# ANNUAL REPORT 2018

## HEAT PUMPING TECHNOLOGIES

Technology Collaboration Programme on Heat Pumping Technologies - HPT TCP

iea Energy Technology Network

International Energy Agency

IEA HPT

Technology Collaboration Programme on Heat Pumping Technologies

# Image sources

**Front page**

- Clean Energy Week in Malmö, May 2018, HPC
- ExCo meeting in Malmö 2018, May 2018, HPC
- Heat Pump Symposium in Ghent, Belgium, October 2018, HPC
- IEA TCP national coordination day in Prague, Czech Republic, October 2018, HPC
- ExCo meeting in Brussels, October 2018, HPC

**HPT TCP (p. 6-7)**

- iStock Photo
- Illustration, HPC

**Highlights (p. 8)**

- Heat Pump Symposium in Ghent, October 2018, HPC
- Clean Energy Week in Malmö, Sweden, May 2018, HPC

**13th IEA Heat Pump Conference (p. 10-11)**

- NOC of the 13th IEA Heat Pump Conference
- www.pexels.com

**HPT TCP Annexes**

- p. 20 - University of Warwick
- p. 23 - BDH
- p. 26 - Heat Pumping Technologies
- p. 27 - Collage HPC
- p. 28 - CRIEPI, Chillventa 2018
- p. 29 - The IEA HPT Annex 48 team
- p. 30 - JRC EU, 2016
- p. 31 - UIBK
- p. 32 - BWP (Bundesverband Wärmepumpe (BWP) e.V.), Fraunhofer ISE
- Fraunhofer ISE
- p. 34 - The IEA HPT Annex 51 team
- p. 35 - AIT Austria, CETIAT France
- p. 36 - Skanska
- p. 37 - XYLEM
- p. 38 - Graphic courtesy Navigant Consulting, Inc. and US Department of Energy Building Technologies Office, Emerging Technologies Program
- p. 39 - University of Maryland
- p. 40 - Ozone Action Fact Sheet, OZFS/16/11-1
- p. 41 - US EPA, 2014

**Outlook into the Future (p.46)**

- Pexels
- Clean Energy Week in Malmö, Sweden, May 2018, HPC
- Comfort and Climate Box workshop, January 2019, HPC

---



**HPT TCP Annual Report 2018**

***www.heatpumpingtechnologies.org***

April 2019

# Content

# Message from the Chairman

Our new Strategic Work Plan (see page 6-7) and the request for extension for the period 2018 to 2023 were approved by the IEA Committee on Energy Research and Technology (CERT) in February 2018. This means that we can continue our international collaboration among sixteen countries with ten ongoing Annexes (projects) in the field of heat pumping technologies. The Strategic Work Plan aims to tackle the expected future challenges and to contribute to the IEA's Sustainable Development Scenario. In order to achieve this, we must widen our scope and enter new areas of technology, as well as improve the collaboration within the IEA Energy Technology Network, and with external partners.

I am happy to report that already during the first year of the new term we have been able to prepare and launch Annexes in nearly all our strategic areas.

In the so far primary field of our activities, *affordable and competitive technologies for heating*, we launched an Annex with the aim to develop an integrated heating and cooling system. This Annex, Comfort and Climate Box (CCB), combines heat pumps and storage systems for improved energy efficiency and better economics. The project was established together with the IEA Technology Collaboration Programme on Energy Storage (ECES TCP) and will contribute to Mission Innovation Challenge #7: Affordable Heating and Cooling of Buildings. It is expected that more TCPs will collaborate and that projects will be supported by Mission Innovation funding.

A rather new field of activities of the HPT TCP is the *development of more efficient cooling and air-conditioning systems, especially in warm and humid countries*. This is of high relevance, since according to IEA Executive Director Fatih Birol's foreword in The Future of Cooling report (2018) "The world faces a looming cold crunch". By initiating the Annex 53 Advanced Cooling / Refrigeration Technologies Development we contribute to this important strategic area of action.

The Annex Heat Pumps in Multi Vector Energy Systems is in preparation and will contribute to the strategic area *flexible, sustainable and clean system solutions (e.g. in urban areas)*. It will be a follow-up of the Annex Heat Pumps in District Heating and Cooling Systems. A technological challenge is the integration and effective use of the *opportunities offered by digitalisation and Internet of Things* in heat pumping technologies. An Annex with this topic is prepared and will be launched during spring 2019. The new Annex 54 Heat Pump Systems with Low GWP Refrigerants is already well on track, and contributes to the strategic area *new, alternative or natural refrigerants with lower global warming potential, high thermodynamic potential and low toxicity for both new and existing applications.*

The only strategic area in which we have not drafted a proposal during this first year of the new term is *new or special markets and applications, including automotive, industry and consumer products (e.g. white goods).*

In addition to these technology-related efforts, communication and collaboration are highly important areas of action in the new strategy. We continue to improve our website and the HPT Magazine, and are active on LinkedIn and Twitter. During 2018 we had promising contacts with several countries interested to become members of HPT TCP.

The new European General Data Protection Regulation (GDPR) caused some additional challenges and was a setback for us. We had to cut the links to many of our former subscribers and readers, and significant effort was spent to recover our level of outreach.

To enter into new areas of technology, intensifying communication, and acquiring new Member Countries is only possible with highly motivated and experienced people collaborating in our TCP. I thank the operating agents and their experts in the Annexes, the staff of the Heat Pump Centre, and the ExCo delegates for contributing and supporting all these activities. My special thanks to the people of the IEA Secretariat and the IEA Energy Technology Network who support us. Finally, I would like to extend my appreciation to our member countries and their funding agencies. Without their financial support our activities would not be possible.

Stephan Renz, Chairman of the Executive Committee

# International Energy Agency

**About the International Energy Agency (IEA)**
The International Energy Agency (IEA) examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries, 8 association countries and beyond. The IEA's mission is guided by four main areas of focus: 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 Experts' 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, each covering a different group of technologies: energy end-use, fossil fuels, fusion power, and renewable energy. Each Working Party oversees 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 collaborative partnerships focused on a wide range of energy technologies. The TCPs are organised under the auspices of the International Energy Agency (IEA), but the TCPs are functionally and legally autonomous. Today there are 38 TCPs in operation with over 6 000 experts from around 300 public and private-sector organisations from over 50 countries. 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 revised the Strategic work plan for the Programme during 2018. The new one follows below.

## Strategic Work Plan 2018 - 2023

***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.

***Strategic Objectives***

» *Energy Security*
- Heat pumping technologies are frequently demonstrated and deployed in appropriate applications
- Heat pumping technologies are a key element in new cross-cutting, affordable solutions for heating and cooling

» *Economic Development*
- The innovation rate for heat pumping technologies is increased
- Capacity building is improved
- Cost-effective solutions are identified, demonstrated and accepted by end users

» *Environmental Awareness*
- More policy makers are aware of the potential of heat pumping technologies to fulfil the IEA's mission

» *Engagement Worldwide*
- HPT TCP has more member countries
- HPT TCP is an active player in, or partner to, other international initiatives and organisations

* IEA's Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP)

## Strategy

Advance the RDD&D* of heat pumping technologies through

- creation of research opportunities
- providing networking possibilities and meeting places for academia, industry, private sector markets and policy makers to collaborate under new Annexes (projects) and activities within the HPT TCP.

Perform 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 to a larger extent:

a. Affordable and competitive technologies for heating
b. More efficient cooling and air-conditioning, especially in warm and humid climates
c. 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.
d. Possibilities offered by the developments in the area of digitalisation and Internet of Things
e. New or special markets and applications, including automotive, industry and consumer products (e.g. white goods)
f. New, alternative or natural refrigerants with lower global warming potential, high thermo-dynamic potential and low toxicity for both new and existing applications

Contribute to advanced and/or disruptive innovations through cross-cutting networking and collaboration with other TCPs and relevant organisations.

Communicate the results and impact from the RDD&D work, tailor the messages using appropriate channels to reach relevant target groups.

Provide IEA and standardisation organisations with reliable and independent guidance, data and knowledge about heat pumping technologies.

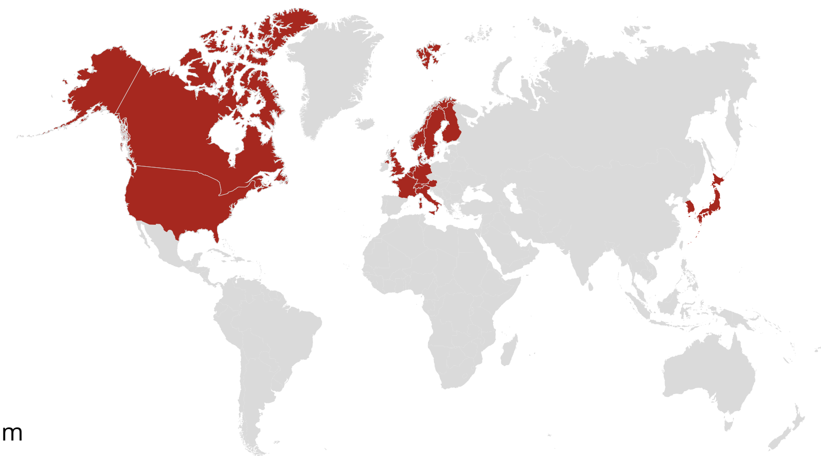
Increase activities to attract new members, including IEA key partner and association countries.

### *Activities*

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

**HPT TCP MEMBER COUNTRIES**

- Austria
- Belgium
- Canada
- Denmark
- Finland
- France
- Germany
- Italy
- Japan
- The Netherlands
- Norway
- South Korea
- Sweden
- Switzerland
- The United Kingdom
- The United States



* Research, Development, Demonstration and Deployment

# Highlights 2018

**Request for Extension of the HPT TCP**
In February 2018, the request for a five-year extension of the HPT TCP was approved by the IEA Committee on Energy Research and Technology (CERT) 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 strategic work plan for the HPT was elaborated (see page 6).

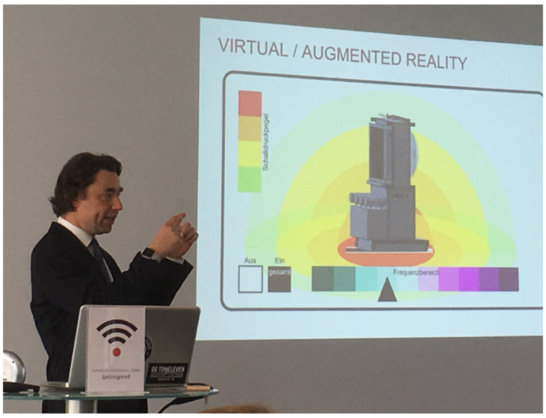
The cornerstones of the HPT TCP are the Annexes. In accordance with the revised strategic work plan, two new Annexes were approved in 2018: "Advanced Cooling/ Refrigeration Technologies" (HPT Annex 53, see page 38) and "Heat pump systems with low GWP refrigerants" (HPT Annex 54, see page 40).

Further, three other Annexes within the prioritized areas in the strategic work plan have been prepared, and will hopefully be started during 2019: "IoT for Heat Pumps", Comfort & Climate Box – Speeding up market development for integrating heat pumps and storage packages", and "Heat pumps in multi vector energy systems, second phase - Showing flexibility benefits through HP implementation in DHC networks".

**Executive Committee Meetings**
Two meetings of the HPT TCP Executive Committee (ExCo) were held in 2018:

- May 23-24, Malmö, Sweden
- October 11-12, Brussels, Belgium

**Cooperation with IEA groups**
Heat Pump Centre (HPC) represented the HPT TCP at the Building Coordination Group (BCG) meeting in Vienna, on January 25. All TCPs present reported on highlights and on ongoing and planned activities and projects. A workshop was held, aiming at prioritizing among the eighteen ideas that had been selected at the Future Building Forum, a cross-TCP initiative. HPT expressed interest in participating in two R&D clusters, combining ideas and using a systemic approach. The first cluster included the topics *Integrate passive design with active facades, Understand occupant behaviour, and Dehumidification solutions*. The second included *Guidance for planning and design of integrated infrastructures, Study big data, and Demonstrate state of the art of district cooling and integrated infrastructures*.
The SHC TCP organised a joint TCP meeting in Paris on March 26, where HPC represented HPT. Other participating TCPs were SHC, DHC, EBC, Bioenergy, the Industrial Energy-Related Technologies and Systems (IETS), and the Photovoltaic Power Systems Programme (PVPS). Also, the IEA and its Working Party on Energy End-Use Technologies (EUWP) were represented. All TCPs gave presentations, and TCP collaboration was discussed. In general, all TCPs are in favour of further collaboration. It was also pointed out by IEA that the ExCo delegates has a national responsibility to arrange national events for interaction and dissemination of outcomes from the TCP network projects and other relevant activities at the national level.




HPC participated in the IEA TCP national coordination day in Prague, on October 2. The aim was to discuss TCP participation of the Czech Republic, among them HPT TCP. Other TCPs present were DHC, SHC, and Bioenergy. During the meeting, IEA emphasized that cooling is one of the clean energy technologies that are not on track.

**Mission Innovation**

The Mission Innovation (*http://mission-innovation.net/*) is a global initiative of twenty-three 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.

