Technology Collaboration Programme
by IEA

ANNUAL REPORT 2019

HEAT PUMPING TECHNOLOGIES

Technology Collaboration Programme on
Heat Pumping Technologies - HPT TCP

IEA HPT

Technology Collaboration Programme
on Heat Pumping Technologies

Image sources

Cover
- EHPS 2019, HPC
- National Experts meeting 2019, HPC
- 2019 China Heat Pump Annual Conference, HPC
- ExCo meeting in Espoo Finland, May 2019, HPC
- ExCo meeting in Gaithersburg USA, November 2019, HPC

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- Screenshot IEA webpage

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- www.pexels.com

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HPT TCP Annual Report 2019
www.heatpumpingtechnologies.org
April 2020

Content

Message from the Chairman

During 2019, numerous countries have significantly accentuated their targets for reducing greenhouse gas emissions. For example, the EU Parliament, various countries, and numerous cities worldwide have declared a climate emergency. One of the driving forces behind this was the increasing demand for immediate action to stop climate change, which were raised and demonstrated by young people.

As an energy-efficient, locally emission-free heating technology, heat pumps can substantially contribute to the decarbonisation of the buildings and industrial sectors. Heat pumps are therefore given an important role in the Sustainable Development Scenario (SDS) of the IEA. For example, in the SDS, the sales of heat pumps as heating systems for buildings is to increase fivefold worldwide by 2030. In its Tracking Clean Energy Progress (TCEP) report, IEA deemed heat pumping technologies as not being on track, thus not being able to achieve the market penetration that is necessary according to the SDS. We must therefore review our activities and carefully consider opportunities and challenges for faster implementation in the market.
At the same time, it is of utmost importance that more energy efficient cooling technologies than the current ones are implemented in the near future. This will offer comfort cooling to the world's population, curbing the rapid growth in energy demand for air conditioning. Here the TCP has an active role to play.
The core of our activities are the projects, Annexes, which are performed over a period of three to four years in internationally cooperating teams. The ten projects that are ongoing largely cover the topics of our strategic work plan 2018 - 2023. This is also due to the well-structured process led by the Heat Pump Centre (HPC) for developing new projects.

Communication of the findings and results of the projects is done by the members of the Annex teams in their home countries, presentations at conferences, contributions on our website and in our magazine, and in the reports we publish. The Annex teams, together with the HPC, also act as an expert competence network, e. g., for comments on request from the IEA Secretariat.

Further, it is important for the international development and dissemination of the technology that as many countries as possible participate in the HPT TCP. It is therefore particularly gratifying that China has joined us in 2019 as the 17th member country. We are in active contact with several potential member countries.

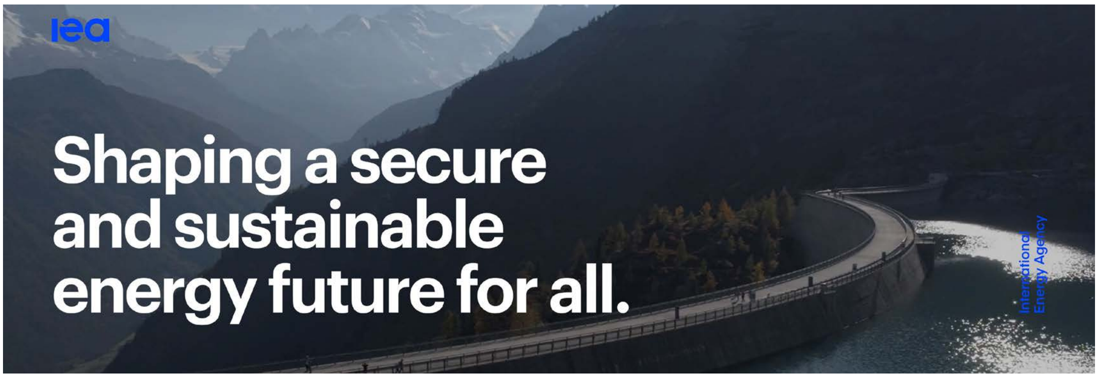
An important instrument for communication of the development and application of heat pumping technologies is our international heat pump conference, which takes place every three years. During 2019, we have worked intensely to prepare for the event planned for South Korea in 2020.

With our organization and our activities to develop and communicate knowledge regarding heat pumping technologies for heating and cooling and their application in the market, we are fundamentally well positioned. In 2020, we will review our strategy, and derive measures from the IEA -TCEP requirements to bring heat pumps on track and thus increase our contribution to alleviate the climate emergency.

This is only possible with the 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 to and supporting all these activities. My special thanks to the people at 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 IEA is at the heart of global dialogue on energy, providing authoritative analysis, data, policy recommendations, and real-world solutions to help countries provide secure and sustainable energy for all.

The IEA was created in 1974 to help co-ordinate a collective response to major disruptions in the supply of oil. While oil security remains a key aspect of its work, the IEA has evolved and expanded significantly since its foundation.

Taking an all-fuels, all-technology approach, the IEA advocates policies that enhance the reliability, affordability and sustainability of energy. It examines the full spectrum of issues including renewables, oil, gas and coal supply and demand, energy efficiency, clean energy technologies, electricity systems and markets, access to energy, demand-side management, and much more.

Since 2015, the IEA has opened its doors to major emerging countries to expand its global impact, and deepen co-operation in energy security, data and statistics, energy policy analysis, energy efficiency, and the growing use of clean energy technologies. For more information, visit ***www.iea.org***

The IEA global innovation network

- Around 40 autonomous expert groups, known collectively as the Technology Collaboration Programme and individually as collaborations or TCPs
- Thousands of experts from governments, academia and industry
- Entities participating from 55 countries
- All technology sectors

The **Technology Collaboration Programme (TCP)**, a multilateral mechanism established by the International Energy Agency (IEA) 45 years ago, was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of thousands of experts across government, academia and industry in 55 countries dedicated to advancing common research and the application of specific energy technologies.

Currently there are 38 individual technology collaborations working across several technology or sector categories: energy efficiency end-use technologies (buildings, transport, industry and electricity), renewable energy and hydrogen, fossil energies, fusion power, and cross-cutting issues. These technology collaborations are a critical, member-driven part of the IEA family, but they are functionally and legally autonomous from the IEA Secretariat. The breadth of the analytical expertise in the Technology Collaboration Programme is a unique asset in the global transition to a cleaner energy future. For more information visit: ***www.iea.org/tcp***

Welcome to the 13th IEA Heat Pump Conference "Mission for the Green World"

The 13th IEA Heat Pump Conference (HPC2020) will be held in Ramada Plaza Hotel Jeju, Korea, April 26-29, 2021 (originally planned for May 2020, but postponed to April 2021 due to the new corona outbreak, see below).

The conference venue is located in the center of the World Heritage Site, showing the beauty of Jeju Island. At the conference, a wide scope of heat pumping technologies will be discussed with the theme 'Heat Pumps – Mission for the Green World.

On Monday April 26, the first day of the Conference will start with a number of technical workshops with challenging topics organized by HPT Annex participants , HPC and other IEA TCPs. Six workshops are moderated by Operating Agents of on-going or finalized HPT Annexes. The other two workshops are moderated by the Heat Pump Centre. The workshops will have speakers from all continents, giving an overview of the state of the art in the market, experience and current research topics with challenging issues for discussion.

The topics of the workshops are:

- Heat pumps in smart grids and hybrid heat pump (HPT Annex 42 and HPT Annex 45)
- Heat pump water heaters, a challenging future (HPT Annex 46)
- Design and integration of heat pumps for nZEB (HPT Annex 49)
- Heat pumps in multi-family buildings for space heating and DHW (HPT Annex 50)
- Heat pumps with low-GWP refrigerant (HPT Annex 54)
- Energy storage with heat pumps: Comfort and Climate Box - CCB (ECES/HPT Annex 55)
- Comfort and Climate Box solutions for warm and humid climates (Heat Pump Centre)
- Trend scanning, HPT TCP half-term strategy evaluation (Heat Pump Centre)

After the plenary opening session, the conference will continue for three days in four parallel tracks of presentations. The topic of each track is summarized below.

Track 1:
Heat pumps in residential application for Single- and Multifamily buildings, Digitalization and fault detection, Energy storage, Air source heat pumps, Multifunctional heat pumps with ventilation and cooling, Test and calculation methods, and Alternative/new refrigerants/cycles;

Track 2:
Market and policy, Heat pumps with hybrid technologies, Ground source and solar heat pumps, Heat pumps for smart grids and district heating and cooling, Domestic hot water heat pumps, and Heat pumps for commercial buildings;

Track 3:
Three sessions of Air-conditioning technologies, four sessions of Industrial heat pumps including waste heat applications, Domestic hot water heat pumps;

Track 4:
Working fluids and refrigerants, Risk assessment of refrigerants, Non-traditional technologies, Sorption and gas driven heat pumps, Systems and components development, Nearly zero energy buildings.

In the HPC2020, more than 220 high quality papers will be presented in the technical sessions, and participants will encounter numerous cutting-edge presentations on heat pumps. In addition, the conference will serve as a forum to discuss the latest developments in heat pumping technologies, and exchange valuable knowledge regarding market, policy, and standards. Exhibitions will be held at the conference, to share products and technologies from domestic and foreign companies. On Wednesday September 28 a technical tour is arranged to power plant and seawater heat pump demonstration sites.

Regarding the unexpected postponement of HPC2020, the Conference Organizing Committee sincerely hope for your understanding. The decision of postponement was based on the assessed risk associated with organizing the conference in May. Also, the selection of the new dates is based on the hope and belief that the traveling situation will have improved by April 2021, and that at the same time the submitted papers will not be too old for presentation. In the meantime, additional promotion of the conference will be provided to enhance the conference quality and participants' satisfaction. Although the conference is delayed, we are confident that the event in April 2021 will be even more successful with your continuous support.

Additional updates and details will be provided on the website of the conference *www.hpc2020.org* and via *www.heatpumpingtechnologies.org.*

13th IEA HEAT PUMP CONFERENCE
2020 | JEJU KOREA

Images of Jeju and Night view of Ramada Plaza Hotel Jeju.

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. We continuously observe the development and requirements of our energy system and revise our strategy every five years, according to the objectives of the IEA.

