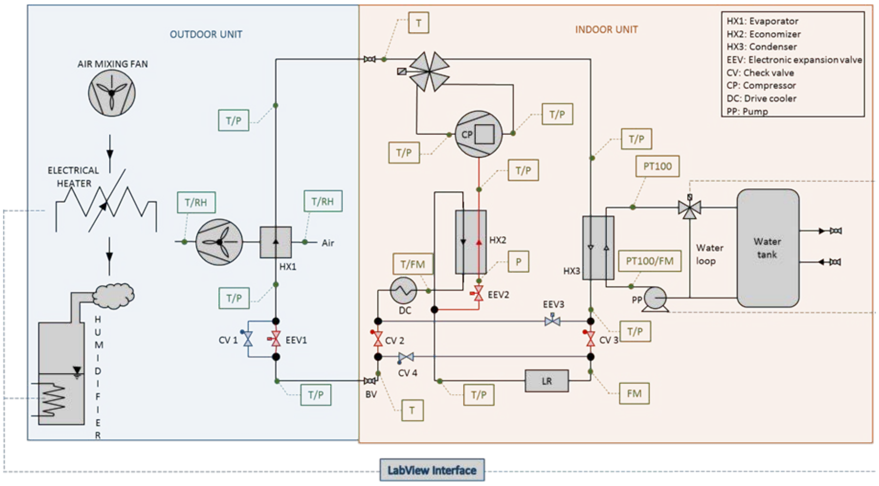


Figure 2. Modelling domestic hot water systems

**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, by delivering:

» A scenario for future developments based on a market analysis;
» A calculation model for the objective comparison of domestic hot water systems and concepts with heat pumps and/or other technologies;
» Deeper insight into the use of domestic hot water as a base for test and standardization;
» A roadmap on Research and R&D and new concepts in practice and research, supported by monitoring results;
» A web-based information platform with information market approach and training courses of participating countries.

**PROGRESS**

The market overview reports of participating countries have been summarized. An important deliverable is an overview of national policies and market developments.

An important conclusion is that the use of hot water is a fairly unknown figure, creating uncertainty for the overall design of a DHW system. Often, capacities are too large and storage tanks significantly oversized, giving unnecessary energy losses and relatively low overall SPFs. Good, well-designed systems can have SPFs as high as 4.0 for domestic hot water heat pumps.

Regarding modelling, two models are available. One model for stratification is now being tested by the annex participants. This topic, stratification/thermocline in storage tanks, has been a research topic for a number of years with solar thermal systems, but not so much with heat pumping technologies.

An overview of R&D in participating countries and other countries, such as China, Germany, Austria and Sweden, is underway. Two important levels of R&D are discerned:

» R&D at institutes and universities with a longer term focus, often fundamental;
» Development with heat pump manufacturers, more focused on market needs.

In connection to the 12th IEA Heat Pump Conference, Annex 46 participants organized a workshop on the combination of solar energy and heat pumps, related to thermal energy storage. This workshop can be seen as a great added value to the Annex, deepening the relation with solar energy. There is a synergy between solar energy and heat pumps; the market is mostly interested in the photovoltaic-heat pump combination.

**Project duration:**
August 2015 – July 2018

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ANNEX

47

# HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS

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.

> ***There is a large potential for Heat Pumps in District Heating Systems. Heat savings can cost-effectively reduce the heat demand in Europe by 30-50 %***

A growing number of countries have realized that district heating is a way to phase out fossil fuel. An example is Denmark, where several systems have been implemented.

**OBJECTIVE**

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.


Figure 2. Some case studies from task 2.

**PROGRESS**

Country reports describing the market and energy reduction potential have been made for Denmark, Switzerland and Austria. They all show that there is a large potential for heat pumps in existing District Heating systems, in both large central plants, large decentralised plants and in small decentralised plants. However, district heating competes with biomass in the scenarios for the future.

A total of 29 different cases with implementation of heat pumps in District Heating Systems have been described, and the final number will be around 40. The different cases will all be assembled in an inspiration catalogue, where planners of new projects can gather information and inspiration regarding different solutions with different heat sources, and for different District Heating Grids.

**Project duration:**
January 2015 – December 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 two 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.

***"The findings of this annex confirm that heat pumping technologies are already today a key technology for commercial and industrial processes"***

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.