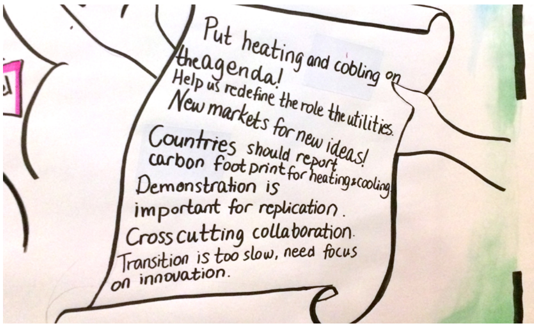
The IEA TCP Network has an infrastructure, procedures and large amount experts to be able to effectively contribute to the MI Initiative. The MI has established eight Innovation Challenges (IC). At an early stage, IC#7, "Affordable Heating and Cooling for buildings", was identified as being of particular interest to the HPT TCP. Within this, MI has identified heat pumps and storage as key technologies to focus on.

As a co-initiative between HPT and the Energy Storage (ECES) TCPs, the joint project Comfort and Climate Box was launched by the Chairman of HPT TCP, Stephan Renz. This was done during the Solution Summit, which was an official side event of the MI-3 meeting (see below), as the very first project within the MI Challenge #7. The Comfort and Climate Box is led by The Netherlands by financing the operating agent. The aim of the project is to construct a solution that can be used by various types of residential buildings all over the world. For this to succeed the solution must be smart, efficient and reliable. And maybe most important of all: it has to be affordable.

**Clean Energy Week in Malmö, Sweden, in May**

In May, the Clean Energy Week was arranged in Malmö, Sweden. This was organised in conjunction with the third Mission Innovation Ministerial (MI-3) and Ninth Clean Energy Ministerial (CEM9) meetings. In general, HPT TCP was broadly represented at the events, and an ExCo meeting was held during the week.

HPT TCP were co-organisers of the Arena for Sustainable Heating and Cooling. Representatives from industry, policy and research organizations met to inform each other and discuss sustainable solutions for low carbon and fossil free heating and cooling. One of the topics was the success story of heat pumps in Sweden and another the initiative of creating a fossil-free energy district introducing a local digital market place for energy. A third topic was recovery of heat from the ventilation air of the London Underground by a heat pump to heat apartments and schools. Some key messages were sent from the arena to the ministers at the ministerial meeting. Some of these were: "Put heating and cooling on the agenda!", and "Countries should report carbon footprint for heating and cooling and set up targets to be followed up".




**Heat Pump Symposium in Ghent, Belgium**

The Belgian organisation ODE Organisatie Duurzame Energie (the Organisation Sustainable Energy) and their WPP Warmepompplatform (Heat Pump Platform) organized a Heat Pump Symposium in Ghent, Belgium, in October. This was made in conjunction with the fall ExCo meeting and several of the ExCo delegates participated. The Platform for decarbing heat in Flanders, market statistics, outlooks and policies for countries within and outside of Europe were presented. In addition, the HPT TCP and three of its Annexes, Annex 49, 51 and 52, were presented.

# Welcome to the 13th IEA Heat Pump Conference



The 13th IEA Heat Pump Conference will be held in Jeju Island from Monday, May 11th through Thursday, May 14th in 2020. With the theme 'Heat Pumps – Mission for the Green World', we aim to address global climate change and discuss necessary actions.

**Previous Conferences**
The upcoming conference will be 13th of the series of conferences held by the International Energy Agency (IEA) Heat Pumping Technologies TCP (HPT TCP). Preceding conferences were held in Austria (1984), USA (1987, 2005), Japan (1990, 2011), The Netherlands (1993, 2017), Canada (1996, 2014), Germany (1999), China (2002), and Switzerland (2008). After successful histories in Japan and China, it is the fourth Heat Pump Conference to be held in Asia, and the first to be held in the Republic of Korea.

**Conference Venue**
The conference venue is Ramada Plaza Hotel Jeju located in Jeju City, easily accessible from Jeju airport. Jeju Island is a famous holiday destination in Southeast Asia, with beautiful beaches, volcanic mountains, and extra-ordinary cuisine. Home to the natural World Heritage Site, Jeju Volcanic Island and Lava Tubes, participants and those accompanying will certainly enjoy visiting the beautiful island. In addition to sightseeing opportunities, a variety of technical tours are planned.

**Conference Goal**
heat pumping technologies, as a reliable and confirmed technology, is the key equipment for energy savings and green-house gas reductions with its wide range of application to various energy sources. The upcoming conference will serve as a forum to discuss the latest technologies in heat pumping technologies, and exchange valuable knowledge in market, policy, and standards information on related technologies. Exhibitions will be held at the conference, to share products and technologies from domestic and foreign companies.

**Conference Topics**
Within the conference program, participants will encounter numerous cutting-edge presentations on the following issues:

- Recent Advances on Heat Pumping Technologies
- Environment-friendly Technology
- Systems and Components
- Field Demonstration and Multi-disciplined Applications
- Research and Development
- Policy, Standards, and Market
- International Activities

**Conference Structure**
Within the conference program, participants will encounter numerous cutting-edge presentations on the following issues:

- Keynote and Plenary lectures by renowned researchers
- Oral and poster presentations on innovative heat pump technologies, applications and markets
- Exhibitions of heat pumping technologies equipment
- Workshops on collaborative projects, connected to annexes in the HPT TCP
- Technical tours
- Sight-seeing programs
- Social gatherings

**Call for Abstracts and Papers**
The abstract submission system is now open. The abstracts will be screened by a Regional Coordinator and authors will be advised of acceptance. Important dates are given below.

**Organization**
The conference is organized by the International Organizing Committee (IOC) and the National Organizing Committee (NOC) on behalf of the Executive Committee of the IEA HPT TCP.

| | |
|---|---|
| **Per Jonasson** | Chairperson IOC, Swedish Refrigeration & Heat Pump Association, Sweden |
| **Sophie Hosatte** | Vice-Chairperson IOC, CanmetENERGY, Canada |
| **Hideaki Maeyama** | Vice-Chairperson IOC, HPTCJ<br>(Heat Pump and Thermal Storage Technology Centre of Japan) |
| **Min Soo Kim** | Chairperson NOC, Seoul National University, South Korea |
| **Minsung Kim** | Conference Secretariat, Chung-Ang University, South Korea |

For further information, please refer to the Conference website with the 1st announcement of the 13th IEA Heat Pump Conference. http://www.hpc2020.org/

# Important dates


| | |
|---|---|
| **January 1, 2019** | Abstract submission open |
| **May 15, 2019** | Abstract submission due |
| **November 1, 2019** | Full paper submission due |
| **February 15, 2020** | Final paper submission due |

# Heat Pump Centre

The Heat Pump Centre (HPC) plays a central role in the HPT TCP, communicating factual and balanced information on heat pumping technologies, promoting HPT TCP activities, supporting the Executive Committee (ExCo), the operating agents of the Annexes and new member countries and stimulating the generation of new activities. RISE Research Institutes of Sweden has been appointed to manage the HPC.

In February 2018, the request for extension of HPT TCP for the years 2018-2023 was approved by IEA. The strategic work plan for 2018-2023 states that outreach activities will be done to new types of companies, networks, organizations and researchers, and also to other countries, in order to broaden the scope of the RDD&D activities of the TCP.

**New Member Countries**
HPC has been in contact with several potential new member countries.

HPC and the HPT Chair have had a continuous dialogue with China throughout the year, and China has accepted the invitation to become a member. In December the letter of designation was signed by the Ministry of Science and Technology (MOST) in China. The membership procedure will formally be finalized when the signature page from IEA has been sent to and returned from the contracting party in China. Throughout the membership procedure, support has been given to China from the HPC, the HPT Chair and the IEA secretariat.

Estonia has contacted HPC and expressed its interest in becoming a member. An official invitation has been sent, as well as information on the formal procedure. The next step is for Estonia to send a letter of acceptance for membership.

Mexico has shown interest in joining HPT TCP. They have not yet sent in an application to be invited as a member. HPC has had initial correspondence with Romania about becoming a member. Contacts are also established with India and the Czech Republic.

**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. It is published as an online magazine, and linked to via the HPT website. The Magazine is free of charge to read for anyone, regardless of whether the reader lives in an HPT member country or not.

During 2017, it was decided that the authors for Column, Strategic Outlook and National Market Report would be designated by the ExCo delegates, according to a schedule in order to make sure that all member countries were represented in the magazine. This has been implemented during 2018.

A short version of the HPT Magazine has been developed and distributed to subscribers via e-mail as a newsletter. In this, selected articles from the magazine are summarized by HPC in a language adapted to a broader audience.

During 2018 HPC arranged that the Magazine and its articles receive a DOI number (Digital Object Identifier), in order to make it more attractive for authors and to be able to better follow citations. Three issues of the HPT Magazine were published during 2018: No. 1/2018 "Flexible, sustainable and clean system solutions", No. 2/2018 "Affordable Heating and Cooling", and No 3/2018 "Low GWP refrigerants – system solutions and components".

**Website and Social Media**
The development of the HPT website is continuously on-going. During 2018, the focus was on improving and harmonizing the annex sub-sites and to create an increased influx of news from the annexes to the site together with operating agents. Other parts are also updated with relevant information.

Social media such as Twitter and LinkedIn have been used to spread the awareness of HPT TCP and heat pumping technologies to a broader audience.

**The IEA Heat Pump Conference**
The next IEA Heat Pump Conference will be held in Jeju, Korea, in May 2020. The HPC has supported the preparations for the conference which have begun, with a dialogue with the Korean National Organising Committee (NOC). The conference guidelines have been reviewed and revised by HPC together with a Task Force Group, in order to achieve a more robust conference organization in the future.

**Activity Generation**

The HPC has supported the process to start new Annexes in accordance to the strategic work plan and the decisions from the last ExCo meetings. The HPC also maintains regular contact with the annexes' operating agents, supporting them with formal participation letters, templates for reports, maintaining their annex sub-subsites, teamsites etc.

Two new annexes were started during 2018: "Long term performance measurement of GSHP Systems serving commercial, institutional and multi-family buildings" (Annex 52) and "Advanced Cooling/Refrigeration Technologies Development" (Annex 53). Early 2019, Annex 54 will start: "Heat pump systems with low GWP refrigerants".

Also, the HPC has supported the development of the first joint Annex that will support the Mission Innovation Challenge #7 Affordable Heating and Cooling for Buildings. The project builds on collaboration between the two TCPs ECES and HPT, and is coordinated by the Netherlands.

**60 Seconds**

During 2018, the Heat Pump Centre has continued to distribute the "60 seconds" email. 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 to IEA Publications**

The HPC has coordinated the review, and also reviewed, the IEA reports "The future of cooling" and "Tracking of Clean Energy Process". As a result of HPT TCP efforts, heat pumps are mentioned several times as the first example of clean energy technology in the latter publication.

**International Collaboration Promotion**

The HPT TCP and the HPC have good relations with several national and international organisations, including EHPA, IIR, ASHRAE, AHRI/ AHRTI, and China Heat Pump Association (CHPA). Monica Axell and Caroline Haglund Stignor from HPC have participated in many international events.

- Monica participated in the BCG Meeting in Vienna on January 25, as a representative for the HPT TCP.

- Caroline visited the Korean national exhibition "2018 HVAC Korea" in Seoul on February 22, 2018. She held a presentation about IEA and the HPT TCP at a workshop entitled "Symposium on the activation of heat pump industry" organized by the Heat Pump Industrial Forum in Korea.

- Caroline promoted the HPT TCP at the Cold Climate HVAC International conference in Kiruna, Sweden, March 12-15 and had a booth there.

- Monica participated in IEA TCPs' meeting in Paris on March 26, organized by SHC TCP. The purpose was to discuss TCP collaboration and any other inter-TCP issues. Possible TCP collaboration related to Mission Innovation was discussed at the meeting as well as the first joint project between ECES and HPT, the Comfort and Climate Box.

- Caroline participated in the DecarbCities forum, arranged by the European Heat Pump association (EHPA), which took place on May 16 in Vienna and brought together representatives from cities, planners, the heat pump industry, and other related industry.

- The HPC team co-created and participated in the arena for sustainable heating and cooling on May 22, during the Clean Energy Week in Malmö, Sweden.

- Monica attended a conference arranged by IRENA in September and was one of the panelists in a session about electrification of heat moderated by Thomas Nowak from EHPA.

- In August Caroline was invited by the China Heat Pump Association to give a presentation at the China Annual Heat Pump Conference & 7$^{th}$ International Air-source Heat Pump Development Forum about the HPT TCP and European Standards and Energy Labelling Regulations for air-to-water heat pumps. Later during the year, in December she was invited to the 5$^{th}$ International Congress of Refrigeration (ICRT) which took place in Zuhai, China, to give two presentations on the same themes.


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

**Contact**
Dr Monica Axell
Tel. +46 10 516 55 19
*monica.axell@ri.se*

# 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).

| | | |
|---|---|---|
| FUEL-DRIVEN SORPTION HEAT PUMPS | 43 | AT, **DE**, FR, IT, KR, SE, UK, US |
| 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, **DE***, DK, FR, JP, UK |
| 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, IT, NL |
| ACOUSTIC SIGNATURES OF HEAT PUMPS | 51 | **AT**, DE, DK, FR, IT, SE |
| (NEW) LONG TERM PERFORMANCE MEASUREMENT OF GSHP SYSTEMS SERVING COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS | 52 | DE, FI, NL, NO, **SE**, US, UK |
| (NEW) ADVANCED COOLING/REFRIGERATION TECHNOLOGIES DEVELOPMENT | 53 | DE, IT, KR, **US** |
| (NEW) HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS | 54 | IT, JP, KR, **US** |

NEW

# Meetings 2018

**Annex 43**

- *Stockholm (SE), 15-16 May.* Update on gas heat pumps development at Polimi with Ariston, at Warwick University, and at Fraunhofer ISE together with Fahrenheit.
- *Pisa (IT), 16-17 July.* Workshop on future of Sorption Technology, initiated and organized by CNR, Politecnico di Milano, Fraunhofer ISE, and University of Warwick.
- *Freiburg, (DE), 27-28 November.* Announcement of Boostheat GHP to enter the market with claimed high Seasonal Gas Utilization Efficiency. Discussion of latest results from gas heat pump projects.