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

1. Advance 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.

2. 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 thermodynamic potential and low toxicity for both new and existing applications

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

4. Communicate the results and impact from the RDD&D work, tailor the messages using appropriate channels to reach relevant target groups, including policy makers, national and international energy and environmental agencies, utilities, manufacturers, system designers, industry associations, researchers and end-users

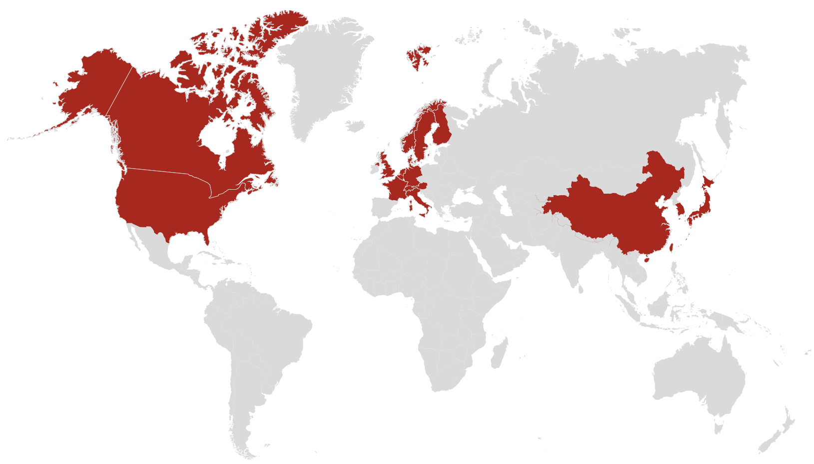
5. Provide IEA and standardisation organisations with reliable and independent guidance, data and knowledge about heat pumping technologies, separately or in combination with other technologies

6. 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
- China
- Denmark
- Finland
- France
- Germany
- Italy
- Japan
- The Netherlands
- Norway
- South Korea
- Sweden
- Switzerland
- United Kingdom
- The United States



* Research, Development, Demonstration and Deployment

Organization of the HPT TCP

The work within the HPT TCP is organized in several interacting layers.

The Executive Committee (ExCo) is the board of the HPT TCP. Meetings are held twice a year. At the meetings, each member country has one vote. The meeting locations alternate between the member countries and regions.

National Teams (NTs) are important for promotion of the HPT TCP at the national level. The National Teams are experts on their countries' needs regarding industry, markets, deployment, research and development activities. It is a forum for discussion, networking and creation of new ideas. Thus, an interactive process where the National Team shares information with the ExCo delegates, the Heat Pump Centre, and other National Teams is highly important.

Annexes are the cooperative projects within the HPT, and are a central activity of the HPT TCP. Within these, new knowledge is elaborated through collaborative RDD&D work. They are conducted on a combination of cost sharing and task-sharing basis by the participating countries. They are often conceived at the joint National Experts' meetings.

The Heat Pump Centre (HPC) is the central communication activity of HPT TCP. This involves information dissemination, for instance regarding project reports, the HPT Magazine and the HPT Website; nowadays also social media such as LinkedIn and Twitter (@heatpumpingtech). It also involves programme support to ExCo, NTs and Annex coordinators (called Operating Agents, OAs), as well as stimulating and supporting the generation of new activities, arranging National Experts' meetings, representing the TCP at IEA meetings, supporting IEA publications, and conducting outreach activities.

This is the HPC Staff :

Monica Axell, General Manager
Monica has a long and extensive experience of heat pumping technologies. Through meetings and conferences for the HPC and others, she also has many contacts within not only this field, but generally within the field of energy, and beyond.
monica.axell@ri.se

Caroline Haglund Stignor, Assistant Manager/Annex Manager
Caroline also has a long and extensive experience of heat pumping technologies. Together with Monica, she is often the face of the HPC, presenting and representing HPT TCP in current and future member countries, and conferences.
caroline.haglundstignor@ri.se

Christina D-Nordström, Coordinator/Administrator
Christina is an experienced administrator, who is used to handling large and complicated projects. She is the person to contact for general issues regarding the HPT TCP and HPC.
christina.d-nordstrom@ri.se

Ulrica Örnemar, Communication
Ulrica's communication skills cover the esthetics of producing all kinds of publications, as well as how to catch the readers' eyes on social media.
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Johan Berg, Magazine, Annual report, statistics, Member country report
Johan enjoys streamlining texts received from authors within or outside the TCP, for HPT publications.
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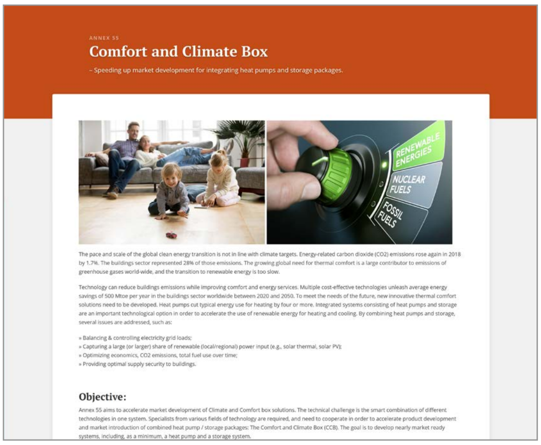
Kerstin Rubenson, Communication
With a background as a scientific journalist, Kerstin is the ideal writer of condensed appealing texts for publications.
kerstin.rubenson@ri.se

Highlights 2019

New member country: China
During 2019, China joined the HPT TCP, after a period of continuous dialogue. HPT TCP has, together with the IEA secretariat, given support to China in their final steps of the membership procedure.



Two annexes completed
Both Annex 45 and Annex 47 were completed during 2019.

Annex 45 made clear that hybrid heat pumps, driven by fossil fuels and electricity, may serve as a gateway to low-carbon heating. Once the user is used to the heat pump functionality, it should be easier to take the step to all-electric heating with a standard heat pump. The Final Report for Annex 45 can be downloaded at:
https://heatpumpingtechnologies.org/annex45/

Annex 47 has shown that heat pumps can become a cornerstone in district heating and cooling grids. They are able to utilize low-temperature and waste heat sources, facilitate the integration of renewable power in electricity networks, increase the share of renewable energy in heating grids, and minimize grid losses. This makes them an economically viable option. Annex 47 created a catalogue with 39 cases with heat pumps in district heating networks, see the figure. The Final Report for Annex 47 can be downloaded at:
https://heatpumpingtechnologies.org/annex47/

New annexes launched, and in the pipeline
Three new Annexes in line with the strategy plan of the TCP started their work during 2019: "Advanced Cooling/Refrigeration Technologies Development" (Annex 53), "Heat pump systems with low GWP refrigerants" (Annex 54) and "Comfort and Climate Box" (HPT Annex 55 / ECES Annex 34). Annex 55 aims at speeding up market development for integrating heat pumps and storage packages, and is a joint annex between the HPT TCP and the Energy Energy Storage TCP. It is performed in collaboration with Mission Innovation, a global initiative of 23 countries and the EU, to accelerate clean energy innovation.

One Annex was approved and will start in early 2020, "Internet of Things for Heat Pumps" (Annex 56). Further, one Annex proposal was approved: "Flexibility by implementation of heat pump in multi-vector energy systems and thermal networks".

The role of heat pumps highlighted in new IEA Report: Tracking Clean Energy Progress
A new web-based publication by IEA, Tracking Clean Energy Progress (TCEP), points out that the share of heat pumps as a heating solution must triple to 2030 in order for the world to reach the two-degree scenario. The report provides recommendations on how these technologies and sectors can get 'on track' with the IEA's Sustainable Development Scenario. HPC has collaborated with IEA regarding the publication of this report for heat pumps, which is available on the IEA website.

Activities and achievements

New member countries
China joined the HPT TCP in 2019, after a period of continuous dialogue. Throughout the membership procedure, the HPC, the HPT Chair and the IEA secretariat has supported China. The HPT TCP put some extra effort during 2019 into welcoming China into the TCP.

The HPC is investigating the possibilities of communicating via WeChat in China, which is commonly used. When studying the website traffic, we see an increasing interest from Chinese website visitors as an effect of our effort and the new membership.

In addition to China, HPC has been in contact with several potential new member countries. Especially noteworthy are the contacts with India. Estonia may join HPT TCP in 2020. Other potential member countries are Mexico, Chile, Spain, and the Czech Republic.

[this is in line with the Strategy point 6. See page 9]

Executive Committee meetings
Two meetings of the HPT TCP Executive Committee (ExCo) were held in 2019:

- » May 22-23, Espoo, Finland;
- » November 13-14, Gaithersburg, US

Ongoing, new, and completed annexes
The projects within the HPT, the annexes, are the heart of the HPT TCP activities.

During 2019, seven annexes were on-going:

- "Fuel-driven sorption heat pumps" (Annex 43);
- "Domestic Hot Water Heat Pumps" (Annex 46);
- "Industrial Heat Pumps, Second Phase" (Annex 48);
- "Design and integration of heat pumps for nZEB" (Annex 49);
- "Heat Pumps in Multi-Family Buildings for space heating and DHW" (Annex 50);
- "Acoustic Signature of Heat Pumps" (Annex 51);
- "Long term performance measurement of GSHP Systems serving commercial, institutional and multi-family buildings" (Annex 52).

See further pages 18-19 and 22-33.

Two annexes were completed:

- "Hybrid Heat Pumps" (Annex 45);
- "Heat Pumps in District Heating and Cooling systems" (Annex 47).

See further pages 11 and 20-21.

Three new Annexes in line with the strategy plan of the TCP were initiated during 2019:

- "Advanced Cooling/Refrigeration Technologies Development" (Annex 53);
- "Heat pump systems with low GWP refrigerants" (Annex 54);
- "Comfort and Climate Box" (HPT Annex 55 / ECES Annex 34).

See further pages 12 and 34-39.

One Annex was approved and starts early in 2020: "Internet of Things for Heat Pumps" (Annex 56), see pages 12 and 40-41.

Further, one Annex proposal was approved:

- "Flexibility by implementation of heat pump in multi-vector energy systems and thermal networks".

This builds on Annex 47. See page 43.

[Strategy points 2a, 2c, 2d, 2f, and 3]

Generation of new potential annexes

The National Experts' meeting, organized by HPC, was held in Nuremberg, Germany, in October, with good attendance, and lively and fruitful informal discussions. As usual, the main focus of the meeting was to generate new activities in the form of Annexes and to discuss annex ideas and proposals, in particular in connection to the HPT strategy.

At the meeting, several Annex ideas in relation to the strategic area the strategic area 2e (see page 9), New or special markets and applications, including automotive, industry and consumer products (e.g., white goods) were discussed. This has so far resulted in a proposal for a new annex about High Temperature Heat Pumps, for industrial and other types of applications and some other ideas have been decided to be taken further within the HPT (see Outlook for the Future, page 42).

[Strategy points 2c and 2e]

Member Country Reports

Each member country will summarise its heat pumping technology-related research, policy, and market aspects in a so-called Member Country Report. These reports have now been received from most member countries, and published on the ExCo team website, where they are available for the HPT member countries. A synthesis report will be assembled when all of the reports have been received.