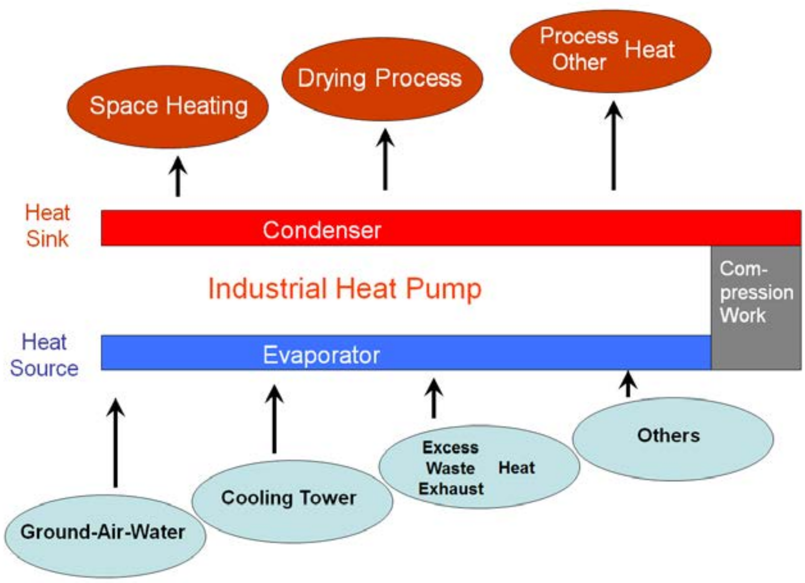


Figure 1. Possible heat sources and heat sinks for industrial heat pumps.

**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.

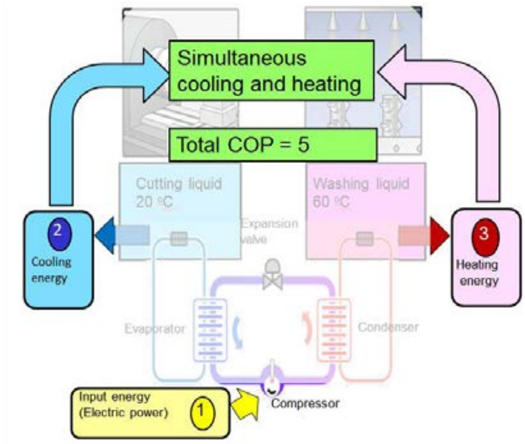


Figure 2. Application of heat pumps to cutting and washing processes.

**PROGRESS**

Case studies in different industry segments and countries have been compiled, structured by performance of heat pump as well as installed power, and environmental and economic aspects. A methodology to evaluate best practice has been designed. Japan alone has listed nearly a hundred good practices. In this way, the Annex can provide the affluent information on IHPs that is required by stakeholders.

Application of heat pumps to cutting and washing processes was shown as the best practice of machinery industry in Japan. To begin with, a heat pump for a washing process and a cutting process was installed in 2009. After the effect was verified through field tests, thirteen more heat pumps were installed in 2010. These fourteen heat pumps consist of six cooling/heating type machines with a heating capacity of 22 kW, and eight heating-only type machines with a heating capacity of about 44 kW. The heat pump has a total COP of 5 under simultaneous cooling and heating, and can accommodate unbalanced cooling and heating demands.

The findings of this annex confirm that heat pumping technologies are already today a key technology for commercial and industrial processes.

**Project duration:**
April 2016 – March 2019

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ANNEX

49

# DESIGN AND INTEGRATION OF HEAT PUMPS FOR nZEB

As of January 2019, all new public buildings will have to fulfil the requirements of a nearly Zero Energy Buildings (nZEB), and by 2021, all new buildings in the EU shall comply with nZEB requirements, according to the recast of the EU Energy Performance of Buildings Directive (EPBD). Also in the USA and Canada, as well as in Asian countries such as Japan and China, nZEB targets are to be introduced in the time frame between 2020 and 2030.