**Annex 45**

- *Freiburg (DE), April.* Discussion on market development and policy barriers for hybrid HPs.
- *London (UK), September.* Discussion on draft and structure of final report.

**Annex 46**

- *Tokyo (JP), May.* Discussions on R&D for DHW HPs. This must be based on actual needs and fit for the application markets.
- *Buchs (CH), November.* Discussions on the modeling challenge of the heat pump configuration, system, and boundary conditions.

**Annex 47**

- *Skype, May 9.* Discussion regarding tasks 3 and 4, content and progress.
- *Luzern (CH), June 18.* Discussion regarding tasks 3 and 4.
- *Skype, August 27.* Status and discussion regarding Task 3 report.
- *Skype, September 6.* Status meeting.
- *Skype, September 13.* Discussion of new annex proposal.
- *Skype, September 24.* Discussion of new annex proposal.
- *Aarhus (DK), November 15.* Discussion regarding finalization of the project.

**Annex 48**

- *Vienna (AT), June 4-5.* Setting up the share point possibilities and using this tool. Preparation for the ICR in Montreal 2019 to present the Annex in a session.
- *Nuremberg (DE), October 14.* Preparing for the workshop the next day at Chillventa CONGRESS. Two contributions from Kassel University.

**Annex 49**

- *Trondheim (NO), June 7-9.* Presentation of interim results on nZEB monitoring and system integration for nZEB in participating countries.
- *Gaithersburg (US), November 7-9.* Presentation of further results in nZEB monitoring and design issues for integrated heat pumps in nZEB.

**Annex 50**

- *Video Conference, June 7.* Update of simulation and monitoring. Presentation of the country reports that have not been presented. Discussion of the best practice sheets
- *Utrecht (NL), November 12.* Working Meeting

**Annex 51**

- *Villeurbanne (FR), January 16–17.* Finalisation of task- and subtaskleads, discussions on Task 1-2, definition of roadmap for Task 3-7.
- *Borås (SE), June 27–28.* Discussions of task 1-7, selection of heat pumps for round robin test.

**Annex 52**

- *Malmö (SE), May 24-25.* Presentation of 35 GSHP long-term monitoring projects in 9 countries.
- *Oklahoma (US), November 15-16.* The first draft of the bibliography was compiled and the applicability of the SEPEMO system boundaries was discussed.

# Selected Publications 2018

**Annex 43**

- Scoccia, R., Toppi, T., Aprile, M., Motta, M.
  *Absorption and compression heat pump systems for space heating and DHW in European buildings: Energy, environmental and economic analysis.*
  Journal of Building Engineering **16**, 94-105, 2018.

**Annex 46**

- Nawaz, K., Shen, B., Elatar, A., Baxter, V.D., Abdelaziz, O.
  *Performance optimization of $CO_2$ heat pump water heater.*
  International Journal of Refrigeration **85**, 213–228, 2018.

- Nawaz K., Shen B., Elatar A. et al.
  *Hydrocarbons as natural refrigerants for heat pump water heating applications.*
  13th IIR Gustav Lorentzen Conference on Natural Refrigerants. Proceedings, Valencia (ES), 2018.

- Deutz, K.R., Cauret, O., Rullière, R., Haberschill, P.
  *Multi-criteria air source heat pump water heater optimization combining optimized thermodynamic performance and control.*
  10th International Conference on System Simulation in Buildings, Liege (FR), 2018

**Annex 47**

- Schmidt, R.R.
  *Barriers and Opportunities for Large-Scale Heat Pumps in Austrian District Heating and Cooling Networks*
  4DH Conference, Copenhagen (DK), 2018

- Hangartner, D.
  *Heat Pumps in District Heating and Cooling Systems – Case studies*
  4DH Conference, Copenhagen (DK), 2018

**Annex 48**

- Arpagaus, C.
  *High Temperature Heat Pumps.*
  Chillventa Congress, Nuremberg (DE), 2018.

- Kaida, T.
  *Industrial heat pump applications in japan.*
  Chillventa Congress, Nuremberg (DE), 2018.

- Reinholdt, L.
  *Industrial heat pumps in district heating (Denmark).*
  Chillventa Congress, Nuremberg (DE), 2018.

**Annex 49**

- Ochs, F., Dermentzis, G., Siegele, D., Ksiezyk, A.
  *Neuer Ansatz für die primärenergetische Bewertung von NZEBs – Demoprojekt Innsbruck Vögelebichl.*
  PV Symposium, Bad Staffelstein (DE), 2018.

- Ahmed, K., Carlier, M., Feldmann, C., Kurnitski, J.
  *A new method for contrasting energy performance and near-zero energy building requirements in different climates and countries.*
  Energies **11**, 1-22, 2018.

- Wemhoener, C., Schwarz, R.
  *Space cooling application with solar absorber.*
  Eurosun, Rapperswil (CH), 2018.

**Annex 51**

- Reichl, C., Emhofer, J., Popovac, M., Drexler-Schmid, G., Wimberger, P., Linhardt, F., Alten, K., Fleckl, T.
  *International Research: Acoustic Signatures of Heat Pumps.*
  11de Warmtepomp Synposium, Communicatiehuis, Ghent (BE), 2018.

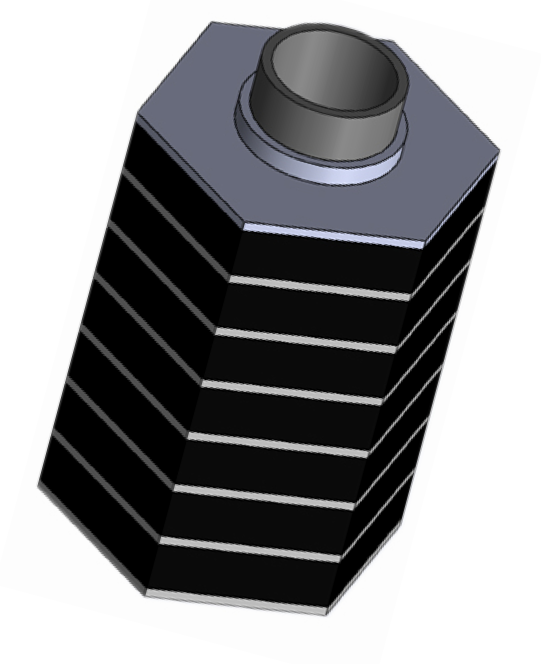
- Reichl, C., Emhofer, J., Popovac, M., Drexler-Schmid, G., Wimberger, P., Linhardt, F., Alten, K., Fleckl, T.
  *Akustische Emissionen von Wärmepumpen*.
  Chillventa Congress, Innovationstag Kältetechnik, Nuremberg (DE), 2018.

- Wimberger, P., Emhofer, J., Reichl, C.
  *MicLocator - Determine multiple microphones' positions using sound wave delay and trilateration.*
  68th Annual Meeting of the Austrian Physical Society, Graz (AT), 2018.

# 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 gained more attention again 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. 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.



> ***They are seen as a complementary technology to electrically driven heat pumps with a potential to reduce the requirements on the electric grid.***

As the end users 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 have been addressed. Furthermore, political decision makers are of interest since governments set the boundary conditions for future development for a carbon emission-free society.

**OBJECTIVES**

- Widen the market acceptance of fuel driven heat pumps, increasing the market awareness for this technology;
- identify market barriers and opportunities to allow smooth and sustainable market entrance and deployment of the technology;
- quantify the economic, environmental and energy performance of integrated fuel driven sorption heat pumps in heating systems in a range of climates, countries and building standards;
- identify the most suited system layouts and which type of fuel-driven heat pump fits best to a specific building and 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.

Figure 1. The "Kebab design": Novel finned tube and shell adsorber with compacted active carbon for ammonia adsorption.

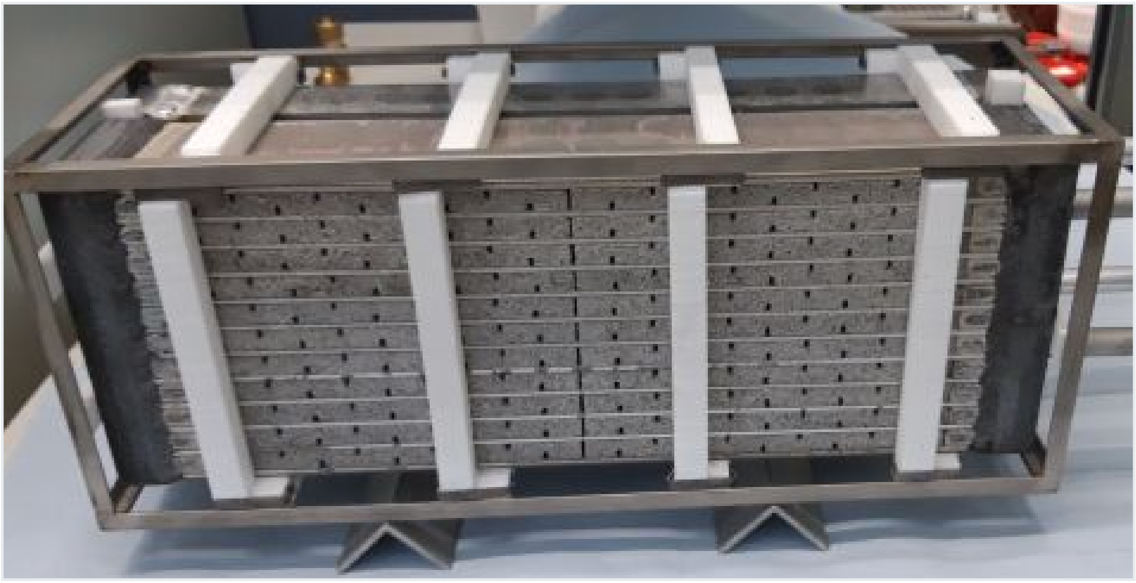


Figure 2. Compact zeolite-water adsorption module based on aluminum fibre heat exchangers (Fraunhofer) with direct crystallization coating (Fahrenheit).

**RESULTS**

Within the Annex, a common view on market requirements and potential was found for different markets. This led to a report within the Mission Innovation Heating & Cooling Innovation Challenge on Sorption Heat Pumps. Gas (natural gas, biogas, hydrogen, etc.) heat pumps for domestic use is potentially a very large market if they can become the successor technology to the condensing boilers, the annual worldwide production of which exceed 13 million units. Sorption technology can reduce gas consumption for domestic heating by 40% (existing products) and may increase the savings to 60%, with corresponding decreases of GHG emissions.

Regardless of the technology, the major challenge for sorption heat pumps to become established as mainstream systems is capital cost. The only product of less than 20 kW power is made in small numbers, with a retail cost of around €10,000. There is consensus that if the production of this heat pump would increase to 100,000 per year or more, costs could drop to €3,000. There is also a need for lower capacity systems (about 10 kW) and for compact units that would not require special skills to install.

Progress has been made with several projects both for ad- and ab-sorption Gas Heat Pumps (GHP). At Politecnico di Milano (Italy), a water-ammonia absorption gas heat pump based on plate heat exchangers (PHE) is under development and shows promising results, in terms of compactness as well as efficiency at high supply temperatures. Also the company Ariston (Italy) is working on an absorption gas heat pump for the residential market. University of Warwick (UK) has received funding for the development of an adsorption gas heat pump based on active carbon and ammonia as working fluid, using a promising new adsorber design. Fraunhofer ISE (Germany) works on the development of a zeolite-water based GHP, with a consortium of industry partners.

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

**Operating Agent:**
Peter Schossig, Fraunhofer Institute for Solar Energy Systems ISE, Germany
*peter.schossig@ise.fraunhofer.de*

**Participating countries:**
Austria, France, Germany, Italy, South Korea, Sweden, UK, USA.

**Further information:**
*www.heatpumpingtechnologies.org/annex43*

# ANNEX 45

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

A hybrid heat pump is the combination of a heat pump with a traditional fossil-fuelled boiler. By combining two heating technologies using a single control strategy, it is possible to flexibly use the heat pump or boiler part of the heating installation, allowing the optimization of heat production according to local considerations, for instance regarding $CO_2$ emissions or load balancing. Further, a hybrid heating system generally has lower investment costs than an all-electric heat pump and will often fit within comparably tight spaces. Since a fossil-fuelled heater is always available as an auxiliary, hybrid systems are enablers for the use of heat pumps in retrofits.

A wide range of possible setups are possible. However, note that a configuration consisting of a heat pump and an electrical resistance heater is not considered a hybrid setup.

Although heat pumps have been on the market for several decades, the combination of an HP and boiler into a package under a single control strategy is relatively new on the market. During the Annex's three years, the market for hybrid HPs has changed from non-existent into a growing wave of interest in hybrid HPs as an intermediate step towards renewable heating.