[Strategy point 5]

The IEA Heat Pump Conference

The next IEA Heat Pump Conference will be held in Jeju, Korea. More than 200 papers have been received. The HPC has supported the preparations for the conference, and promoted it in various channels.

[Strategy point 4]

HPT Magazine, HPT Newsletter, Website and Social Media, 60 Seconds

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. Three issues of the HPT Magazine were pub-lished during 2019, with the following topics: No. 1/2019 "Heat Exchangers", No. 2/2019 "Industrial Heat Pumps", and No 3/2019 "Cooling for the Future".

HPC has increased the number of followers in social media and reached the communication targets for 2019. HPC has been active on social media and published news and retweets on LinkedIn and Twitter. The HPC continuously follows the traffic and number of readers of our communication channels and notes a steady increase. The HPC has also continued to support the Operating Agents (OAs) of the Annexes to improve their annex subsites. This is important as the Annex pages are the most visited on the HPT site, every month.

During 2019, the Heat Pump Centre has continued to distribute the "60 seconds" e-mail. This is a monthly, brief, bullet-format information page, giving an overview of HPC activities during the last month. It is distributed to the ExCo, and those involved in annexes and national teams.

[Strategy point 4]

IEA

The HPC team and the ExCo Chair has continuous contact with the IEA secretariat regarding various issues, and participates actively in workshops and meetings representing the TCP. For instance, they support IEA regarding certain key publications. An example is the report regarding heat pumps in the series Tracking Clean Energy Progress (TCEP), a series which contains one report for each of 45 critical energy technologies and sectors. HPC collaborated with IEA regarding publication of the TCEP report for heat pumps, which is available on the IEA website (*https://www.iea.org/reports/tracking-buildings/heat-pumps*). Specifically, the report states that the share of heat pumps as a heating solution must triple to 2030 in order for the world to reach the two-degree Celsius Scenario (2DS) in the IEA's Sustainable Development Scenario.

[Strategy point 5]

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). During 2019, HPC participated in many international events, for example the EHPA Heat Pump Forum 2019, in Brussels, Belgium, and had a booth representing the TCP at the International Congress of Refrigeration, ICR 2019, in Montreal, Canada, and at the European Heat Pump Summit (EHPS) in Nuremberg, Germany. In addition, at the ICR 2019 four HPT Annexes arranged workshops where results and outcomes from the Annexes were presented and discussed, and several Annexes were in the program of EHPS in Nuremberg.

[Strategy point 3]

Mission Innovation

The Mission Innovation (MI) 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 MI has established eight Innovation Challenges (IC). The Mission Innovation Challenge #7, "Affordable Heating and Cooling in Buildings", has developed a work plan for the priority areas. The IEA TCP Network has an infrastructure, procedures and a large amount of expertise to be able to effectively contribute to the MI Initiative. HPC follows the progress in #IC7 and the progress of Mission Innovation at an overall level and informs the rest of the TCP about the progress on a regular basis. There are ongoing discussions about a continuation of Mission Innovation after 2021.

Mission Innovation was invited and made a speech at the IEA TCP Universal Meeting. The recently started HPT Annex 55 (ECES Annex 34) was highlighted as one of the success stories from Mission Innovation, see page 38. The IEA emphasized that it aims to stimulate collaboration between TCPs; this Annex is a perfect example.

Most important for the HPT TCP is the recently initiated discussion about a possible new work stream in # IC7 regarding energy districts. Another important conclusion is that storage is highly regarded in the European Community (EC).

[Strategy point 3]

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).

NEW

Finalized 2019

a-f indicates which strategy the Annex is linked to, see page 9

FUEL-DRIVEN SORPTION HEAT PUMPS	43	AT, **DE**, FR, IT, KR, SE, UK, US	a
HYBRID HEAT PUMPS (Finalized 2019)	45	CA, DE, FR, **NL**, UK	a
DOMESTIC HOT WATER HEAT PUMPS	46	CA, CH, FR, JP, **NL**, KR, UK, US	a
HEAT PUMPS IN DISTRICT HEATING AND COOLING SYSTEMS (Finalized 2019)	47	AT, CH, **DK**, SE	c
INDUSTRIAL HEAT PUMPS, SECOND PHASE	48	AT, CH, **DE***, DK, FR, JP, UK	e
DESIGN AND INTEGRATION OF HEAT PUMPS FOR NZEB	49	AT, BE, **CH**, DE, NO, SE, UK, US	a, c
HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW	50	AT, **DE**, FR, IT, NL	a
ACOUSTIC SIGNATURES OF HEAT PUMPS	51	**AT**, DE, DK, FR, IT, SE	a
LONG TERM PERFORMANCE MEASUREMENT OF GSHP SYSTEMS SERVING COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS	52	DE, FI, NL, NO, **SE**, US, UK	a, b
ADVANCED COOLING/REFRIGERATION TECHNOLOGIES DEVELOPMENT	53	CN, DE, IT, KR, **US**	b
HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS	54	IT, JP, KR, **US**	f
COMFORT AND CLIMATE BOX (NEW)	55	AT, BE, CA, CH, CN, DE, FR, IT, **NL**, SE, TR**, UK, US	a, b
INTERNET OF THINGS FOR HEAT PUMPS (NEW)	56	**AT**, FR, DE, CH	d

* Operating Agent from Germany, but no other parties from the country participate.
** TR = Turkey, from ECES TCP

Selected Publications 2019

Annex 43
Zhu, C., Gluesenkamp, K.R., Yang, Z., Blackman, C.
Unified thermodynamic model to calculate COP of diverse sorption heat pump cycles: Adsorption, absorption, resorption, and multistep crystalline reactions.
International Journal of Refrigeration 99, 382-392, 2019.

Glanville, P. et al.
Demonstration and simulation of gas heat pump driven residential combination space and water heating system performance.
ASHRAE Winter Conference, Atlanta (USA), 2019.

Annex 46
Le, K. X., Huang, M. J., Hewitt, N. J.
Domestic high temperature air source heat pump: performance analysis using TRNSYS simulations
International High Performance Buildings Conference, Purdue (USA), 2018.
https://docs.lib.purdue.edu/ihpbc/315

Huang, M. J., Dai, Y. J, Shah, N. Wilon, C., Hewitt, N. J.
Performance analysis on developed EVI air source heat pump with seasonal heat demand,
IIR International congress of refrigeration, Montreal (CA), 2019.

Bando, Y., Hattori, H., Amano, Y.
A status-transition model for CO_2 heat pump water heater based on modified Lorentz cycle.
International Journal of Thermodynamics. 22, 26-33, 2019.
10.5541/ijot.499185

Annex 48
Wilk, V., Lauermann, M., Helminger, F.
Decarbonisation of industrial processes with heat pumps.
IIR International congress of refrigeration, Montreal (CA), 2019

Kaida, T., Fukushima, M., Iizuka, K.
Application of R1224yd(Z) as R245fa alternative for high temperature heat pump.
IIR International Congress of Refrigeration, Montreal (CA), 2019.

Perdu, E., Fourmiqué. J.-M.
120°C heat pump integration in Ghent heating district network.
European Heat Pump Summit, Nuremberg (DE), 2019.

Annex 49
Rominger, R., Wemhoener, C., Buesser, S.
Investigations of speed controlled heat pumps for NZEB in IEA HPT Annex 49.
J. Phys.: Conf. Ser. 1343 012078, 2019.

Wemhoener, C., Rominger, L., Buesser, S., Magni, M., Ochs, F., Betzold, Ch., Dippel, Th.
Simulation-based methodology for comparison of nZEB requirements in different countries including results of model calibration tests.
Building simulation 2019, Rome (IT), 2019.

Annex 51
Fleckl, T., Reichl, C.
Annex 51 "Acoustic Signatures of Heat Pumps" in the framework of the International Energy Agency Technology Collaboration Programme on Heat Pumping Technologies (IEA HPT).
IIR International Congress of Refrigeration, Montreal (CA), Workshop Acoustics of Heat Pumps.

Emhofer, J., Reichl, C.
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IIR International Congress of Refrigeration, Montreal (CA), Workshop Acoustics of Heat Pumps.

Vering, C., Klingebiel, J., Nürenberg, M., Müller, D.
Simultaneous energy efficiency and acoustic evaluation of heat pump systems using dynamic simulation models.
IIR International Congress of Refrigeration, Montreal (CA), Workshop Acoustics of Heat Pumps.

Annex 52
Naicker, S. S., S. J. Rees, S. J.
Long-term high frequency monitoring of a large borehole heat exchanger array.
Renewable Energy 145, 1528–1542, 2020. (Published online in 2019)
https://doi.org/10.1016/j.renene.2019.07.008

Bockelmann, F., Fisch M. N.
It works – Long-term performance measurement and optimisation of six ground source heat pump systems in Germany.
Energies 12, 4691, 2019.
https://doi.org/10.3390/en12244691.

Spitler, J.D., Gehlin S.E.A.
Measured performance of a mixed-use commercial-building ground source heat pump system in Sweden.
Energies 12, 2020, 2019.
https://doi.org/10.3390/en12102020

Annex 53
Emaikwu N., Catalini D., Muehlbauer J., Takeuchi I., Radermacher R., Hwang Y.
Development of a cascade active elastocaloric regenerator.
13th International Conference on Energy Sustainability, Bellevue (USA), 2019.

Qian S., Wang Y., Yuan L., Yu J.
A heat driven elastocaloric cooling system.
Energy 182, 881–899, 2019.

Kim J., Kim D. H., Kim Y., Kim H. S., Seo Y. -S., Park H. G., Yoon S. H.
Analytic approach to analysing the performance of membrane dehumidification by pervaporation.
Journal of Mechanical Science and Technology 33, 1–6, 2019.

ANNEX 43

FUEL-DRIVEN SORPTION HEAT PUMPS

INTRODUCTION

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

> ***An objective is to identify the most suited system layouts and which type of fuel-driven heat pump fits best to a specific building type and climate***

As the end user on the demand side, city councils and housing corporations owning large housing estates are important target groups. On the supply side, heat pump manufacturers, power companies, technical consultants as well as planners/installers 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.

An example of a novel component for fuel-driven sorption heat pumps is shown in Figure 1.