Thus, adapted building technology for different building uses, like residential or office use, is of high interest and will have to be provided by building and planning companies in the short term. In principle, the nZEB concept balances the energy consumption of the building with renewable energy generation on-site. Thereby, the transition of the building to a prosumer comprising both energy consumption and energy generation on-site is made. Despite this principal concept all across the EU, nZEB criteria and definitions vary among the EU member states. Policy maker will have to shape the requirements in order to drive the markets to high performance buildings which also contribute to energy generation by on-site renewables.
An archetype concept to reach nZE consumption is the combination of solar PV and heat pumps, a so-called all-electric building. Annex 49 will investigate the design and integration of heat pumps in nZEB in order to improve the performance of the building technology in terms of the energy- and cost-efficiency of system layouts. Since nZEB buildings as prosumers interact with connected energy grids, also the grid interaction is an important feature. Thus, energy flexibility by self-consumption, demand response capability and grid supportive operation may be subjected to additional requirements for future building system technology. Therefore, design and control will be important features to enable buildings to interact with the connected energy grids, at the single building level as well as at neighbourhood or district level.

> ***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.***

**OBJECTIVES**

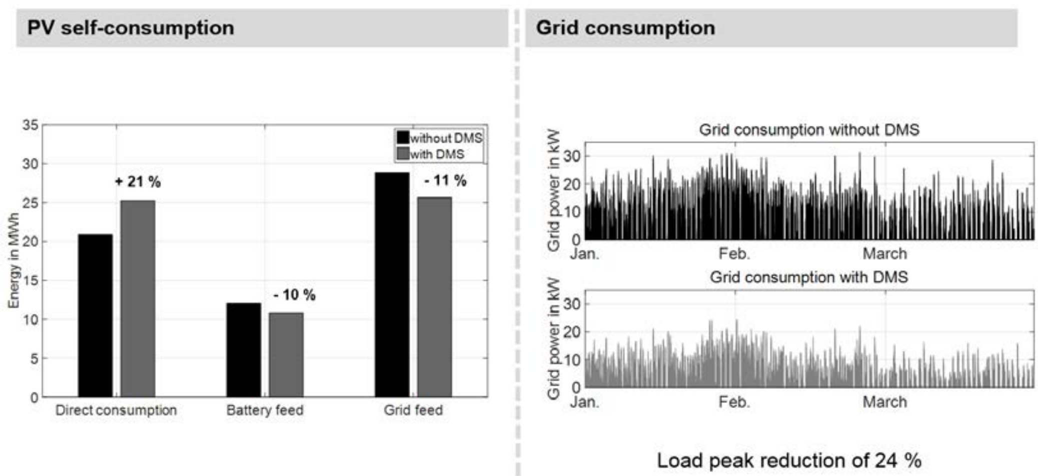


Figure 1. Simulation results of load management of heat pump and storage for grid supportive operation in the project HerzoBase of TH Nuremberg.

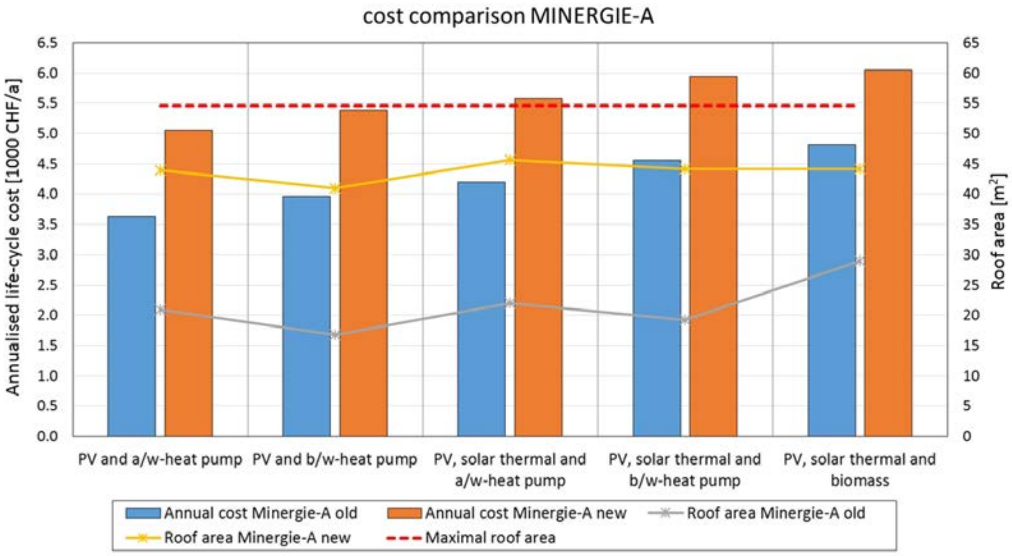


Figure 2. Comparison of old and new Net Zero Energy Building requirements according to the Minergie-A label regarding annualised system cost of different heat generation systems.