There are two package setups:

**1. Add-on**
The heat pump is used as an additional system next to a boiler. This enables retrofitting existing boilers into hybrid systems. There is no need to actually physically integrate heat pump and boiler, they can be installed in separate rooms. If controlled by a single control system, hybrid operation can be optimised.

**2. Integrated**
These are boiler/HP combinations sold as one integrated physical package, consisting of boiler, heat pump, and controls, that are designed to operate as one unit. This may be delivered as a single physical 'box' or consist of loose components, allowing freedom of installation geometry.

> ***"the HP electricity demand can be completely decoupled from the heating demand at any time, providing a structural solution for local grid congestion."***

**OBJECTIVES**
The Annex focuses on

- » overview of the market opportunities for hybrid HPs;
- » overview of demonstration projects in the participating countries;
- » modelling and discussion on control strategies;
- » the role of hybrid HPs in the transition towards 100% renewable/carbon neutral heating.

Since the market development for hybrids is only starting to take off, the objective of this Annex has turned into discussing the general position of hybrids within the domestic heating sector, rather than focusing on implementation or performance details.

**RESULTS**
The thermal power of the heat pump component is an important determinant for the investment cost and operation strategy. If the boiler component always has sufficient peak power, the size of the HP component can be selected to meet optimum criteria (e.g. investment cost, regulations, etc.).

The coverage ratio for the heat pump component depends on the relative power of the HP part compared to the total peak heat demand. Figure 1 is a typical example. Depending on climate conditions, the shape of the curve may differ between countries, but the behaviour will be similar.

For a very small heat pump component, the coverage ratio rapidly rises. Thus, a given increase

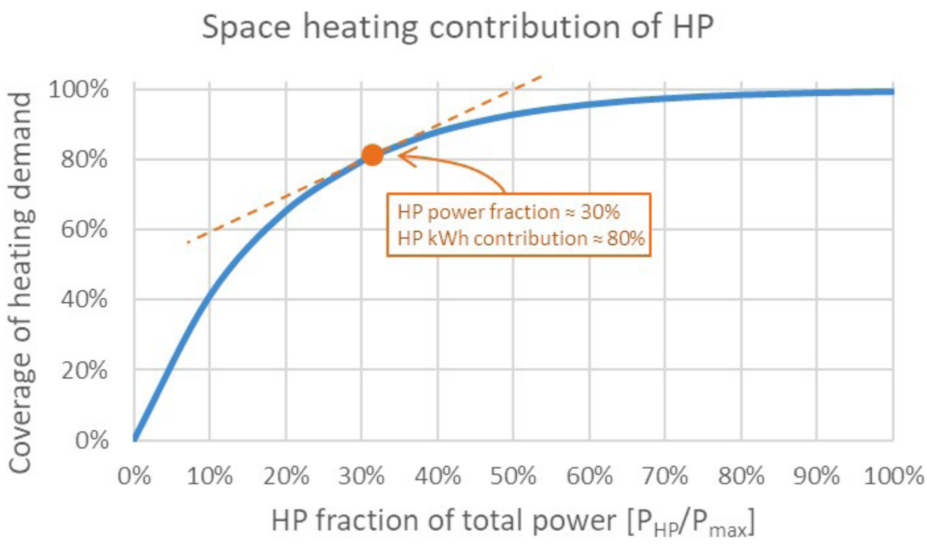



Figure 1. Coverage ratio for the heat pump component as a function of the fraction of total power.

in HP capacity leads to a larger increase in coverage ratio. For large coverage ratios, this is reversed: a given increase in HP capacity leads to a smaller increase in coverage, since the maximum heating power is only used for a short time each year, while a certain baseload of power demand will be needed throughout the heating season.

An HP capacity of around 30% of the maximal heating power demand strikes the middle ground between those behaviours, and is often advised as an optimal compromise between HP investment costs and HP contribution to the heating demand. Figure 1 shows that a large HP component is not necessary to achieve a sizeable contribution to the total heating demand, and thus contribute significantly to renewable energy use. In effect, a larger HP component does not improve performance, but leads to higher costs. Depending on the chosen control strategy, hybrid HPs may be able to serve several different purposes. This versatility in physical configuration as well as control strategies is the central defining characteristic of hybrid HPs. It is thus logical to expect many differing market opportunities for hybrid HPs, depending on the local circumstances in any given market.

Since hybrids can be applied in existing buildings, they provide a potential for significant $CO_2$ savings that can be tapped into immediately and on a large scale. This also allows for markets and users to get used to heat pumps, preparing for large-scale electrification of domestic heating within the next decades.

Typical HP smart grid flexibility is based on the principle of time-shifting electricity demand. These approaches have the common characteristic that, eventually, the full heating demand must be delivered by the heat pump. It is impossible to completely 'shield' the electricity grid from a specific demand peak. Sooner or later, the energy demand must be satisfied.

For hybrid HPs, the situation is different. Because it is possible to switch from electricity to gas or oil, the HP electricity demand can be completely decoupled from the heating demand at any time, providing a structural solution for local grid congestion.

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

**Operating Agent:**
Peter Wagener / Paul Friedel, Business Development Holland b.v., the Netherlands
*wagener@bdho.nl*

**Participating countries:**
Canada, France, Germany, the Netherlands, UK.

**Further information:**
*www.heatpumpingtechnologies.org/annex45*

# ANNEX 46

## DOMESTIC HOT WATER HEAT PUMPS

Throughout the developed world, the heating of water for domestic use is one of the largest consumers of energy in the household sector (10 - 20%). In particular, water heaters is one of the most complex product categories due to a large variety of product types, technologies, and fuels used for heating water. These range from individual to collective systems, also using combined systems, hybrid systems and fresh water systems, with different terminology in different regions of the world. The actual energy consumed depends on consumer usage patterns and ambient environmental conditions, more so than for any other domestic appliance. Such a complexity creates a number of challenges for policy makers seeking to understand and effectively manage water heating energy consumption.

An efficient domestic hot water (DHW) 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 energy efficient generation device like a heat pump can be nullified by poor system integration, or large storage or distribution losses. The overall system efficiency is a key point. This makes the choices for the efficient heating of domestic hot water for new buildings and renovation a challenge.

Many concepts are still based on the traditional method of installation and calculation. General and publicly available models calculate hot water consumption on the basis of the living area and a standard occupancy depending on the surface of the housing. In comparison with real life, these methods very often lead to oversizing of the DHW production and storage.

As homes become better insulated, energy consumption for space heating decreases. It is therefore more important to have a clear picture of the energy consumption for hot water heating. A basis for a good choice is an objective calculation model in which different concepts of systems can be juxtaposed. In the energy market many calculation models are available, often on a commercial basis.

> ***Not meeting the expectations is poison for a new technology - a second chance will often not be given***

Climate, location and building-specific components, often traditional for certain regions, are the basis of these models, and it is difficult to make clear comparisons between them. Given the market of models already on the market, it does not make sense to develop an 'own' Annex 46 model. Instead, with the existing and available models, we need to discuss and develop guidelines on how to act.

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

**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 domestic hot water heat pump concepts and systems for new as well as existing buildings. This will be achieved by

- reviewing system concepts and available domestic hot water heat pumps;
- gaining deeper insight into the use of domestic hot water to create a solid basis for test and standardization procedures;
- developing and validating a model for objective comparison of domestic hot water heat pumping technologies and system
- databasing with showcases for concepts;
- creating a web-based information platform to serve participating countries by publishing information on their market approach and training courses;
- an overview of R&D on domestic hot water HPs, along with the R&D still needed.

**RESULTS**

Since 2010 the market of Domestic Hot Water Heat Pumps (DHWHP) has been the fastest growing segment. Volume sales of air to water heat pumps are likely to surpass the other heat pump categories. The significant change of the market is the continued boom of sanitary hot water or cylinder-integrated air-to-water (ATW) heat pumps, and the market is likely to continue growing at the same pace over the next 5 to 10 years. In spite of these growth rates, the world-wide market for heat pump water heaters is still small compared to the other types of water heating equipment sold.

There is great diversity in markets, due to existing markets and cultural differences in hot water usage. These diversities give different scenarios and will have different consequences for the R&D Road Map that is under development. Except for in Japan and China there is no clear government policy focusing on Domestic Hot Water Heat Pumps as a product, in any country.

During two working meetings, fruitful R&D discussions have taken place. At the first meeting, in Tokyo, the general feeling of the participants was that

• end-users are not aware of the advantages on the long term and will traditionally go for the cheapest solution. Governmental legislation is necessary;

• the traditional installer is not really capable (on a large scale needed for a market transition) to give consumer advice and install the best option. This often results in oversizing;

• grid operators are interested in the storage capacity of DHW Heat Pumps.

The first analysis on R&D was discussed at the meeting in Buchs, Switzerland. Main discussion points were the modeling challenge of the heat pump configuration itself and of the system, as well as a number of important boundary conditions, focusing on future work on DHWHP. The main topics:

• refrigerants. Most widely used in DHW HPs are R134a, R410A, both being high-GWP and being out-phased under the widely supported Montreal Protocol and Kigali Agreement. There is a lot of literature available in this field, but not much specifically on hot water heat pumps;

• *Legionella*. Legislation is not harmonized, where existing legislation focuses mainly on thermal disinfection. Whilst the risks to human health should clearly remain a priority when setting regulations in this area, the impact of $CO_2$ emissions of an over-conservative approach suggest that further study in this area is required;

• test procedures and standards. There are a large number of test methods for heat pump water heaters. Thus, manufacturers have to undertake a different set of tests to be able to sell their products on the worldwide market. A harmonisation framework has been proposed for this purpose, and a first step has been made with the publication of the ISO Draft HP-WH-19967-Part1-DIS registration;

• collective systems. These occur in Multi Family Buildings (Annex 50) and District Heating Systems (Annex 47). Seemingly simple solutions are available for single family houses, but for collective systems, solutions are more complex due to the demand for high temperatures in central distribution systems and the ownership relation in buildings. The low efficiency of collective DHW systems is well known by field practitioners.

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

**Operating Agent:**
Onno Kleefkens, Phetradico C&P, the Netherlands
*onno@phetradico.com*

**Participating countries:**
Canada, France, Japan, the Netherlands, South Korea, Switzerland, UK, US.

**Further information:**
*www.heatpumpingtechnologies.org/annex46*

ANNEX
# 47

## HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS

District heating in general, and heat pumps connected to the grid in particular, are predicted to play a key role in the energy grid and supply for the future. With the implementation of district heating, it is possible to cover up to 50% of the heating demand in Europe, and heat pumps can deliver around 25% of the energy to the district heating grid. The Heat Roadmap Europe 4 scenarios, with a large share of district heating in the energy system, show that the $CO_2$ emissions can be reduced by more than 70% compared to today's situation.

Heat pumps may prove to be a key technology in the future district heating grid in several ways:

1. Heat pumps can act as a balancing technology, supporting intermittent energy sources;
2. Heat pumps phase out fossil fuels from the energy system;
3. Heat pumps make it possible to use very low (below 60 °C) and ultra-low (below 45 °C) temperatures in the district heating grid;
4. Heat Pumps make it possible to minimize energy losses in the district heating grid.

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

Some of the barriers to the large-scale integration of heat pumps are the lack of heat sources (often only available in small decentralized quantities) or low temperature level of the sources (low efficiency). Similarly, most operators lack experience regarding the integration and operation of heat pumps in existing district heating systems, compared to well-known biomass- or gas-based generation units. This Annex is aimed at overcoming these and other barriers.


Figure 1. Operating agent Denmark has together with Austria, Switzerland and Sweden completed 38 extensive case studies. The studies are found at: *https://heatpumpingtechnologies.org/annex47/publications/*

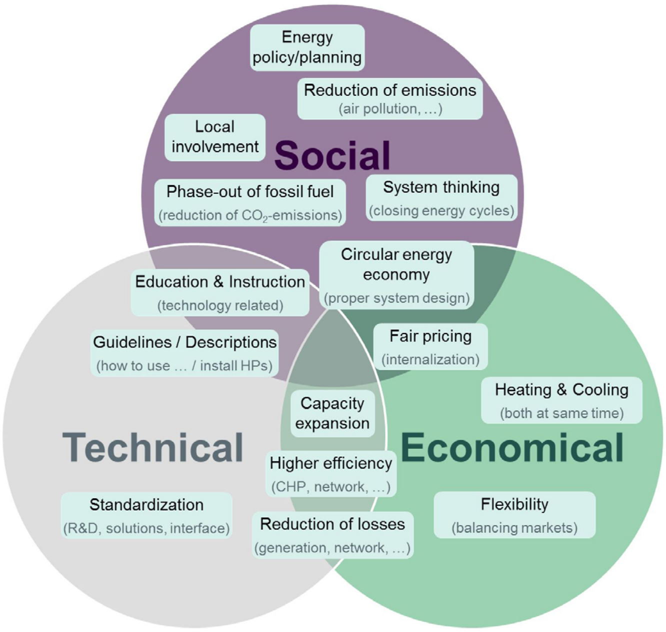



Figure 2. Some possible solutions and aspects that could promote heat pump integration into district heating networks.

**OBJECTIVES**

- To gather information and ideas for policy makers, decision makers and planners of energy systems in urban areas concerning the possibilities and barriers related to the implementation of heat pumps in District Heating and Cooling systems;
- to suggest how heat pumps can be implemented in both new and older district heating systems in the best way;
- to explore the possibilities of increasing the share of renewable energy or using excess heat in the different systems by using heat pumps, as well as minimizing system losses by using heat pumps.