In addition to cost, a successful market introduction of further gas heat pump products depends

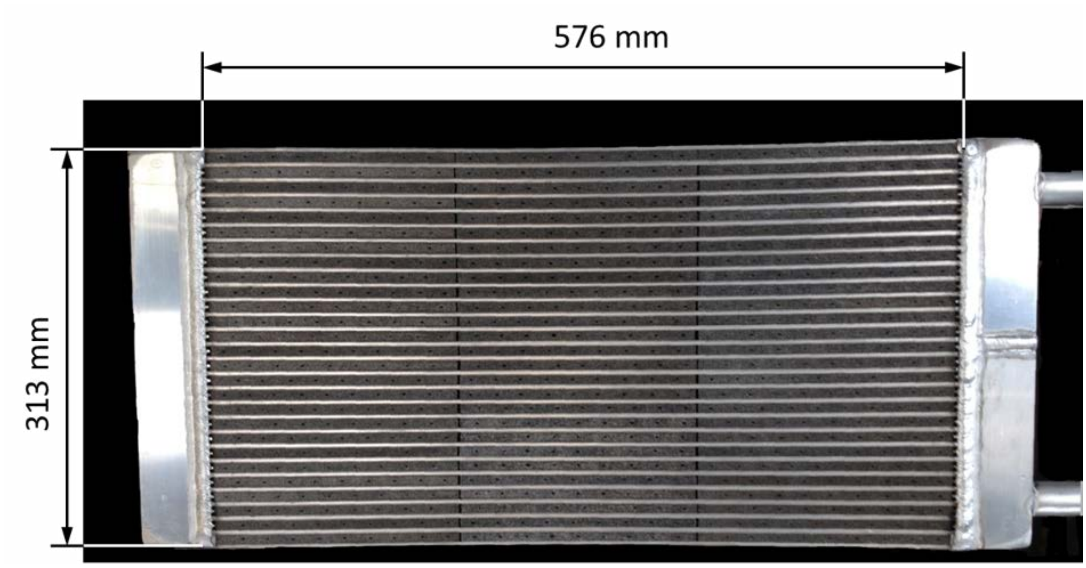

Figure 1. Fibre heat exchanger developed and tested by Fraunhofer and Fahrenheit GmbH. The heat exchanger with headers has a length of 700 mm, the width is 45 mm. The volume with headers is approximately 10 litres. Covered with a directly crystallized zeolite layer, it is supposed to be used as adsorber in a zeolite-water adsorption gas heat pump.

on robust and efficient appliances. In 2019, a simulation study prepared by Fraunhofer ISE showed the potential and limitations of currently market available sorption gas heat pumps. Compared to a gas condensing boiler, CO_2 savings of 30% and more are currently possible.

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.

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 are 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.

Several simulation studies have been performed, demonstrating the potential of gas driven sorption heat pumps for different building types, climates and heat distribution systems. It was shown that compared to a condensing boiler, savings in primary energy use of up to 40% are possible with existing products, and 60% is in reach with ongoing developments.

In December 2019, three late-stage 23 kW Gas Absorption Heat Pump (GAHP) prototypes were installed in three different homes in the Chicago, Illinois area, see Figure 2. All three homes are configured for space and water heating, without any backup energy source. A fourth home will be commissioned in January 2020 on a single-family home in Toronto, Canada, where the 23 kW GAHP will provide all of the space and water heating.

MEETINGS

No meetings were held in 2019.

Figure 2. Gas Heat Pump prototype in field test installation.

Project duration:
October 2013 – May 2019

Operating Agent:
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Participating countries:
Austria, France, Germany, Italy, South Korea, Sweden, UK and USA

Further information:
www.heatpumpingtechnologies.org/annex43

ANNEX

45

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

INTRODUCTION

Hybrid systems, consisting of a boiler or furnace in conjunction with a heat pump, have been used in commercial buildings for quite some years now, see Figure 1. Domestic applications are, however, still relatively new. The goal of this annex was to develop knowledge on the technical development and the market opportunities for hybrid heat pumps. This annex has thus served as a first comparative overview of the opportunities for hybrid HPs in the participating countries.

By combining an electrical HP with a fossil-fired boiler/furnace, it is possible to flexibly choose the optimal heating device. This allows to optimize heat production, e.g., according to CO_2 emissions, running costs, primary energy use, grid congestion or load balancing.

> ***The final report should be considered as a first important step towards defining the advantages of hybrid systems and their typical application areas***

Additionally, a hybrid heating system may have 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 a back-up, hybrid systems are an enabler for the use of heat pumps in retrofit situations. Hybrid heat pumps may serve as a gateway to low-carbon heating.

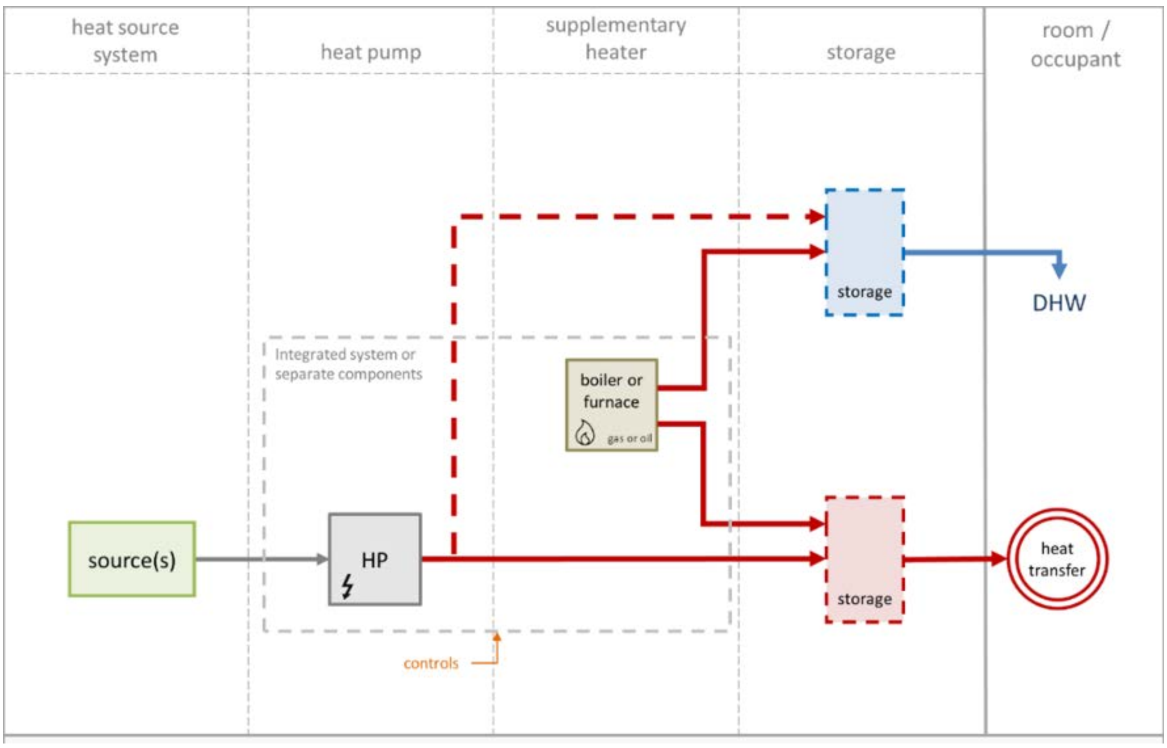

Figure 1. General layout for a hybrid heat pump system (dashed components optional).

A growing wave of interest in hybrid HPs as an intermediate step towards renewable heating can be noticed in France, the Netherlands and the UK. Especially in the Netherlands, hybrid HPs make up a sizable portion (5 – 10% in 2019) of all newly installed heating installations.

OBJECTIVES

Since the market development for hybrids is only starting to take off, the objective of this Annex became focused on discussing the general position of hybrids within the domestic heating sector, rather than focusing on implementation or performance details. The final report of the project should be considered as a first important step towards defining the advantages of hybrid systems and their typical application areas and role in the transition towards carbon neutral heating for homes.

RESULTS

During the project, some specific advantages of hybrid HPs have been found and discussed in detail. These include, for instance, immediate CO_2 emission savings, and the flexibility of being able to use electricity, gas or oil. Regarding investment and operation costs, hybrids tend to be more favorable, albeit not universally so.

Use cases are very different according to local circumstances, policy goals and needs. Each country has some appropriate use cases, while no single use case is relevant for all countries. This is summarized in Table 1.

MEETINGS

No meetings were held in 2019.

FINAL REPORT

The Final Report for Annex 45 can be downloaded at: *https://heatpumpingtechnologies.org/annex45/*

Table 1 – Overview of use cases for hybrids in participating countries.

Situation	Problem/driver	Hybrid provides...	Applies to...
Collective heating / multi-family houses	Renewable energy with best business case.	Optimal balance between investment and CO_2 savings.	NL, DE
Houses with PV-installations	Maximize use of self-produced renewable electricity.	Hybrid systems can be optimized for hot water production during PV peak production.	DE
Existing houses on gas grid or oil-fired boilers	CO_2-savings hard to achieve without renovation.	Immediate savings, without the need for building renovation. No "lock-in": future renovation will still provide extra savings on fossil fuels.	NL, DE, CA, FR
Small houses	No space for hot water storage tank.	With hybrids, HP can provide at least baseload, boiler can still cover hot water.	NL, UK
"Hard-to-treat" houses	Limited technical/architectural options for building-related measures. E.g. in monuments and old buildings.	Elegant way to provide at least a minimum amount of CO_2-savings, without necessitating (deep) renovation.	NL, UK, DE
Houses with LPG- or oil-fired boilers	Boiler fuel is expensive.	Immediate savings on fuel use.	DE, FR
Weak electricity grid or "end-of-the-line" grid connections.	Capacity of electricity grid too small for all-electric heat pump.	Maximal use of renewable energy with minimal peaks in grid load.	UK, CA, FR
New built houses	Renewable targets / building regulation	Desired amount of renewable energy or energy performance	FR
Add HP to planned AC installation	Heating reference (furnace) is low-cost, AC installation needed	By choosing a reversible HP, with cooling as primary function, part of the heat demand can become low-CO_2 for a limited investment	CA
Enabler for large-scale grid management	Several grid-load issues: e.g., renewable production electrical vehicles, mass-deployment of HPs	Electricity demand from hybrid systems can be switched off at will, providing plenty of smart grid potential.	Future development

Project duration:
September 2015 – May 2019

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Participating countries:
Canada, France, Germany, the Netherlands and UK

Further information:
www.heatpumpingtechnologies.org/annex45

ANNEX

46

DOMESTIC HOT WATER HEAT PUMPS

INTRODUCTION

Throughout the developed world, the heating of water for domestic use is one of the largest consumers of energy in the household sector (10 to 20% energy share). This is becoming a challenge for policy makers. The reason for this high share is twofold. On the one hand, the tendency for lower energy demand for space heating, due to a strict governmental policy on energy performance for new domestic buildings and inherently better insulation. On the other hand, higher comfort demands by the end user of hot water, and the relatively high temperatures required by legislation for domestic hot water.