- » 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.

## PROGRESS

In Germany, control strategies for a group of eight plus-energy single family houses have been studied by simulation, Figure 1. The system consists of two central capacity-controlled heat pumps for space heating connected to a low-temperature heating grid, and decentralized domestic hot water storages with booster heat pumps. Simulations studies confirm that by load management of the heat pumps and connected central and decentral storages, grid interaction is decreased and peak load can be reduced by 24 %. In the USA, field test of integrated air-source heat pump prototypes have been concluded. The measurements showed a 35 % reduction compared to standard technology, fulfilling the current energy requirements. It is expected that in near zero energy ready buildings 40-60 % reduction can be reached. In Switzerland, new requirements for Net Zero Energy Buildings according to the MINERGIE-A label have been evaluated, Figure 2. Due to the change of balance boundary from the building technology to the total energy including plug loads, system costs for single family houses have increased, but heat pumps are still among the most efficient and cost-effective solutions for single family houses. Evaluations will be continued for other building types. Furthermore, a definition of nZEB within Annex 49 has been discussed and a simulation framework to compare systems solutions has been set up.

**Project duration:**
October 2016 – November 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 multifamily 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.

Figure 1. A multi-family building in Weiz, Austria which has been constructed in 2014/15. It consists of 10 apartments on three floors, a 957 m² heated floor area, and it conforms to the passive house standard (wood frame construction, floor heating system, controlled ventilation with heat recovery).

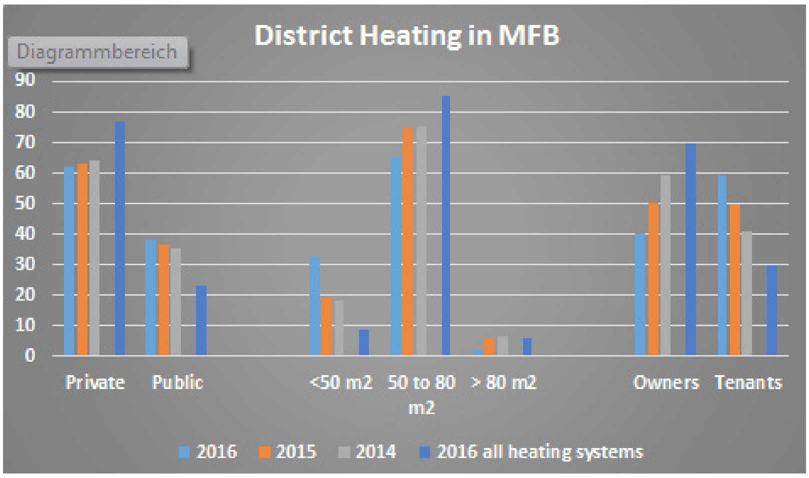


Figure 2. Task 1 is in progress. The illustration serves as an example for multi-family buildings in France. Almost 225 000 flats were built in 2016 (+6.6 % compared to 2015). Most of these multi-family buildings are private ones for owner-occupiers, with an average floor area of 61 m².

## 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 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 chores, 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

To further increase the acceptance of heat pumps, reduction of acoustic emissions is important. To minimize noise annoyance, more focus must be put on the acoustic emissions at steady state and on the transient behaviour of acoustic signatures during different operating conditions. Especially, air to water heat pumps provide a convenient and effective way to exploit potential energy savings and are often used in retrofit installations making acoustic improvements crucial for both the new and retrofit markets.

In Annex 51, acoustic emissions are covered in a hierarchical approach considering the following levels: the component level (low noise components), the unit level (system approach of combining the components, unit control, transient acoustic features) and finally the application level (building and neighbourhood including smart grid, psychoacoustic effects and acoustic propagation). In Task 2, three appliances are selected and will consecutively be characterized by the participating institutes.

Options for noise measurement techniques (see figure 1) for improved understanding, measuring and description of the acoustic performance are an important focus of Annex 51. Seen from a global perspective, the current legislation (gathered and summarized in Task 1) – serving the needs of the different locations – varies considerably between countries. The Annex will contribute to guidance and future standards (see figure 2) in this field in the short and long term, to help in harmonizing the different local approaches for the benefit of all involved stakeholders.