**RESULTS**

An idea catalogue which shows different implementation cases has been created, with 39 different cases where heat pumps are integrated in a district heating grid. It is available at the Annex 47 webpage.

It is evident that the correct design of the heat source system and the heat sink is as important as the dimensioning of the heat pump itself. Within the project, an Excel-based easy-to-use tool has been developed that can be used to pre-estimate feasibility and cost-effectiveness.

Further, some "best practice" strategies for the operation of heat pumps in combination with a central storage unit have been found:

- heat pumps with dynamic pricing and demand-side management (DSM) are more resilient to market risks, since dynamic operation counteracts fluctuations in fuel and electricity prices;
- heat pumps increase the flexibility of district heating systems by expanding the heat generation portfolio. This enables fast commissioning and low start-up costs, and takes advantage of thermal batteries and the volatility of the electricity market;
- heat pumps can be used to increase renewable heat generation. In addition, low-temperature heat sources and alternative heat sources, such as waste heat, can be used.

**Project duration:**
January 2015 – December 2018

**Operating Agent:**
Svend Pedersen, Danish Technological Institute, Denmark
*svp@dti.dk*

**Participating countries:**
Austria, Denmark, Sweden, Switzerland.

**Further information:**
*www.heatpumpingtechnologies.org/annex47*

# ANNEX 48

# INDUSTRIAL HEAT PUMPS, SECOND PHASE

Securing a reliable, economic and sustainable energy supply as well as environmental and climate protection are important global challenges of the 21st century. Increasing the production and use of renewable energy and improving energy efficiency are the most important steps in order to achieve these goals of energy policy.

Although impressive efficiency gains have already been achieved during the past two decades, energy use and $CO_2$ emissions in manufacturing industries could be further reduced if best available technologies were to be applied worldwide. In the previous 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 industry and how to overcome barriers: short payback periods are possible (less than two years), large reductions 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 experience, the main goal of Annex 48 is to overcome difficulties and barriers for the market introduction of industrial heat pumps.

> ***Industrial heat pumps have a great potential for more efficient use of energy and reduction of $CO_2$ emissions in industrial processes***

In Annex 48, we have compiled information on heat pumping technologies for industry, policymakers, industrial planners, designers, and stakeholders, as well as heat pump manufacturers in such a way that it will lead to a better understanding of the opportunities. This information can then be used to reduce primary energy consumption and $CO_2$ emissions as well as energy costs of industrial processes.

**OBJECTIVES**

Annex definition of Industrial Heat Pumps (IHP): 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 applica-

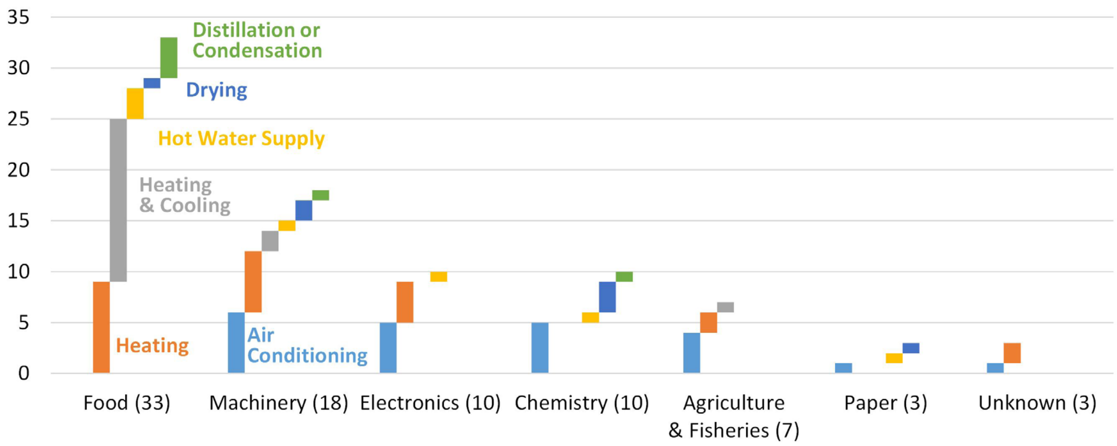



Figure 1. Installation cases in Japan in various industries and processes

tions, using existing and new case studies. Best available technologies and best practices should be selected based on a matrix describing type of installation, technology, system, temperatures, capacities and effects, e.g., savings of energy, $CO_2$ emissions or cost;

- Producing information material for IHP training courses;
- Present the IHP potential for more efficient use of energy and reduction of greenhouse gas emissions, to policy makers.

## RESULTS

### *R717 (Ammonia) Hybrid Heat Pump for Heating and cooling*

The rejuvenation and upgrade of the old and defunct Philips Factories in Eindhoven is a project of conversion of living and working quarters to an ecological and economic lifestyle. The 40 000 m² of apartments and business premises require 800 kW of heating/cooling capacity. In addition to decreasing energy consumption and operational costs, the objective regarding HVAC was the application of natural gases and to harvest energy from the outside air by heat pumps that follow the seasonal weather pattern. The system is fully automated and PLC-controlled to switch according to demand, from heating to cooling mode. The same dry cooler used in summer to reject heat to the atmosphere is used in winter to harvest the energy of ambient air for heating.

### *Systematic Heat Pump Integration with industrial processes (Dairy Plant)*

For this case, the theoretical background for systematic heat pump integration with industrial processes has been summarized. After an analysis of available tools, an easy-to-use set of guidelines for practitioners was derived. The application of tools was done based on the set of guidelines with data from a dairy plant, see Figure 2. The baseline was recorded, a pinch analysis for the heat recovery was made, and the heat pump design was suggested. Results of the heat pump with 8 000 operating hours annually, 10 ct €/kWh electricity cost, and 35 ct €/m³ gas cost, are gas savings of € 243 600 per year and an additional electricity cost of € 39 200 per year. The total investment cost is € 331 400, and the payback time is 1.6 years.

The successful systems above were presented at the heat pump session at the Chillventa Congress.

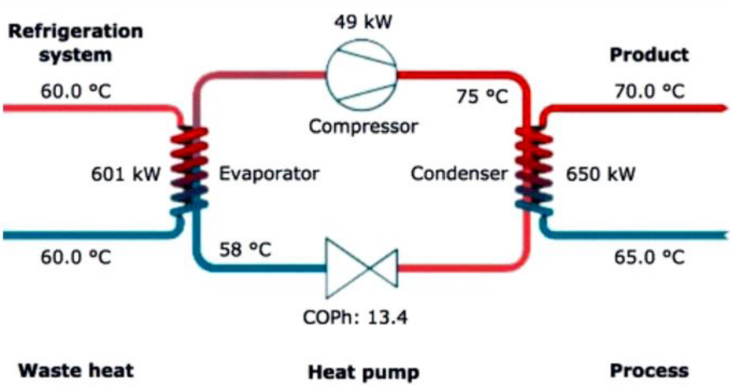



Figure 2. Dairy Plant: Heat Pump Integration.

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

**Operating Agent:**
Rainer Jakobs, Information Centre on Heat Pumps and Refrigeration, Germany
*jakobs@izw-online.de*

**Participating countries:**
Austria, Denmark, France, Japan, Switzerland, UK
(Germany is OA but not participating country)

**Further information:**
*www.heatpumpingtechnologies.org/annex48*

# ANNEX 49

## DESIGN AND INTEGRATION OF HEAT PUMPS FOR nZEB

Nearly Zero Energy Buildings (nZEB) have begun to be the current requirement in the EU member states, since by January 1, 2019, all new public buildings will have to fulfil the requirements of a nearly Zero Energy Buildings (nZEB) according to the recast of the EU Energy Performance of Buildings Directive (EPBD). Even though this so far only refers to public buildings, each member state decided individually on the nZEB definition, leading to a variety of nZEB definitions and criteria to rate nZEBs at the national level, see Figure 1. By 2021, all new buildings in the EU must comply to nZEB requirements. Also, in the USA and Canada, as well as in Asian countries like 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. However, nZEB criteria and definitions vary among the EU member states. Policy makers will have to clarify the requirements in order to drive the markets to high performance buildings, which also contribute to energy generation by on-site renewables.

> ***"The compliance with ambitious nZEB requirements is facilitated by the high performance of heat pumps in nZEB application, yielding further benefits such as demand response"***

An archetype concept to reach nZE consumption is the combination of solar PV and heat pumps, a so-called all-electric building. IEA HPT Annex 49 will investigate the design and integration of heat pumps in nZEB in order to improve the performance. 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 become an additional requirement and benefit for the future energy system. Therefore, design and control will also be important features in order to enable buildings to interact with the connected energy grids, at the single-building level as well as at the neighbourhood or district level.

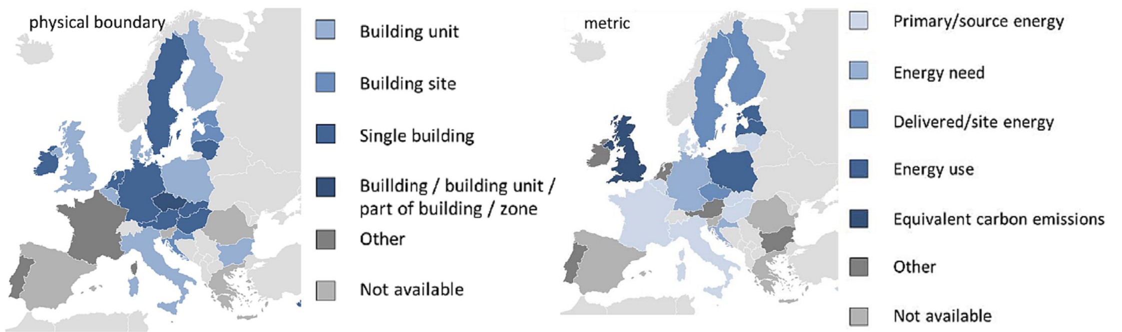



Figure 1. The criteria *physical boundary* and *metric* in the definition of nZEB in EU member states.

Figure 2. Photo of the two multi-family houses of the project Vögelebichl in Innsbruck.

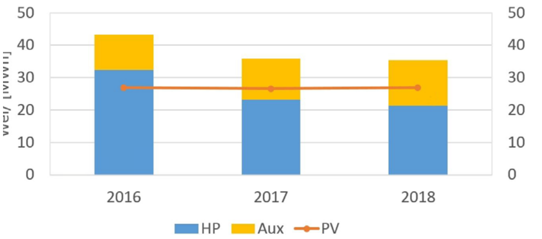



Figure 3. Electric consumption for HP and auxiliary energy of the two multi-family houses of the project Vögelebichl in Innsbruck. The first-year consumption is higher due to higher heating demand for drying out the construction moisture content during the first year of operation.

## OBJECTIVES

- Update and comparison of nZEB definitions in the participating countries;
- Design and control of heat pump systems for different applications in residential and office buildings in terms of attainable performance, reduced cost and capability of demand response as well as load match characteristics;
- Investigation of integration options for heat pumps in connection with other building and storage technologies for multi-functional operation and energy flexibility;
- Real-world performance characterisation by monitoring of nZE-buildings in the participating countries;
- Recommendations for integrated heat pump systems as well as heat pump design and control in single nZEB and groups of nZEB/nZEB neighbourhoods.

## RESULTS

The nZEB project Vögelebichl in Innsbruck (two multi-family houses in passive house standard with solar PV, solar thermal and HP system of the social housing company NHT, see Figure 2), was monitored for three years. By means of simulation-based optimization of the heat pump and control of the system, the annual electricity demand could be reduced from the initial 43 MWh to 35 MWh, see Figure 3. Further optimization measures will be implemented; predictions indicate that the nearly Zero Energy balance can be reached.

In Switzerland, a five-storey building with a building envelope approaching passive house level and with mixed residential and office use has been monitored for several years. Results of the energy balance in 2017 show an overall seasonal performance factor (SPF) for space heating and cooling (chiller and free-cooling operation) and domestic hot water production of 5.2. The nZEB balance regarding building technologies is slightly missed due to lower yield than expected of the façade integrated PV.

Furthermore, a calibration of simulation models and a comparison of different simulation programs in order to determine the ambition level for nZEB in different countries has been performed in Annex 49.

**Project duration:**
October 2016 – November 2019

**Operating Agent:**
Carsten Wemhoener, Institute of Energy Technologies, HSR University of Applied Science, Switzerland
*carsten.wemhoener@hsr.ch*

**Participating countries:**
Austria, Belgium, Germany, Norway, Sweden, Switzerland, UK, USA

**Further information:**
*www.heatpumpingtechnologies.org/annex49*

# 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 all countries. Apart from the power generation and transportation sectors it is the most important sector regarding emission of greenhouse gases. Accordingly, the radical reduction of $CO_2$ emissions from buildings is crucial for achieving climate neutrality.

Applying heat pump technologies and renewable energy is more complex for multifamily buildings than for newly build apartments, since multifamily houses have a range of special heat demand characteristics. Firstly, the share of domestic hot water demand of the overall heat demand varies with varying building standards as well as with 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 a challenge on the way to a broader dissemination of heat pumps in multifamily buildings.

Thus, Annex 50 will focus on solutions for multifamily houses with the attempt to identify barriers for heat pumps on these markets and how to overcome them. According to the demands of the participating countries, both new buildings and retrofit will be considered, as well as buildings with higher specific heating demands.