Regarding Heat Pump Water Heaters we generally mean a mono-bloc air source heat pump (Figure 1), defined as a single unit with heat pump (containing compressor, expansion valve, evaporator and condenser), with a storage tank integrated, often located underneath the heat pump. These mono-bloc systems will remain the preferred solution in many cases for single family houses. However, there are a large number of alternatives for sanitary hot water with heat pumps in domestic applications, other than the mono-bloc, for single family houses and multi-family buildings, as well as for sanitary hot water systems for hotels, hospitals, sporting facilities,

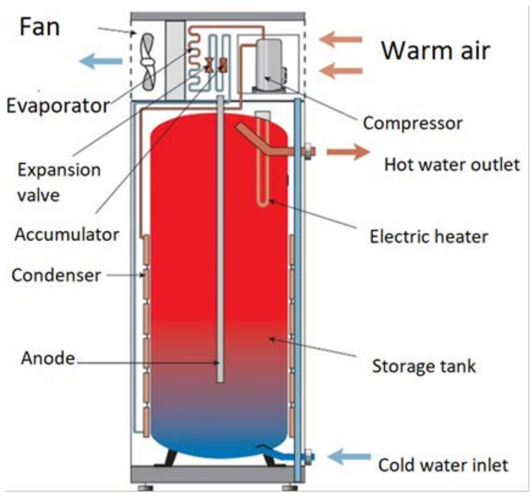

Figure 1. A common type of Heat Pump Water Heater, mono-bloc air source heat pump.

> ***"... for increased market penetration ... attain larger policy awareness of the market potential of heat pump water heaters."***

etc. There is a large number of technologies available with regional differences in demand and usage, thus showing a greater complexity than space heating/cooling systems.

However, in essence, hot water systems consist of a heat generator (i.e., a heat pump), an insulated storage system/tank and a system distributing the hot water to draw-off points or heat exchangers. These are generally located in a smaller system at the required temperature, often dictated by legislative requirements.

In the residential market there is a need for downsizing, noise reduction, and cold weather specifications, as well as higher efficiency and lower price. Although the monobloc Heat Pump Water Heaters have reached an important level of maturity on the market, there is still significant room for improvement. Heat pump water heaters are by far the most efficient way to heat water. However, a heat pump water heater in itself is not very energy efficient, since in the process of heating and draw offs a lot of losses occur. In addition to research and development in the technology focusing on refrigerants, condenser configurations, storage size and increasing the efficiency by smart controls, there are a number of market challenges that need to be tackled.

The necessary short-term effect for increased market penetration is to attain larger policy awareness of the market potential of heat pump water heaters. In advocating the right policy there is a fine line between supporting the interests of commercial market players selling or installing heat pump technologies, and the sometimes large economic interests of companies selling competing and often traditional technologies. Straightforward policy support for DHW HPs is therefore very rare and not consistent across Europe, North America and Asia. The good best practice example "Introduction Subsidy Scheme" initiated by the Japanese Government for the

ECO-Cute cannot simply be copied by other countries. Awareness must be achieved at the political level. This can be achieved by summarizing the conclusions and recommendations in comprehensible language on one-pagers (flyers) that can be distributed or used by individual countries.

OBJECTIVES

The objective of the Annex is to analyse the information on DHW heat pumping technologies and structure it to the market - ranging from end user to consultant, building constructor, and policy maker - in such a way that leads to a better understanding of the opportunities, and implementing them in order to reduce the use of primary energy consumption, lower CO_2 emissions and lower energy costs.

RESULTS IN 2019

The work during 2019 was characterized by summarizing the results of the annex work into reports that will be published. Main conclusions:

Refrigerants: no single alternative refrigerant fulfills all the ideal requirements. The F-gas Regulation provides incentives for the use of refrigerants with reduced GWP. Thus, direct emissions from Heat Pump systems are expected to be reduced. However, this does not necessarily result in lowering the climate impact, expressed in terms of the Life Cycle Climate Performance (LCCP) value. LCCP evaluation can be necessary in order to account for the entire climate impact of a system when selecting an alternative refrigerant.

Legionella: Heat pumping technologies are well suited and capable to deliver the required temperatures to fight *Legionella*.

System models: Objective comparisons of systems from a policy point of view have to be based on the chain efficiency, from primary (fossil) energy to the end. There is no publicly available model taking into account the technologies of water heating in systems nor innovative solutions for multifamily buildings.

Technical models: EDF, Waseda University, Oakridge National Laboratories and Ulster University have been working on modelling with a number of different perspectives. The Annex has outreached to parties from non-participating countries through IIR contacts, such as KTH and Universitat Politècnica de València, sharing important information.

Research and Development: In the participating countries, some specific programs for R&D on heat pump water heaters are or have been running, and some general R&D programs run in which heat pump water heater technologies are supported, among other techniques. Important topics for development, focusing on local market acceptance are

» System technologies
» Installer-focused technologies (Figure 2);
» End-user focused technologies;
» Water quality management technologies;
» Smart technologies.

During 2019, two dissemination workshops were held: in Seoul, to inform Korean experts on the results, and at the ICR 2019 Conference in Montréal, together with the chair of the IIR working group on heat pumps.

MEETINGS

2019 was the final year of Annex 46. Discussions focussed on the potential continuation of the Annex, mainly on modelling and optimizing the technology. However, it was decided to end the Annex by September 2019.

• Seoul, Korea. May 2019. Working meeting. Discussion on final reports. Proposal for extension regarding technical modelling.

• Montréal (Canada). August 2019. Working meeting. Discussion regarding a new Annex and extension to prepare for Workshop at the Conference.

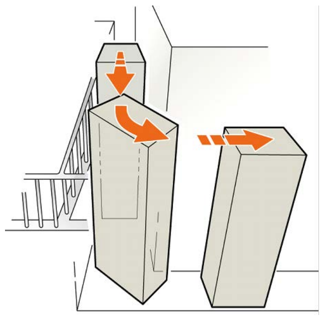

Figure 2. Since Japanese houses are often small, the compactification of appliances is also progressing. Companies have developed slim and compact hot water storage tanks, to enable installation even in very narrow spaces.

Project duration:
April 2016 – September 2019

Operating Agent:
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Participating countries:
Canada, France, Japan, the Netherlands, South Korea, Switzerland, UK and USA

Further information:
www.heatpumpingtechnologies.org/annex46

ANNEX

48

INDUSTRIAL HEAT PUMPS, SECOND PHASE

INTRODUCTION

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

Industrial heat pumps (IHPs) are active heat-recovery devices that raise the temperature of waste heat in an industrial process to a higher temperature to be used in the same process or another adjacent process or heat demand. IHPs are necessary for the reduction of energy consumption and GHG emissions through the increased utilization in industry. They are an important tool for the electrification of industrial processes. The aim of the Annex is to understand the worldwide activities of industrial heat pumps

While impressive efficiency gains have already been achieved in the past two decades, energy use and CO_2 emissions in manufacturing industries could be reduced further, if best available technologies were to be applied worldwide. In the previously completed Annex 35 "Application of IHPs" the results show the successful integration of heat pumps in industry, and how to overcome barriers.

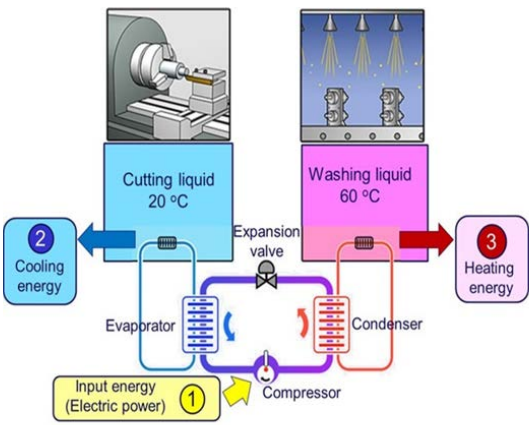

Figure 1. Application of heat pumps for industrial cutting and washing processes

> ***IHPs are an important tool for the electrification of industrial processes***

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 IHPs. This will be done by arranging the information on heat pumping technologies for industry, policymakers, industrial planners and designers, stake holders as well as heat pump manufacturers in such a way that it will lead to a better understanding of the opportunities. Then it will be possible to use this information to reduce primary energy consumption, CO_2 emissions as well as energy costs of industrial processes.

The definition of IHPs in this Annex is

- heat pumps in the medium and high power range;
- temperatures up to 200 °C;
- used for heat recovery and heat upgrading in industrial processes;
- tool for the electrification of industrial processes.

OBJECTIVES

- Development of a framework which structures information on IHP applications, using the existing and new case studies. Best available technologies and best practices should be selected;
- distribution of condensed and clear information material for policy makers, associations, and industries;
- the IHP potential for more efficient use of energy and reduction of greenhouse gas emissions should be shown;
- creating information material for IHP (training) courses.

RESULTS

Research and practical applications show increasingly clear that IHPs can provide heating/cooling to industrial applications and district grids. The latest outcomes of the Annex show more than three hundred good practices of IHPs in a variety of applications, such as drying, washing, evaporation, and distillation processes. A wide range of industries can benefit from this technology. Information material based on experience across the regions (Europe-Japan) has been assembled and was published in connection with the EHPS 2019.

The industrial process of drying is a very promising application for heat pumps, and is suggested by all Annex members for future work in R&D. The quality of the process could be improved, and energy cost and CO_2 emissions could be reduced. AIT leads a European project, "Dry-Ficiency", see Figure 2. EDF sees a great demand for this purpose in the paper industry. Japan is also starting a project in this direction according to CRIEPI.

High temperature heat pumps (HTHPs) are high temperature heat pumps with heat sink temperatures in the range of 100 to 160 °C. They may become increasingly commercialized during the coming years. Major applications have been identified, particularly in the food, paper, metal and chemical industries.

Meetings

• Tokyo, Japan, May 13. Working meeting, in cooperation with NEDO. Homepage, guidelines and information tools; HPT Magazine No 2/2019 (IHP issue); preparations for workshop next day and the ICR in Montreal 2019.

• Yokosuka Area, Japan, May 15. Expert meeting at the Central Research Institute of Electric Power Industry (CRIEPI). New refrigerants for high temperature heat pumps; high temperature heat pumps for steam production; drying systems with heat pumps.