Good acoustic design and construction of the units should not be compromised by bad installations. Therefore, training and education are of utmost importance in heat pump acoustics (placement, noise reduction measures, modes of control and operation, see figure 3). Guidelines are prepared for component and heat pump manufacturers, heat pump testing laboratories, engineering consultants, installers and designers. Participants of the Annex will contribute by presenting and discussing the results of their heat pump-related acoustic research projects.

> ***Acoustic guidelines are prepared for heat pump manufacturers, testing laboratories, engineering consultants, installers and designers.***

**OBJECTIVES**

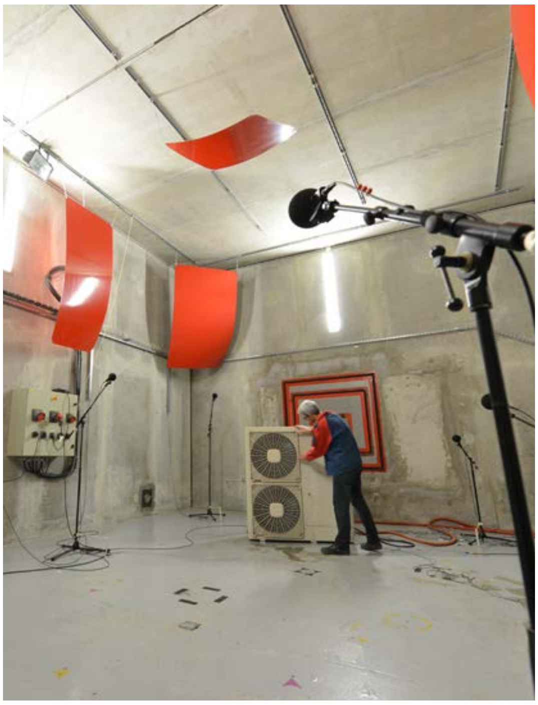


Figure 1. Outdoor HP unit installed in CETIAT's double reverberant room.

» 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; one meeting (Austria, June 2017) held, two planned (France, January 2018, Sweden, June 2018)
» Organization of a concluding international workshop and compilation of proceedings; planned at Mostra Convegno 2020
» Worldwide dissemination to heat pump manufacturers via already available dissemination media
» Acoustic Guidelines for the different levels (Component Level, Unit Level, Application Level).

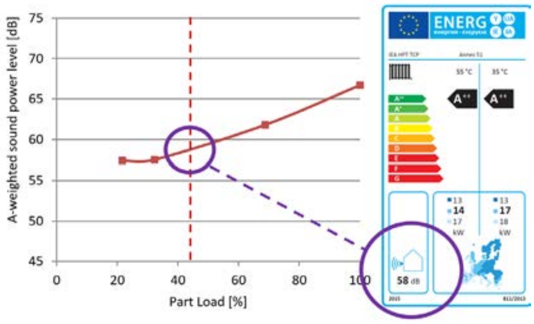



Figure 2. The Energy Label states an outdoor noise level of 58 dB, which is only part of the story.

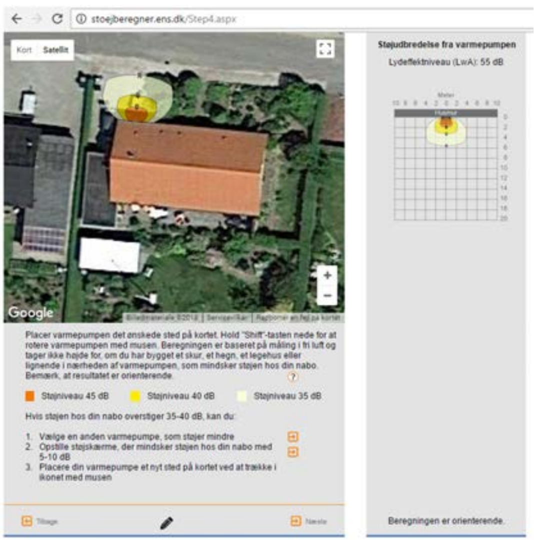



Figure 3. Visualization of the sound power level of a heat pump using the "Heat Pump Sound Emission Calculator" of the Danish Energy Agency.

**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 subsequently measured during the runtime of the annex in different laboratories.

***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***

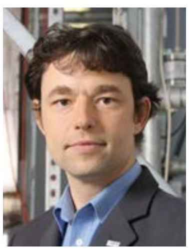
Focusing on acoustic perception, heat pump installation and its environmental effects.