> ***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.***

As the end users 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. If former industrial and commercial areas are overbuilt, entire districts are often created in a very short time with a distinctive atmosphere and modern flair. This is the case in the Düsseldorf district of Derendorf, where the discarded freight yard makes way for the "Neues Düsseldorfer Stadtquartier", which relies heavily on heat pumps.

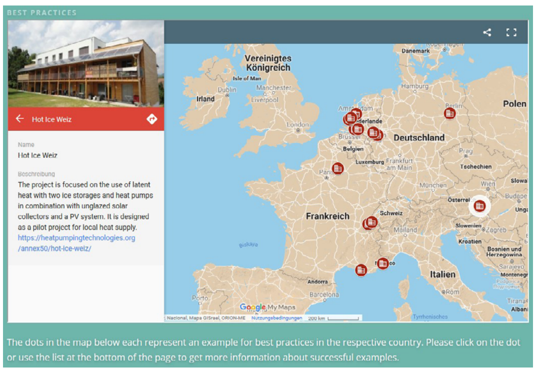
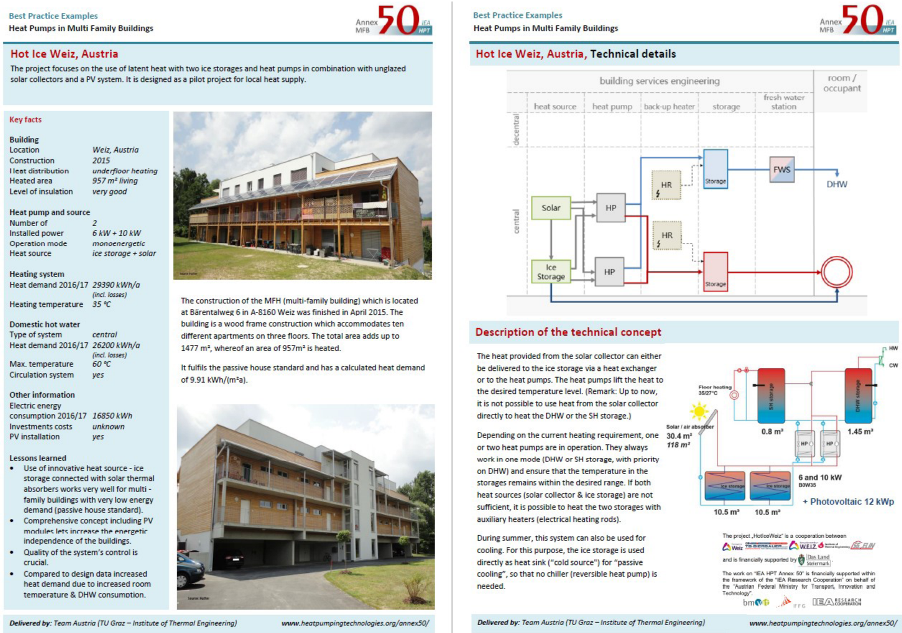



Figure 2. This illustration shows a part of the Website of Annex 50 – Best Practices. Each dot on the map represents an example of a best practice in the respective country. When choosing a dot, more information is opened at the left of the map.



Best Practice Examples
Heat Pumps in Multi Family Buildings

Annex MFB 50 IEA HPT

## Hot Ice Weiz, Austria

The project focuses on the use of latent heat with two ice storages and heat pumps in combination with unglazed solar collectors and a PV system. It is designed as a pilot project for local heat supply.

**Key facts**

| | |
|---|---|
| **Building** | |
| Location | *Weiz, Austria* |
| Construction | *2015* |
| Heat distribution | *underfloor heating* |
| Heated area | *957 m² living* |
| Level of insulation | *very good* |
| **Heat pump and source** | |
| Number of | *2* |
| Installed power | *6 kW + 10 kW* |
| Operation mode | *monoenergetic* |
| Heat source | *ice storage + solar* |
| **Heating system** | |
| Heat demand 2016/17 | *29390 kWh/a (incl. losses)* |
| Heating temperature | *35 °C* |
| **Domestic hot water** | |
| Type of system | *central* |
| Heat demand 2016/17 | *26200 kWh/a (incl. losses)* |
| Max. temperature | *60 °C* |
| Circulation system | *yes* |
| **Other information** | |
| Electric energy consumption 2016/17 | *16850 kWh* |
| Investments costs | *unknown* |
| PV installation | *yes* |

**Lessons learned**
- Use of innovative heat source - ice storage connected with solar thermal absorbers works very well for multi - family buildings with very low energy demand (passive house standard).
- Comprehensive concept including PV modules lets increase the energetic independence of the buildings.
- Quality of the system's control is crucial.
- Compared to design data increased heat demand due to increased room temperature & DHW consumption.

The construction of the MFH (multi-family building) which is located at Bärentalweg 6 in A-8160 Weiz was finished in April 2015. The building is a wood frame construction which accommodates ten different apartments on three floors. The total area adds up to 1477 m², whereof an area of 957m² is heated.

It fulfils the passive house standard and has a calculated heat demand of 9.91 kWh/(m²a).

*Delivered by: Team Austria (TU Graz – Institute of Thermal Engineering)* *www.heatpumpingtechnologies.org/annex50/*

Best Practice Examples
Heat Pumps in Multi Family Buildings

Annex MFB 50 IEA HPT

## Hot Ice Weiz, Austria, Technical details



## Description of the technical concept

The heat provided from the solar collector can either be delivered to the ice storage via a heat exchanger or to the heat pumps. The heat pumps lift the heat to the desired temperature level. (Remark: Up to now, it is not possible to use heat from the solar collector directly to heat the DHW or the SH storage.)

Depending on the current heating requirement, one or two heat pumps are in operation. They always work in one mode (DHW or SH storage, with priority on DHW) and ensure that the temperature in the storages remains within the desired range. If both heat sources (solar collector & ice storage) are not sufficient, it is possible to heat the two storages with auxiliary heaters (electrical heating rods).

During summer, this system can also be used for cooling. For this purpose, the ice storage is used directly as heat sink ("cold source") for "passive cooling", so that no chiller (reversible heat pump) is needed.



The project „HotIceWeiz" is a cooperation between

and is financially supported by Das Land Steiermark.

The work on "IEA HPT Annex 50" is financially supported within the framework of the "IEA Research Cooperation" on behalf of the "Austrian Federal Ministry for Transport, Innovation and Technology".

*Delivered by: Team Austria (TU Graz – Institute of Thermal Engineering)* *www.heatpumpingtechnologies.org/annex50/*

Figure 3. The illustration serves as an example for a best practice sheet. Each sheet presents information about key facts, lessons learned, the technical details and a detailed description of the technical concept.

## OBJECTIVES

- » Enhancement of HP systems and/or HP components for use in 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 is a scope of 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.

## PROGRESS

All country reports have been completed. The situation of each country has been described and examined.

In several countries, simulations are running. With these simulations, fundamental problems and questions of Annex 50 will be answered.

A number of best practice sheets (see Figure 2) have been published. Since there are so many different examples, this will provide various options of the use of heat pumps in multifamily buildings.

The technology screening of the Annex allows us
- to take a closer look at the examples in different countries;
- to evaluate the solutions on the market by the given examples;
- to examine how the heat pumps work in real operation.

The website (https://heatpumpingtechnologies.org/annex50/best-practices/) serves as a pool for the best practices.

**Project duration:**
January 2017 – December 2020

**Operating Agent:**
Marek Miara, Fraunhofer ISE, Germany
*marek.miara@ise.fraunhofer.de*

**Participating countries:**
Austria, Italy, France, Germany, the Netherlands, Switzerland

**Further information:**
*www.heatpumpingtechnologies.org/annex50*

ANNEX

# 51

## ACOUSTIC SIGNATURES OF HEAT PUMPS

In order to further increase the acceptance of heat pumps, reduction of acoustic emissions is important. To minimize noise annoyance, the focus must be on the acoustics emissions at steady state and on the transient behaviour of acoustic signatures during different operating conditions. The placement of the heat pumps is also of utmost importance, as sound emissions exhibit a pronounced directivity. Especially air to water heat pumps provide a convenient and effective way to exploit potential energy savings and are often used in retrofit installations. However, some of their components, such as compressors and fans, typically produce significant levels of noise. This makes acoustic improvements crucial for their deployment.

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 to be characterized by the participating institutes.

During 2018, members of the HPT Annex 51 team convened at CETIAT (France), RISE (Sweden) and DTI (Denmark, see figure 1). Results from the running measurement campaigns were presented and compared. Three heat pumps are "on tour" through Europe at the participating institutes. Results of time dependent frequency- and space-resolved measurements of the Air-to-water Heat Pump are shown in Figures 2 and 3.

### OBJECTIVES

- Increase the acceptance of heat pumps
- Increasing knowledge and expertise at different levels
- Provide input to national and international standardization;
- Preparation of six Annex meetings

> ***In order to further increase the acceptance of heat pumps, reduction of acoustic emissions is important***

- Workshop on acoustics of heat pumps at the ICR2019 Conference in Montreal
- Concluding international workshop and compilation of proceedings
- Worldwide dissemination to heat pump manufacturers

### RESULTS

Figure 2 shows the calculated A-weighted sound power level of the Air-to-water Heat Pump over a period of 200 minutes. During this time, defrosting occurs three times with a typical interval of normal operation of just above one hour. Defrosting can be seen in a drop of electrical power consumption as well as sound power level. The small power and sound power level increase during defrost is attributed to running in reverse mode.

The upper part of Figure 3 shows the frequency-resolved sound power level around a defrost with a length of about 330 seconds. During this time several light green and yellow "lines" can

Figure 1. The IEA HPT Annex 51 team at the 4th working meeting at DTI in Aarhus, Denmark. The group photo was taken in one of DTI's advanced climate chambers used for acoustic measurements based on ISO 3743-1.

be spotted corresponding to the increase and decrease of the frequency of compressor and fan. In the lower part of Figure 3 the frequency-resolved sound pressure level at one selected microphone position is shown. The 330 seconds range again corresponds to the period, where the four-way valve is switched to allowing for a reversed operation to heat up the heat exchanger for defrost. Various small acoustic bands can be traced changing their frequency (y-axis), originating from changes in the rotational speed of fan and compressor.

Three heat pumps (an Air-to-water Heat Pump (see Figure 4), an Exhaust-air Heat Pump Water Heater (HPWH, see Figure 5) and an Air-to-air Heat Pump) are “on tour” through Europe at the participating institutes, with final tests planned for summer 2019. The typical increase in sound power level during the subsequently coverage of the heat exchanger with ice following a defrost is about 5 dB(A) for the tested air-to-water heat pump. Comparing the results of the 60 different microphones positioned around this heat pump during the tests, a sound pressure level range of 5 dB(A) can be noted as the directional dependence of the sound emissions.

The documents on Introductions to Acoustic, Measurement Techniques and Regulations are available on the IEA HPT Annex 51 website.

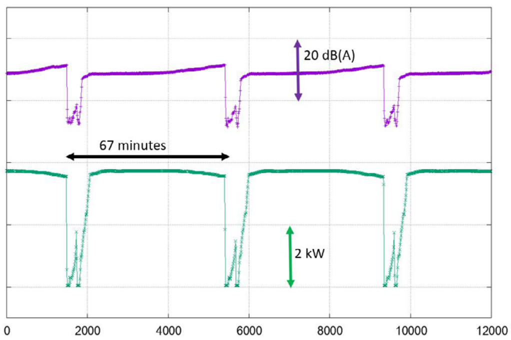



Figure 2. A-weighted sound power level and electric power consumption of an Air-to-Water Heat Pump showing several defrosting cycles.

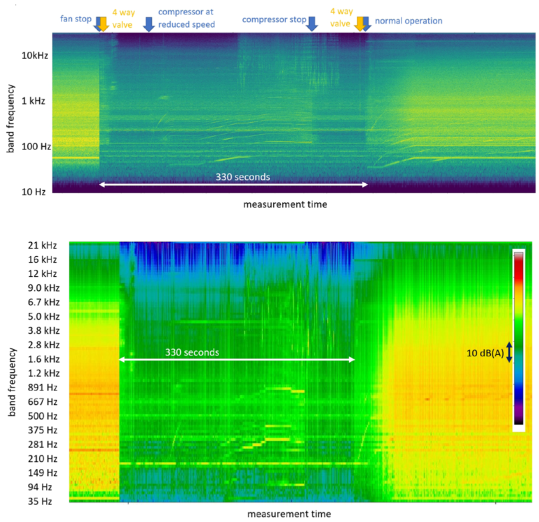



Figure 3. Frequency-resolved acoustic signatures (waterfall representation) during defrosting of an Air-to-Water Heat Pump (upper figure: time-resolved sound power level in third octave band representation; lower figure: time-resolved sound pressure level at one selected microphone position in narrow band representation).

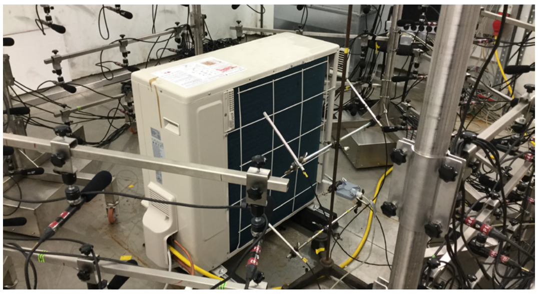


Figure 4. Air-to-Water Heat Pump surrounded by the acoustic dome with more than 60 microphones installed in the climate chamber of AIT.