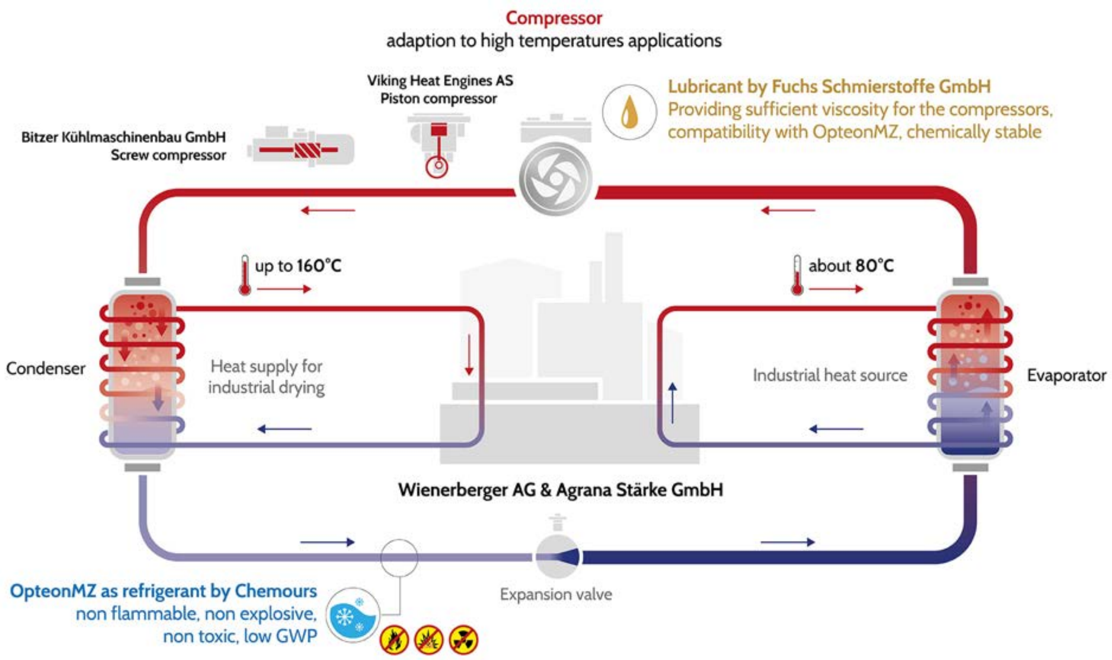

Figure 2. DryFiciency: Adaptation to high temperature heat pumps for industrial processes. Application: (Wienerberger) brick drying and (AGRANA) starch drying. Industries involved: Compressors, lubricants, refrigerants...

Project duration:
April 2016 – March 2019

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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

INTRODUCTION
Nearly Zero Energy Buildings (nZEB) were introduced as building standard for all new public buildings on January 1, 2019, in the EU, according to the recast of the EU Energy Performance of Buildings Directive (EPBD), and the introduction for all new buildings by January 2021 is in preparation. Also in the USA and Canada, as well as in Asian countries, such as Japan and China, nZEB targets are to be introduced in the time frame between 2020 and 2030.

The definitions for nZEB elaborated by the single EU member states differ between the states both in criteria and limits, and are currently not harmonised among the EU member states. Thus, it is hard to assess the ambition level towards high energy performance of this future building standard. Consequently, an evaluation among the countries is needed in order to stimulate policy makers to drive the markets to high performance buildings. Therefore, in Annex 49 a methodology is worked out that will enable a comparison of nZEB implementation across countries.

Against this background, building concepts which comply with nZEB requirements in various applications, such as residential or office use, are highly interesting for the market stakeholders and heating industry. Since the basic concept of nZEB implies a balance between the energy consumption and on-site renewable energy generation, the combination of heat pumps and on-site installed solar PV is already well established in built nZEB. The transition to buildings as prosumers has made it possible for heat pumps to contribute to demand response, as well as increase the self-consumption of the on-site PV yield. This may lead to economic benefits, and energy flexibility may become a future design criterion.-

*"**Monitoring in Annex 49 confirms the high performance of heat pumps in nZEB enabling a cost-effective and energy-flexible implementation of future sustainable buildings**"*

Therefore, Annex 49 investigates the integration of heat pumps in nZEB in order to improve the performance of the building technology in terms of the energy- and cost-efficiency of system layouts. By integrated operation for different building services, high energy performance is achieved by internal heat recovery, e.g., in simultaneous operation. Moreover, in order to provide energy flexibility with the building system, more features are added to the design and control systems. These items are also covered by Annex 49 work, both at the single building level and at the neighbourhood or district level.

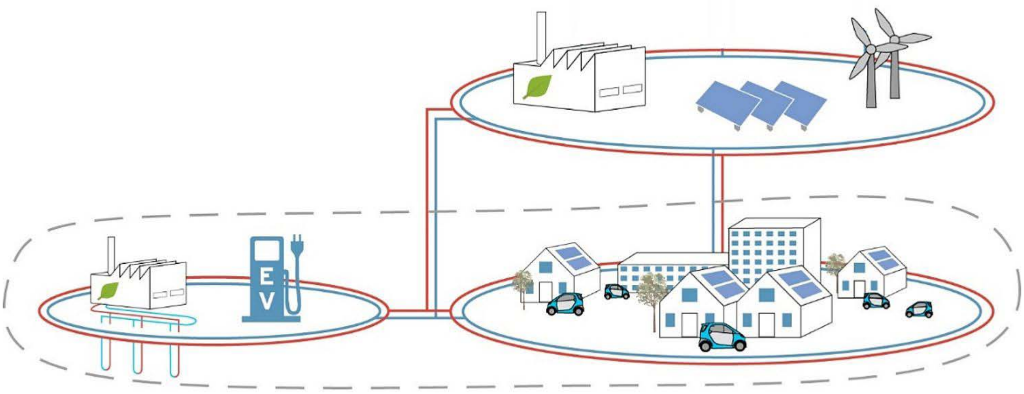


Figure 1. Integration of nZEB at the district level and support of local power grids by energy flexibility.

Figure 2. Heat pump prototype for façade-integration

OBJECTIVES

- Continuous update on nZEB requirements in the participating countries;
- 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, partly accompanied by simulation to optimise building and heat pump performance;
- Design and control of heat pump systems for various applications in residential and office buildings in terms of achievable performance and reduced cost;
- Recommendations for integrated heat pump systems, as well as heat pump design and control in single nZEB and groups of nZEB/nZEB neighbourhoods.

RESULTS

At Technische Hochschule Nuremberg (TH Nuremberg), performance and control are studied by simulation and monitoring of eight row houses. The system consists of two central speed-controlled heat pumps connected by a low-temperature heating grid, and decentralized DHW storages with booster heat pumps. Monitoring results confirm a positive balance of primary energy and CO_2-emissions, which is enabled by the seasonal performance, SPF, of the central heat pumps of 5.6 and the boosters of 4.1.

At TU Graz, a façade-integrated heat pump prototype of 2 kW for heating and cooling of the adjacent office space is developed, Figure 2. A covering PV panel supplies the heat pump and electric battery with electric power. Cooling is by water or an integrated fan coil. Simulation and monitoring in two test rooms, confirm sufficient capacity for cooling of a three-person group office without electric grid. Maximum PV size of 10 m^2 allows to cover 40–60% of heating loads.

In Switzerland, a multi-family passive house with 10 flats is monitored. It has 45 kWp roof- and 36 kWp façade-integrated PV. A ground-source heat pump for space heating, DHW and free-cooling results in low energy use of 49,241 kWh incl appliances. The PV yield of 68,599 kWh_{el} adds up to a 40% annual surplus. Energy management and a 78 kWh_{el} battery increase PV self-consumption. Ongoing monitoring will yield further optimisation.

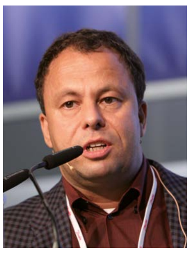
Summarising, the three projects confirm that heat pumps enable highly performing, cost-effective and energy-flexible sustainable nZEB.

MEETINGS

During 2019, two working meetings were held.

• Obergurgl, Austria, February 2019.
Presentation of interim results and nZEB monitoring and system integration. Tech lab tour at University of Innsbruck.

• Estonia, September 2019.
National implementation of nZEB, results of monitoring, design issues for integrated heat pumps in nZEB. Tech tour of the nZEB test house.



Project duration:
October 2016 – May 2020

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ANNEX 50

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

> ***Dealing with the variety of heat demand characteristics is a challenge on the way to a broader dissemination of heat pumps in multifamily buildings***

INTRODUCTION

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 built 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.

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

OBJECTIVES

- Enhancement of HP systems and/or HP components for their adaptation in multifamily buildings;
- Development and demonstration of concepts for application of heat pumps in buildings renovated in terms of energy

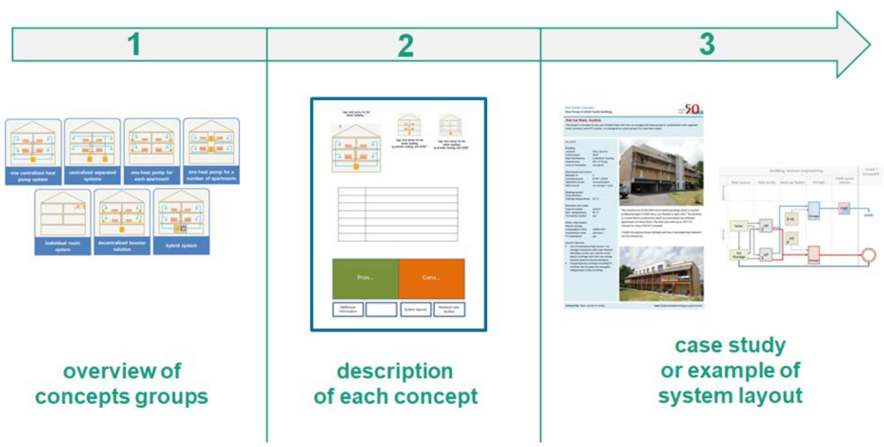

Figure 1. Thanks to the new Matrix tool, it is now possible to structure multi-family buildings with installed heat pumps. This enables even more meaningful forecasts to be made about the development of the heat pump in the housing market.