***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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ANNEX
# 52

# LONG-TERM MEASUREMENTS OF GSHP SYSTEM PERFORMANCE IN COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS

Measured long-term performance data for ground source heat pump systems (GSHP systems) serving commercial (Fig. 1), institutional (Fig. 2) and multi-family 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.

Annex 52 will bridge the gap between those who see the heat pump system as a complex environment and the ground source as a black box, and those who see the ground source as a complex environment and the heat pump system as a black box.

Annex 52 aims to survey and create a library of quality long-term measurements of GSHP system performance for commercial, institutional and multi-family buildings. All types of ground sources (rock, soil, groundwater, surface water) are included in the scope. While previous work will be surveyed, the emphasis of the annex will be on recent and current measurements. The annex also aims to refine and extend current methodology to better characterize GSHP system performance serving commercial, institutional and multi-family buildings with the full range of features shown on the market, and to provide a set of benchmarks for comparisons of such GSHP systems around the world. Timeline for the Annex 52 is shown in Figure 3.

***"Annex 52 will develop performance measurement methods that maximize efficiency of ground source heat pump systems, saving energy and money."***

Analysis procedures that help diagnose poor performance and opportunities for system performance improvements will be investigated. Multiple case studies featuring GSHP system performance measurements for systems around the world will be included and these case studies will serve as reference sets for future benchmarking.

The results from the annex will help building-owners, designers and technicians evaluate, compare and optimize GSHP systems. It will also provide useful guidance to manufacturers of instrumentation and GSHP system components, and developers of tools for monitoring, controlling and fault detection/ diagnosis. This will lead to energy and cost savings.


Figure 1. ASHRAE HQ, Atlanta, USA. A commercial building with an on-going monitoring program.

Figure 2. Studenthuset, Stockholm, Sweden. An institutional building with an on-going monitoring program.

**OBJECTIVES**

- » Survey and create a library of quality long-term measurements of GSHP system performance for commercial, institutional and multi-family buildings. All types of ground sources (rock, soil, groundwater, surface water) are included in the scope.

- » Refine and extend current methodology to better characterize GSHP system performance serving commercial, institutional and multi-family buildings with the full range of features shown on the market, and to provide a set of benchmarks for comparisons of such GSHP systems around the world.

- » The guidelines provided by the SEPEMO project will be refined and extended to cover as many GSHP system features as possible, and will be formalized in a guidelines document.

**OVERVIEW OF TASKS**

***Task 1. Long-term measurement case studies – new and previous***

- Compile an annotated bibliography covering past GSHP system performance studies
- Prepare report covering a number of case studies of GSHP performance monitoring projects in the participating countries, showing various climatic conditions, building types and system configurations

***Task 2. Guide for instrumentation and measurement of GSHP systems***

- Reach consensus on necessary instrumentation and monitoring
- Prepare guideline document on instrumentation and measurement of GSHP system performance

***Task 3. Guide for analysis and reporting of GSHP system performance data***

- Reach consensus on key parameters and analysis procedures for GSHP system performance monitoring
- Prepare guideline document on analysis and evaluation reporting of GSHP system long-term performance

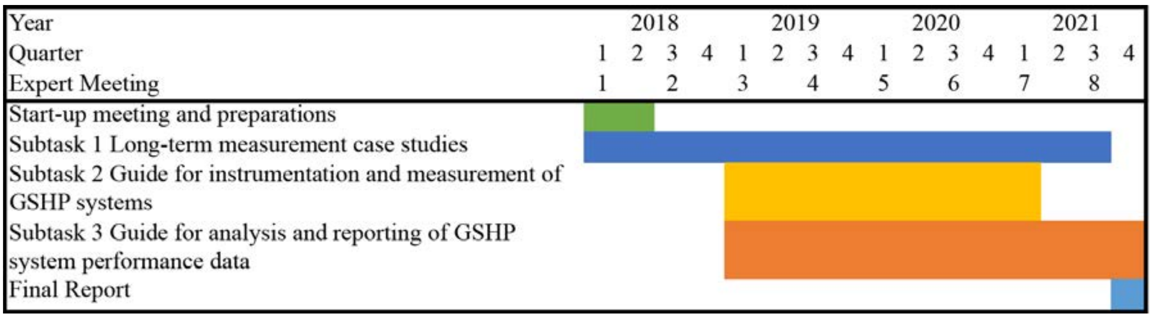


Figure 3. Timeline for Annex 52.