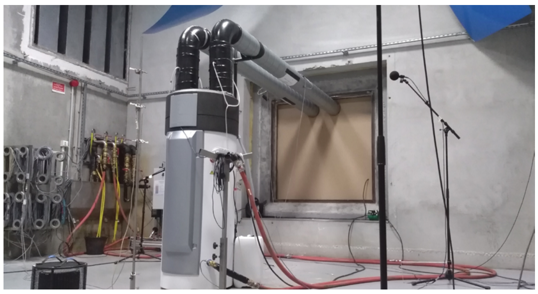


Figure 5. Exhaust Air Heat Pump Water Heater unit installed in CETIAT's double reverberant room.

**Project duration:**
April 2017 – March 2020

**Operating Agent:**

Christoph Reichl, AIT Austrian Institute of Technology, Austria
*christoph.reichl@ait.ac.at*


**Participating countries:**
Austria, Denmark, France, Germany, Italy, Sweden

**Further information:**
*www.heatpumpingtechnologies.org/annex51*

# ANNEX 52

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

Annex 52 has now run for one year and now includes more than 30 long-term performance monitoring GSHP case studies in five countries in Europe and the USA (Figure 1). These monitored Ground Source Heat Pump (GSHP). systems are all serving commercial, institutional or multi-family buildings with heating and/or cooling systems of varying degrees of complexity. While some of these monitoring projects have started recently, others have already gathered performance data for a year or more. All of the monitoring projects make use of some type of ground-source. These ground-sources could be rock, soil, groundwater or surface water. While all the systems provide heating from the ground-source, several of the monitoring projects also make use of the ground as a source for direct cooling, and for pre-heating of ventilation (Figure 2). One of the monitoring systems is a high-temperature borehole storage for a manufacturing complex, and we will compare the results from several years of operation without heat pumps with new data being collected after heat pumps have been added to the system (Figure 3).

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. 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 the performance of these GSHP systems 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.

***By the end of 2018, Annex 52 included more than 30 long-term performance monitoring GSHP case studies in five countries in Europe and the USA.***

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.

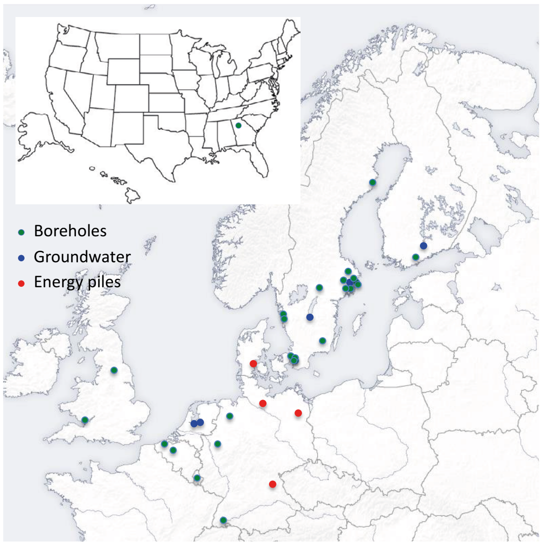



Figure 1. As of December 2018, Annex 52 comprises more than 30 long-term performance monitoring GSHP case studies in five countries in Europe and the USA.


Figure 3. The Skanska HQ building in Stockholm, Sweden, uses the ground as a source for direct cooling, and for pre-heating of ventilation air.

## 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. The high-temperature borehole storage at Xylem in Emmaboda, Sweden, has recently had heat pumps installed, and results from several years of operation without heat pumps will now be compared with new data after heat pumps have been added to the system.

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

**Operating Agent:**
Signhild Gehlin, Swedish Geoenergy Center, Sweden
*signhild@geoenergicentrum.se*

**Participating countries:**
Finland, Germany, Netherlands, Sweden, UK, USA

**Further information:**
*www.heatpumpingtechnologies.org/annex52*

# ANNEX 53

## ADVANCED COOLING/REFRIGERATION TECHNOLOGIES DEVELOPMENT

It is widely acknowledged that air conditioning (AC) and refrigeration systems are responsible for a large share of worldwide energy consumption today, and this demand is expected to increase sharply over the next 50 years, if no action is taken. The IEA anticipates that AC energy use by 2050 will increase 4.5 times over 2013 levels for non-OECD countries and 1.3 times for OECD countries. Similarly, refrigeration demand is expected to increase significantly, particularly in the non-OECD world, with most of the demand related to food preservation and storage. Demand for food is expected to grow by 70% by 2050, relative to 2010.

Worldwide action, both near-term (e.g., increase deployment of current "best" technologies) and longer-term (RD&D to develop advanced, higher efficiency technology solutions), is urgently needed to address this challenge. HPT Annex 53 is focused on the longer-term RD&D need. Technologies of interest follow two distinct paths: those based on the well-known and widely used vapor compression (VC) system, and non-traditional cooling approaches being increasingly investigated (Figure 1). VC technology has had decades of RD&D to date, and this is continuing. It may continue to be the system of choice, especially for the near term, and possibly for the longer term. However, it is also vulnerable to further refrigerant restrictions. Non-traditional technologies (e.g., magnetocaloric, elastocaloric, electrochemical compression) are generally not subject to this challenge, since they do not rely on refrigerants in the traditional sense. For instance, elastocaloric systems are based on the temperature change undergone by certain materials when alternately stressed and relieved (a "solid" refrigerant). This offers the possibility to possibly fashion system heat exchanger components (HX) out of the elastocaloric material with potential system compactness advantages (Figure 2). Further development is needed before elastocaloric (or other non-traditional approaches) are ready for the market.

> ***"This annex focuses on advanced cooling and refrigeration technology R&D to help address the anticipated huge increases in global demand."***

The technical scope of Annex 53 is very broad by design. It is not likely that there will be only one or even a few "right" solutions to the challenge.


Figure 1. Two possible future paths for Refrigeration and AC Systems.

**OBJECTIVES**

Annex 53's main objective is longer term R&D and information sharing, to push development of higher efficiency and reduced greenhouse gas (GHG) emission AC/refrigeration focused heat pump technologies. Specific areas of investigation include but are not limited to the following:

» Advance the technology readiness level (TRL) of non-traditional cooling technologies and alternative compression technologies to the point that forward-thinking manufacturers could be encouraged to engage in subsequent partnerships in bringing them to market;
» Integration with nZEB or other "low energy" buildings and integration with future "smart" electric grid systems (e. g., system integration incorporating waste heat recovery for hot water or other concurrent heating needs, integration with thermal or other energy storage system to maximize flexibility for grid interaction);
» Independent control of latent and sensible cooling and tailoring systems for different climates (e.g. hot dry or hot humid);
» Advances to VC-based technologies, both conventional and non-traditional.

**OVERVIEW OF TASKS**

***Task 1. Identify cooling/refrigeration focus areas for Annex technical contributions***

- Participants will describe the current development status of their candidate technologies and target applications.

***Task 2. Modeling/simulation and lab evaluations of advanced AC/refrigeration technologies***

- This task constitutes the major part of the Annex. Country reports to describe advances in development of candidate technologies including comparison to VC technologies and realistic estimates of cost potential.

***Task 3. Identification of next steps for development/deployment of advanced AC/refrigeration systems***

- This task aims at evaluating design optimization and advancement on the LCCP reduction.

***Task 4. Identification of next steps for development/deployment of advanced AC/refrigeration systems***

- This task aims at reporting work conducted and disseminating information developed in Annex.

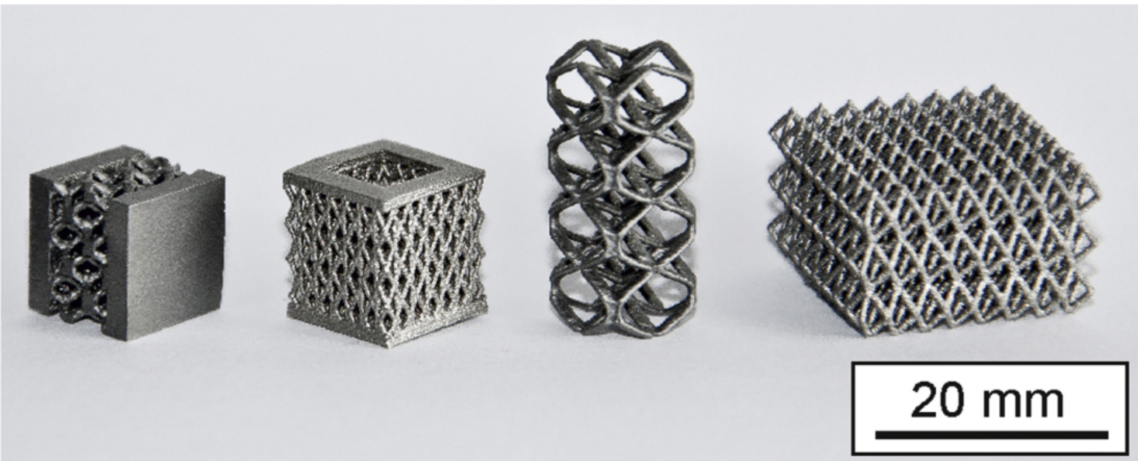



Figure 2. Some possibilities for HX component shapes using EC materials.

Reinhard Radermacher

**Project duration:**
January 2019 – December 2021

**Operating Agent:**
Reinhard Radermacher
University of Maryland, USA
*raderm@umd.edu*

Van Baxter

**Operating Agent:**
Van D. Baxter
Oak Ridge National Laboratory, USA
*vdb@ornl.gov*

**Participating countries:**
Germany, Italy, South Korea, Sweden, and USA

**Further information:**
*www.heatpumpingtechnologies.org/annex53/*

ANNEX

54

# HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS

Under the Kigali amendment to the Montreal Protocol, countries have committed to cut the production and consumption of HFCs by more than 80 percent over the next 30 years (Figure 1). Emissions from the refrigeration and air conditioning sector are projected to grow from 349 megatons (MT) carbon dioxide equivalent ($CO_2$e) in 2010 to 1596 MT $CO_2$e in 2030, because of more than 80% market growth of air conditioning systems, especially in developing countries (Figure 2).

Stationary air conditioning systems account for 37% of global refrigerant emission and 21% of $CO_2$ equivalent emissions of refrigerants. In order to investigate promising alternative refrigerants used for major air conditioning systems in response to this global regulation, the US Air-Conditioning, Heating, and Refrigeration Institute (AHRI) started an industry-wide cooperative research program in the US in 2011 and evaluated a handful of low-GWP alternative refrigerants.

Future heat pump systems will use low-GWP refrigerants and energy efficient technologies to meet the latest international regulations and reduce overall environmental impacts.

> ***This annex promotes low-GWP refrigerants to accelerate phase-down of high-GWP HFCs in air-conditioning and heat pump systems***

At the moment, low-GWP refrigerants candidates are R-32, R-32 mixtures and natural refrigerants (hydrocarbons and $CO_2$) with GWP values lower than 700. Since candidate refrigerants have a wide range of thermophysical properties and thermodynamic characteristics, which are different from current refrigerants, customized and optimized component and system designs for new low-GWP refrigerants are very important.

This annex aims at developing design guidelines of optimized heat pump components and systems for low-GWP refrigerants so that these can be used by heat pump manufacturers.

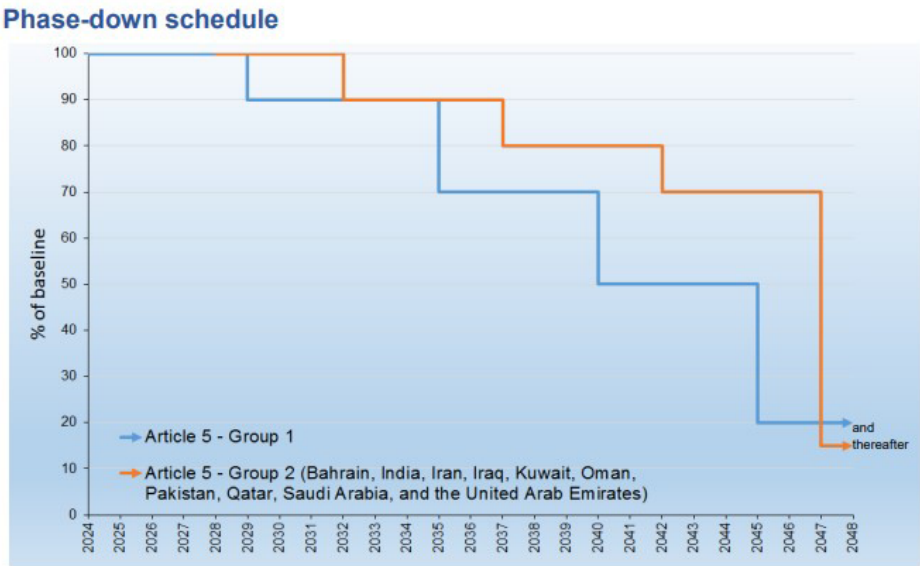



Figure 1. HFC Phase-down Schedule according to the Kigali Amendment to Montreal Protocol.

**OBJECTIVES**

This annex aims at promoting low-GWP refrigerant application to accelerate phase-down of high-GWP HFCs in air-conditioning and heat pump systems for residential and commercial buildings, by:

- Developing design guidelines of optimized heat pump components and system for low-GWP refrigerants through the review of available low-GWP refrigerants, their properties and applicable standards, safety and flammability of refrigerants, and safe use of flammable refrigerants;
- Optimizing heat pump components and systems for low-GWP refrigerants;
- Analyzing the LCCP impact by the current design and optimized design with low-GWP refrigerants;
- Studying the market opportunity of heat pumps with low-GWP refrigerants and low-GWP refrigerants availability for 2030.