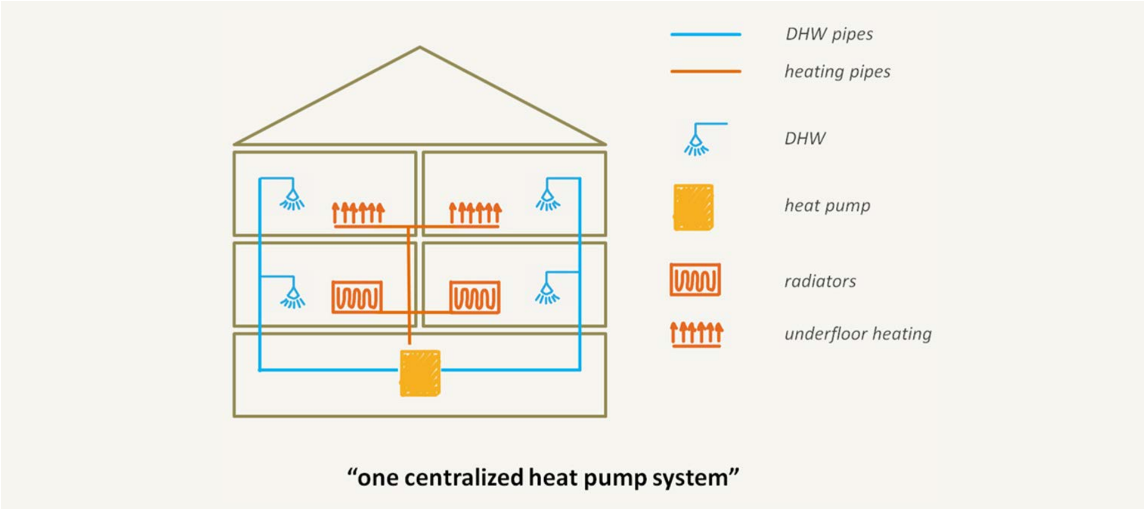

Figure 2. One of the seven schemes for structuring the multi-family buildings.

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.

RESULTS

To consider the heating demand, variables such as behaviour, type of heat pump and structure of the building need to be taken into account. Thus, Annex 50 has developed a 'system-matrix tool', Figure 1. This system matrix divides the consideration of a multi-family building into three steps. First, a division is made into one of seven schemes that describe the type and use of the heat pump in general, Figure 2. This is followed by an analysis with a detailed description of the heat pump and an assessment of each solution. In the last step, a fact sheet will be published, describing a real-use case with all information, such as a description, pictures and a technical concept. The fact sheets give an overview of the various uses of heat pumps in multi-family buildings, and comparisons can be made.

Due to contributions from participating countries, it was possible to find and present a large number of successful examples of HPs in multi-family buildings. All of this is available to everyone on our website using an interactive map. On the map you will find images and a brief description of the objects equipped with heat pumps. Also, you may download detailed fact sheets. The map is constantly updated with new buildings, but it is also possible for anyone to submit a multi-family object with a heat pump. This will appear on the map after an analysis is done with the system matrix.

MEETINGS

• Fribourg, Switzerland, May 2019, Working Meeting. Reports from DK, UK. A tool for modelling and simulation of systems was tested. Search for new case studies.

• Torino, Italy, November, 2019. Final results for a cross-comparison between countries. Update of system matrix for a better view on HP schemes; new case studies for HPs in central Europe.

Project duration:
January 2017 – December 2020

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ANNEX 51

ACOUSTIC SIGNATURES OF HEAT PUMPS

INTRODUCTION

To further increase the acceptance of heat pumps, reduction of acoustic emissions is important. To minimize noise annoyance, more focus must be put on the acoustics emissions at steady state and on the transient behaviour of acoustic signatures during different operating conditions. 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, making acoustic improvements crucial due to their noise-producing components, such as compressors and fans.

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
- workshop on acoustics of heat pumps at the ICR2019 in Montreal, presentation published on the IEA HPT Annex 51 website;
- Concluding international workshop and compilation of proceedings planned at Mostra Convegno 2020;
- Worldwide dissemination to heat pump manufacturers
- Generation and distribution of Acoustic Guidelines for the different levels (Component Level, Unit Level, Application Level) – uploaded onto Annex website.

RESULTS

Three heat pumps have been "on tour" at the participating institutes, their final tests made in 2019. In most cases, the laboratories found similar results. The differences that occur are acceptable, given the variety of test environment and test methods. When larger differences appeared, it was often due to a difficulty of adjusting operating conditions, not an acoustical measurement problem.

> ***Comparison of acoustic results obtained in different measurement environment using various experimental techniques gave good agreement***

Results for the standard rating condition according to EN 14511 are presented in Figure 3. For this operating condition, the spectra are close in the middle range of the spectrum, and the peaks at 315 and 800 Hz are well observed by all laboratories. As usually occurs, larger differences appear at low frequencies, due to modal behavior of the different measurement environments. The overall dB(A) value remains in a range of 1.4 dB(A).

Measurements with a 12-sided frame around the outdoor unit have been performed. The data from 12 microphones at one level of height (Figure 4a) allow the plot of the relative directivity diagram using an overall A-weighted sound pressure level. In Figure 4a, the overall level (using all frequencies) is shown. Figure 4b shows the acoustic radiation directivity of the unit for each octave band in dB(A). The A-weighting is a correction accounting for human hearing.

Due to the fan located on the right front of the casing, the maximum sound level is emitted in this direction and a little bit less on the rear side. The minima can be found on right and left sides

Figure 1. Meeting photo of the 5th working meeting hosted by Fraunhofer ISE on October 17-18, 2019 in Freiburg, Germany.

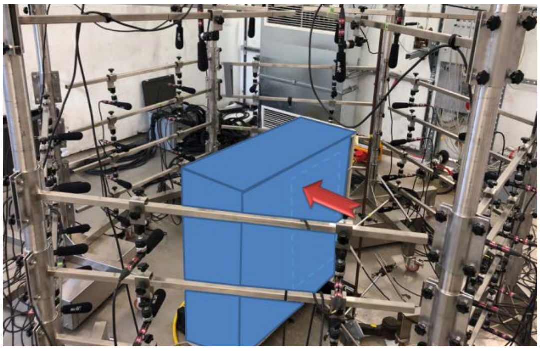

Figure 2. Examples of the heat-pump installation in a reverberant test room and climatic chambers. A microphone array can be seen.

of the heat pump, where there are only blind faces and there is no "opening". The directivity amplitude is not huge, with a maximum range of 7.5 dB, indicating ± 3.75 dB(A) around the mean arithmetical value (see Figure 4a). The octave bands for which the directivity is the most important (elliptic shape in Figure 4b) are also those which contribute the most to the overall level (have a larger dB(A) value).

In the case of an outdoor unit installation in a neighborhood close to a neighbor, this directivity should be considered. Thus, in order to minimise disturbance, the quietest side should be facing the neighbor. However, the effect of this directivity is reduced at longer distance.

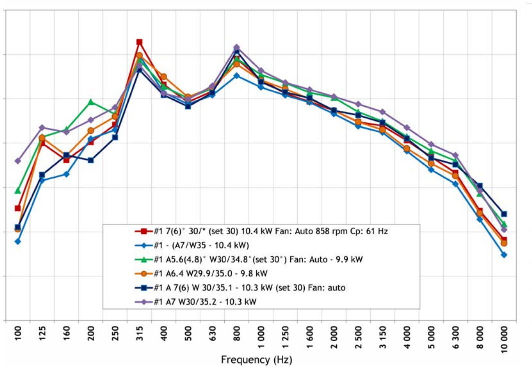

Figure 3. Spectrum of A-weighted sound power levels for Standard rating conditions EN 14511 (#1) from 6 laboratories.

Psychoacoustic tests, which will give input to the test design used in Annex 51, have been carried out by the Acoustic Research Institute of the Austrian Academy of Sciences. A joint acoustic data set will be analyzed using psychoacoustic hearing tests in three different countries. The timeline is defined, data samples will be generated, and psychoacoustic panel tests will be performed by ÖAW, POLIMI and RISE.

MEETINGS

• Aarhus, Denmark, January 22–23, 2019. Working Meeting. Finalisation of task 1, result discussions in task 2, discussions on Task 3 – Task 7, discussions on workshops at ICR2019 and MCE2020.

• Fraunhofer ISE, Freiburg, Germany, October 17-18, 2019. Working Meeting. Result discussions and comparisons in task 2, discussions on Task 3 – Task 7.

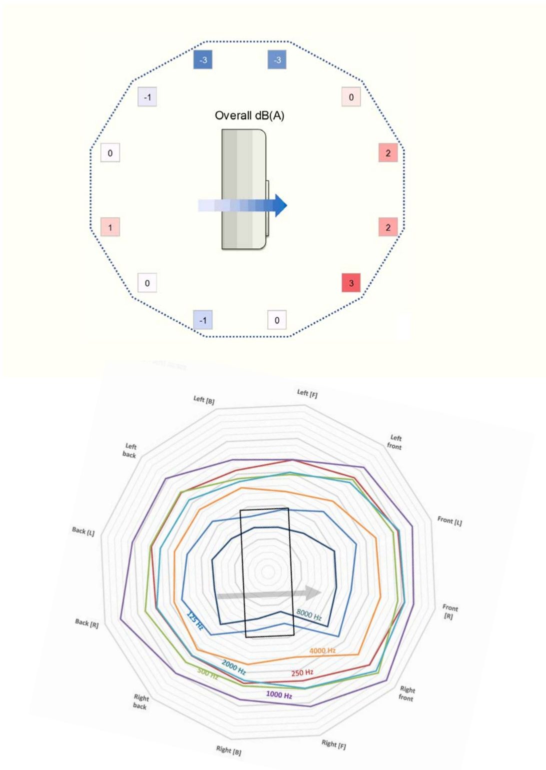

Figure 4. Directivity for the overall A-weighted sound pressure level at 75 cm height (a) and directivity for each A-weighted octave band (b).

Project duration:
April 2017 – December 2020

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ANNEX

52

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

INTRODUCTION

Carefully instrumented and analyzed long-term performance measurements from large GSHP systems are rare but highly valuable tools for researchers, practitioners and buildings owners. In the literature, analyses of good quality long-term performance monitoring data from GSHP systems are sparse, and there is no consensus on key figures for performance evaluation and comparison. Within Annex 52, a bibliography of publications on long-term measurement of GSHP systems is compiled, and the Annex members are working on a wide range of GSHP system performance measurement case studies. Based on this experience, the annex is refining and extending current methodology to better characterize the performance of GSHP systems serving commercial, institutional and multi-family buildings. These systems have a wide range of features and can be considerably more complex than single-family residential GSHP systems. The case studies will provide a set of benchmarks for comparisons of such GSHP systems around the world. One of the necessary steps to achieve this has been to develop an extended system boundary schema for calculation of system performance factors. This schema (Table 1) is a revised and extended version of the *SEPEMO* system boundary schema developed for non-complex residential heat pump systems.