**Project duration:**
January 2018 – December 2021

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# Outlook into the Future

During 2017 the ExCo of the HPT TCP submitted a request for a five year extension of the programme to the IEA Committee on Energy Research and Technology (CERT), which was presented for the EUWP (End Use Working Party) in September. In February 2018, extension of the programme was approved for the period 2018-2023. In conjunction with the preparation work for the request for extension, the vision, mission and objectives of the TCP were revised and an updated strategy work plan for the TCP was elaborated. The Vision and Mission of the HPT TCP are as follows:

**Vision of HPT TCP**
Heat pumping technologies play a vital role in achieving the ambitions for a secure, affordable, high-efficiency and low-carbon energy system for heating, cooling and refrigeration across multiple applications and contexts. The Programme is a key worldwide player in this process by communicating and generating independent information, expertise and knowledge related to this technology as well as enhancing international collaboration.

**Mission of HPT TCP**
To accelerate the transformation to an efficient, renewable, clean and secure energy sector in our member countries and beyond by performing collaborative research, demonstration and data collection and enabling innovations and deployment within the area of heat pumping technologies.

The updated strategy for the TCP includes performing RDD&D activities within the areas of heating, cooling and refrigeration for the building, community, transport and industrial sectors, while widening the scope to include the following points to a larger extent:

- Affordable and competitive technologies for heating;
- More efficient cooling and air-conditioning, especially in warm and humid climates;
- Flexible, sustainable and clean system solutions (e.g. in urban areas) using combinations of heat pumping technologies with energy storage, smart grid, solar and wind energy, thermal networks, energy prosumers, etc.;
- Possibilities offered by the developments in the area of digitalisation and Internet of Things;
- New or special markets and applications, including automotive, industry and consumer products (e.g. white goods);
- New, alternative or natural refrigerants with lower global warming potential, high thermodynamic potential and low toxicity for both new and existing applications.

 

Also during 2017, one new annex within the programme was approved, “Long-term Performance Measurements of GSHP Systems Serving Commercial, Institutional Buildings and Multi-family buildings". The Annex will start in January 2018 (see page 44-45).

Another well-developed proposal for the TCP is an annex about “Advanced cooling / Refrigeration Technologies”. The background to this is that the IEA projects that energy consumption for air conditioning (AC) will increase by 4.5 times by 2050 compared to the 2010 levels for non-OECD countries, vs. 1.3 times for OECD countries. Similarly as for AC, the demand for refrigeration is expected to increase significantly, particularly in the non-OECD world. Most of the demand for refrigeration is related to food preservation and storage, and demand for food is expected to grow by 70 % by 2050, relative to 2010. However, a huge increase in refrigerated transport capacity is needed to properly serve warehouse capacity and reduce food waste. The primary objective is to develop advanced (higher efficiency and lower GHG emission) AC/refrigeration-focused heat pump technologies and promote their deployment to reduce the projected major growth in cooling-related energy consumption anticipated in the coming decades. The principal technology focus areas include advanced traditional vapor compression cycle approaches, alternative compression technologies, and non-traditional cycle approaches.

Other ideas and proposals for new Annexes in line with the new strategy work plan that have been decided to be elaborated further within the TCP are “How to improve the channel between manufacturer and end-user, to extend the good use of heat pumps”, “Internet of Things for Heat Pumps”, “HP systems with low GWP refrigerants”, as well as ”Energy storage with heat pumps in smart energy grids” and “Comfort climate box”, both with connection to the Mission Innovation initiative.

The HPC has been commissioned by the ExCo to coordinate collaboration of the IEA and Mission Innovation activities related to challenge #7 Affordable Heating and Cooling of Buildings Innovation Challenge, as well as other possible challenges.

Further, the TCP will work on attracting new member countries that are key partners or associate members of the IEA, addressing new markets as well as more climate zones. The programme will also contribute to advanced and/or disruptive innovation through cross-cutting networking and collaboration with other TCPs and relevant organisations, and provide IEA and standardisation organisations with reliable and independent guidance, data and knowledge about heat pumping technologies, separately or in combination with other technologies. The TCP will communicate the results and impact from the RDD&D work, tailor the messages using appropriate channels to reach relevant target groups, including policy makers, national and international energy and environmental agencies, utilities, manufacturers, system designers, industry associations, researchers and end-users.

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