**OVERVIEW OF TASKS**

***Task 1. Review of state-of-the-art technologies***

This task aims at reviewing the latest information on low-GWP refrigerants being investigated

***Task 2. Case studies and design guidelines for optimization of components and systems***

Conduct case studies and develop design guidelines for optimizing components and systems for identified refrigerants from Task 1.

***Task 3. Review of design optimization and advancement impacts on LCCP reduction***

Evaluate the effect of design optimization on LCCP reduction.

***Task 4. Outlook for 2030***

Evaluate market opportunities of heat pumps with low-GWP refrigerants, as well as the availability of low-GWP refrigerants in 2030.

***Task 5. Report and information dissemination***

This task aims at reporting work conducted and disseminating information developed in the Annex.

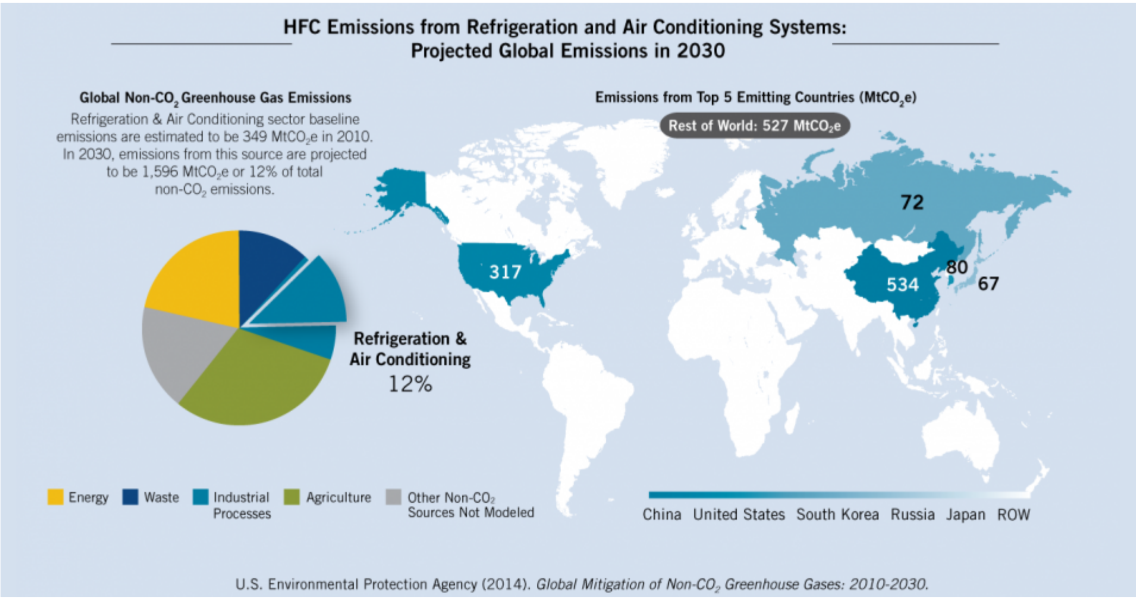



Figure 2. Projected Global Emissions from Refrigeration and Air conditioning Systems in 2030.

**Project duration:**
January 2019 – December 2021

**Operating Agent:**
Yunho Hwang, University of Maryland, USA
*yhhwang@umd.edu*

**Participating countries:**
Italy, Japan, South Korea, Sweden, and USA

**Further information:**
*www.heatpumpingtechnologies.org/annex54/*

# Outlook into the Future

In February 2018, the request for a five-year extension of the HPT TCP was approved by the IEA Committee on Energy Research and Technology (CERT) 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 strategic work plan for the TCP was elaborated (see page 6-7).

For 2019, the ExCo has decided to focus on the TCP's objectives related to

**Environmental Awareness**

- More policy makers are aware of the potential of heat pumping technologies to fulfil the IEA's mission

**Engagement worldwide**

- HPT TCP has more member countries
- HPT TCP is an active player in, or partner to, other international initiatives and organizations

In order to progress towards these objectives, the TCP has selected six prioritized achievements to be reached during 2019:

1. Create increased knowledge about the HPT TCP and heat pumping technologies among prioritized target groups, such as policy makers, a new and broader network to widen the scope of the RDD&D, and possible new member countries in warm and humid climates
2. To become the first and foremost independent source for information regarding heat pumping technologies
3. An efficient tool for trend scanning, to support ExCo and our followers
4. New ideas and proposals for Annexes according to our new strategy plan
5. A more robust structure for the IEA HP Conference organization
6. Reengineering of HPT TCP and Heat Pump Centre procedures

Based on the strategic work plan up to 2023, we will focus on advancing the RDD&D of heat pumping technologies through creation of research opportunities, networking possibilities, and meeting places for academia, industry, private sector, markets, and policy makers to collaborate under new Annexes (projects) and activities within the HPT TCP. In addition, we will work with our strategy related to initiating and performing RDD&D within the prioritized areas to widen the scope of our research activities.

In accordance with the revised strategic work plan, two new Annexes were approved in October 2018 and started shortly thereafter. The first one was *"HPT Annex 53 Advanced Cooling/ Refrigeration Technologies"* (see page 38) and the second one was *"HPT Annex 54 Heat pump systems with low GWP refrigerants"* (see page 40).

Another Annex proposal which will be started during 2019 is *"IoT for Heat Pumps"*. This Annex has already been approved by the Executive Committee, and is in line with the new strategy. The Annex will focus on the opportunities and challenges of IoT-enabled heat pumps. Connected devices will play a major role in the future, addressing multiple aims, such as increased comfort for the user, reduction in energy consumption, and decarbonization of heat supply. The Annex will include both heat pumps for household and commercial applications and heat pumps for industrial applications. It aims to increase knowledge at different levels (OEMs, heat pump manufacturers, consultants, installers, legislators, etc.) and to provide guidance and contributions to the development of future standards.

A joint Annex with the title *"Comfort & Climate Box – Speeding up market development for integrating heat pumps and storage packages"* which is a collaboration between the HPT TCP and the ECES (Energy Storage) TCP is planned to be started during 2019. This Annex will be performed in collaboration with the Mission Innovation (http://mission-innovation.net/) initiative and contribute to their Innovation Challenge IC#7 Affordable Heating and Cooling for Buildings. This Annex will contribute to the objective that HPT TCP is an active player in, or partner to, other international initiatives and is related to the prioritized area (a) and (b) for the TCP's RDD&D activities (see page 7).

The motivation for this Annex is that integrated systems consisting of heat pumps and storage are an important technological option to accelerate the use of renewable energy for heating and cooling. By combining heat pumps and storage, several issues may be tackled, such as grid load balancing; increased self-usage of renewables; optimizing economics, $CO_2$, fuel use and supply security. Commercial development of these packages is progressing slowly. This Combined Annex will help accelerate market development. The goal of this Combined Annex is to develop and disseminate knowledge, evaluate prototypes and coordinate field tests involving HP/storage-packages in existing buildings.

Other Annex ideas that will be developed during 2019 is one on "How to improve the channel between manufacturer and end-user, to extend the good use of heat pumps" and one on "Heat pumps in multi vector energy systems, second phase - Showing flexibility benefits through HP implementation in DHC networks".

In order to be in line with the strategic plan, Annex ideas related to the area (e), New or special markets and applications, including automotive, industry and consumer products (e.g. white goods) should be developed. This will be initiated during 2019.

# Programme Contacts

# Executive Committee Delegates

Find your national Executive Committee delegate in HPT TCP:


**AUSTRIA**
Dr Thomas Fleckl
Austrian Institute of Technology GmbH
Tel. +43 664 2351917
*thomas.fleckl@ait.ac.at*

Ms Sabine Mitter (Alternate)
Energy and Environmental Technologies, Austrian Federal Ministry for Transport, Innovation and Technology
Tel. +43 1 71162 652915
*sabine.mitter@bmvit.gv.at*

**BELGIUM**
Ms Jozefien Vanbecelaere
Beleidsmedewerker PVen Warmtepompen
Tel. +32 2 218 87 47
*jozefien.vanbecelaere@ode.be*

***Flemish Region***
Mr Wim Boydens (Alternate)
Boydens Engineering
Tel. +32 50 83 13 20
*wimb@boydens.be*

***Walloon Region***
Prof Marc Frere (Alternate)
University of Mons
Faculté Polytechnique de Mons
Tel. +32 65 37 42 06
*marc.frere@fpms.ac.be*

***Brussels-Capital Region***
Prof Patrick Hendrick (Alternate)
Université Libre de Bruxelles (ULB)
Department Aero-Thermo-Mechanics (ATM)
Tel. +32 2 650 2658
*patrick.hendrick@ulb.ac.be*

**CANADA**
Dr Sophie Hosatte
CanmetENERGY
Natural Resources Canada
Tel. +1 45 06 52 53 31
*sophie.hosatte-ducassy@canada.ca*

**DENMARK**
Mr Svend Pedersen
Danish Technological Institute
Refrigeration and Heat Pump Technology
Tel. +45 72 20 12 71
*svp@teknologisk.dk*

**FINLAND**
Mr Jussi Hirvonen
Finnish Heat Pump Association SULPU ry
Tel. +358 50 500 2751
*jussi.hirvonen@sulpu.fi*

**FRANCE**
Mr Paul Kaaijk
ADEME
Engineer International Actions and Survey
Tel. +33 4 93 95 79 14
*paul.kaaijk@ademe.fr*

Ms Michèle Mondot (Alternate)
CETIAT
Thermodynamic Systems Development and Partnerships
Tel. +33 4 72 44 49 20
*michele.mondot@cetiat.fr*

Mr François Durier (Alternate)
CETIAT
Director of Development and Partnerships
Tel. +33 4 72 44 49 34
*francois.durier@cetiat.fr*

**GERMANY**
Dr Claus Börner
Projektmanagement Jülich
Energy System: End-Use
Tel. +49 2461 613816
*c.boerner@fz-juelich.de*

Dr Rainer Jakobs (Alternate)
IZW Information Centre on Heat Pumps and Refrigeration
Tel. +49 6163 5717
*Dr.Rainer.Jakobs@T-Online.de*

**ITALY**
Dr Maurizio Pieve
ENEA
Energy Technologies Dept.
Tel. +39 50 621 36 14
*maurizio.pieve@enea.it*

**JAPAN**
Mr Tetsushiro Iwatsubo
New Energy and Industrial Technology Development Organisation (NEDO)
Energy Conservation Technology Department
Tel. +8144 520 5281
*iwatsubotts@nedo.go.jp*

Mr Hideaki Maeyama (Alternate)
Heat Pump and Thermal Storage Technology Center of Japan (HPTCJ)
Tel: +81 3 5643 2404
*maeyama.hideaki@hptcj.or.jp*

Mr Toshihiko Ota (Alternate)
New Energy and Industrial Technology Development Organisation (NEDO)
Tel. +81 44 520 5281
*ohtatsh@nedo.go.jp*

**THE NETHERLANDS**
Ms Marion Bakker
Netherlands Enterprise Agency (RVO.nl)
Tel. +31 88 04 22 677
*marion.bakker@rvo.nl*

Mr Tomas Olejniczak (Alternate)
Netherlands Enterprise Agency (RVO.nl)
Tel. +31 (0)88 602 3317
*Tomas.olejniczak@rvo.nl*

**NORWAY**
Rolf Iver Mytting Hagemoen
NOVAP
Tel. +47 971 29 250
*river@novap.no*

**SOUTH KOREA**
Mr Hyun-choon Cho
Korea Institute of Energy Technology Evaluation and Planning (KETEP)
Tel. +82 2 3469 8302
*energykorea@ketep.re.kr*

Mr Bong-joo Shin (Alternate)
Korea Institute of Energy Technology Evaluation and Planning (KETEP)
Tel. +82 2 3469 8382
*shinskie@ketep.re.kr*

Prof Minsung Kim (Alternate)
Chung-Ang University
Tel: +82 2 820 5973
*minsungk@cau.ac.kr*

**SWEDEN**
Ms Emina Pasic
Swedish Energy Agency
Energy Technology Department
Tel. +46 16 544 2189
*emina.pasic@energimyndigheten.se*

Mr Per Jonasson (Alternate)
Swedish Refrigeration and Heat Pump Association
Tel. +46 8 512 549 55
*per.jonasson@skvp.se*

**SWITZERLAND**
Dr Carina Alles
Swiss Federal Office of Energy
Tel. +41 58 462 43 43
*carina.alles@bfe.admin.ch*

Mr Stephan Renz
(Chairman, Alternate)
Beratung Renz Consulting
Tel. +41 61 271 76 36
*renz@renzconsulting.ch*

**UK**
Mr Oliver Sutton
Department for Business, Energy and Industrial Strategy
Tel. +44 300 068 6825
*oliver.sutton@beis.gov.uk*

Mr Roger Hitchin (Alternate)
+44 20 89 77 55 02
*roger.hitchin@blueyonder.co.uk*

**USA**
Mr Antonio M. Bouza
US Department of Energy
Tel. +1 202 586 4563
*antonio.bouza@ee.doe.gov*

**Heat Pump Centre**
c/o RISE Research Institutes of Sweden
P.O. Box 857, SE-501 15 BORÅS, Sweden
Telephone: + 46 10 516 55 12
E-mail: hpc@heatpumpcentre.org
Internet: www.heatpumpingtechnologies.org