> ***"Four journal papers with two open-source reference data sets have been published, fulfilling one of the Annex 52 goals"***

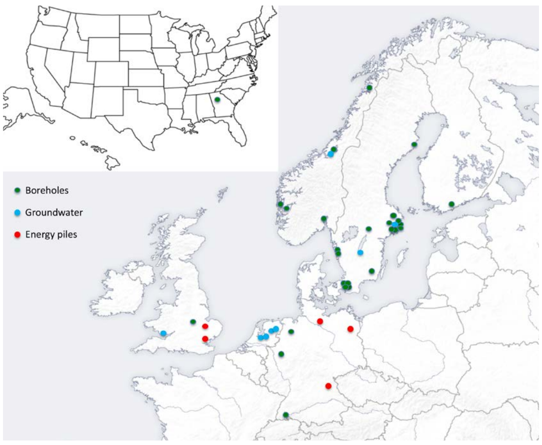

Figure 1. 40 long-term performance GSHP monitoring case studies in seven countries are included in HPT Annex 52.

The outcomes from this 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.

HPT Annex 52 has now reached its midway point. The seven participating countries (Sweden, USA, Finland, Norway, Germany, UK and Netherlands) are contributing 40 case studies of long-term monitored GSHP systems, all serving commercial, institutional or multi-family buildings with heating and/or cooling systems of varying degrees of complexity (Figure 1). So far, four journal papers have been published on three case studies included in Annex 52. For two of these published case studies, the Hugh Aston building in the UK and Studenthuset in Sweden, open source measurement data are available.

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.

RESULTS

40 monitoring case studies in seven countries are currently in progress. These cover a wide range of GSHP applications, including conventional vertical borehole ground heat exchangers, two high-temperature storage systems, groundwater aquifers and energy piles.

An annotated bibliography has been compiled, containing 65 publications describing 55 buildings where long-term performance monitoring of larger GSHP systems have been performed and that contain some form of SPF measurement. More than 20 further references describe monitoring of larger GSHP systems that do not go as far as determining SPF. This fulfils one of the Annex 52 goals.

The work group has proposed a developed system boundary schema, based on the SEPEMO schema but better suited for large and complex GSHP systems.

Four journal papers with two open-source reference data sets have been published. The two published open source data sets fulfil one of the Annex 52 goals. Four conference papers on the work of the Annex have been published to date.

MEETINGS

Two international expert meetings were held in 2019:

• 3rd Expert meeting in Helsinki, Finland, May 23-24 2019: 27 experts from 8 countries.
Instrumentation guidelines, SPF system boundaries, and monitoring case study report templates were discussed.

•4th Expert meeting in London, UK, September 16-17 2019: 20 experts from 7 countries.
First instrumentation guideline draft presented. Performance key indicators were discussed.

Table 1. The proposed system boundary schema as compared with the SEPEMO boundaries. The "+" superscript indicates auxiliary heating/cooling within the boundary. (From Gehlin, S. and Spitler, J.D. 2020. Half-term Results from IEA HPT Annex 52 - Long-term Performance Monitoring of Large GSHP Systems. Proceedings of the 13th IEA Heat Pump Conference, May 11-14, 2020 Jeju, Korea. 2020).

Boundary description	**Boundary levels**											
	0	0+	1	1+	2	2+	3	3+	4	4+	5	5+
Ground Source (CP + GHE)	X	X			X	X	X	X	X	X	X	X
Heat pump unit including internal energy use, excluding internal CP			X	X	X	X	X	X	X	X	X	X
Buffer tank (including CPs between HP and BT)							X	X	X	X	X	X
CP on load-side (between BT & building H/C distr. system)									X	X	X	X
Building H/C distribution system											X	X
Auxiliary heating or cooling		X		X		X		X		X		X
Equivalent in the SEPEMO boundary schema			H1/ C1		H2/ C2	H3					C3	H4/ C4

Project duration:
January 2018 – December 2021

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ANNEX 53

ADVANCED COOLING/REFRIGERATION TECHNOLOGIES DEVELOPMENT

INTRODUCTION

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 absent action to ameliorate the increase. IEA projects that AC energy use by 2050 will increase 4.5 times over 2013 levels for non-Organization of Economic Coordination and Development (OECD) countries and 1.3 times for OECD countries. 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 was initiated in late 2018 and focuses on the longer-term RD&D need. Technologies of interest include the vapor compression (VC) based systems and non-traditional cooling approaches.

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. Further development is needed before elastocaloric (or other non-traditional approaches) are ready for the market.

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.

> ***Researchers have shown highly porous, low pressure drop magnetocaloric regenerators to be critical for efficient operation at high frequencies***

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 HP 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;
- 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.

PROGRESS

The Korean Institute of Machinery and Materials (KIMM) is investigating a membrane technology-based alternative VC heat pump (membrane HP). It includes a membrane dehumidification (DH) unit and indirect evaporative cooling unit and uses water as refrigerant. Since the driving force for DH uses the partial pressure difference of water vapor, a vacuum pump is used instead of a conventional type compressor, Figure 1. Initial test results have proven its potential to effectively cool and dehumidify an air stream.

Non-traditional technologies include magnetocaloric (MC), elastocaloric (EC), and electroca-

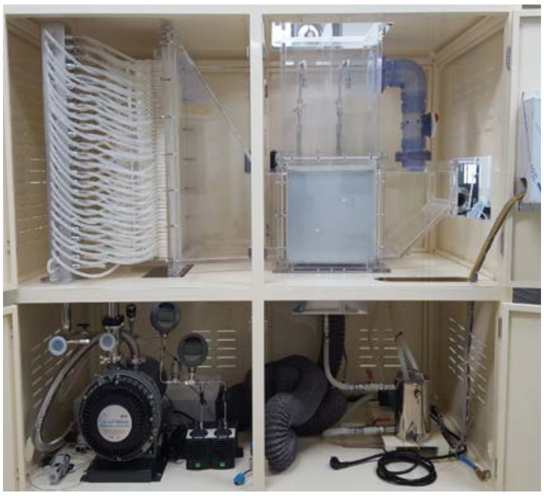

Figure 1. Lab membrane HP system: (top left) membrane DH unit; (top right) evaporative cooling unit; (bottom left) vacuum pump (compression) system; and (bottom right) water supply module.

loric (ElC), with the MC and EC being at a more advanced development state. US teams at the Ames Laboratory and ORNL aim to demonstrate MC system-level performance at higher power density levels. Ames team's MC performance targets are 35 K temperature span with 308 K heat sink temperature, operating frequency ≥10 Hz, and magnetic fields ≤1 Tesla. Increasing operating frequency increases the power density, thus a more compact device and smaller magnetic field. ORNL researchers have shown highly porous, low pressure drop magnetocaloric regenerators to be critical for efficient operation at high frequencies, Figure 2.

EC systems are based on the temperature change undergone by "solid" or shape memory alloy (SMA) or super elastic (SE) materials when alternately stressed and relieved. The University of Maryland team is investigating a design with layered stacks of SMA/SE. Distance between each tube is a key variable. Researchers at Xi'an Jiao Tong University are developing a low-grade heat-driven EC cooling system using a heat-activated actuator made of high-temperature SMA to drive the low-temperature SE refrigerant.

MEETINGS

- Atlanta, GA, USA, Jan. 11: Kick-off meeting; established Annex work plan and reviewed participants' project contributions.
- Freiburg, Germany, Oct. 22-23: Reviewed Participants' progress on projects; reviewed and finalized Annex Task 1 report.

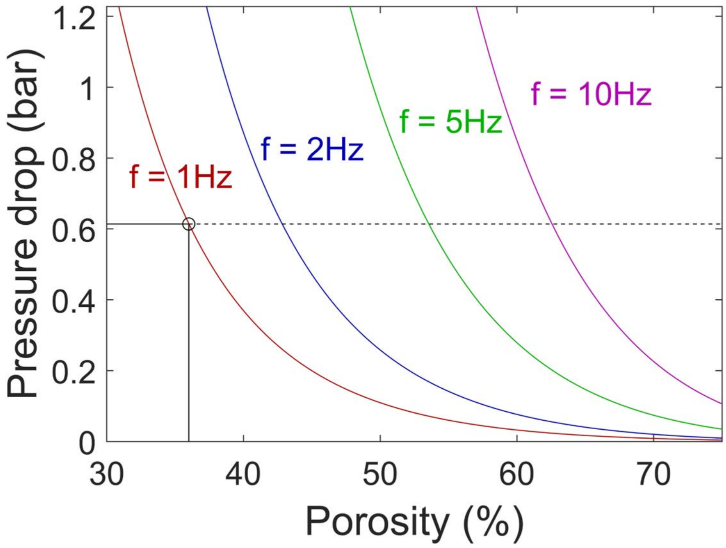

Figure 2. Pressure drop for water across an active magnetic regenerator (AMR) consisting of a packed bed of 200 μm diameter gadolinium (Gd) spheres.

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Project duration:
October 2018 – December 2021

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ANNEX

54

HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS

INTRODUCTION

Annex 54 aims at promoting application of low-GWP (Global Warming Potential) refrigerants, to accelerate phase-down of high-GWP hydrofluorocarbons (HFCs). It will be accomplished by developing design guidelines of optimized heat pump components and systems for low-GWP refrigerants.

> ***Annex 54 aims at promoting low-GWP refrigerant application to accelerate phase down of high-GWP HFCs in air-conditioning and heat pump systems***

PROGRESS

Annex 54 started with four member countries in 2019 and conducted a comprehensive, most-updated review of current research, product development and regulation status of low-GWP refrigerants for the heat pump applications. We summarized the collective efforts by researchers, engineers and regulation committees across the industry with the following highlights:

- Reviewed the progress towards utilizing flammable refrigerants;
- Summarized updates on recent regulations and research advancements in bringing low-GWP refrigerants to residential AC systems;
- Reviewed the current standards and policies for residential and commercial heat pump systems with low-GWP refrigerants;
- Made a case study for applying a very low-GWP refrigerant R-516A in medium pressure R134a chiller applications;
- Provided an update on bringing R32 to window type air conditioner for the US market and split air conditioners for the European market;
- Summarized the on-going activities carried out in Italy about the use of low-GWP refrigerants in heat pumps;
- Conducted literature review for application of low-GWP refrigerants in high temperature heat pumps and showcases;
- Review refrigerant regulations (see Table 1), initiatives & market progress in Japan.

Since future heat pump systems will use lower-GWP refrigerants and energy efficient technologies to meet the latest international regulations and reduce overall environmental impacts, our first efforts conducted in 2019 could provide a good reference for researchers, engineers and policy makers across the HVAC industry. In the long run, Annex 54 study results will promote the application of low-GWP refrigerants and accelerate phase down of high-GWP HFCs in air-conditioning and heat pump systems for residential and commercial buildings.

Table 1: Ignition probability of various refrigerants (normal wall-mounted air conditioner)

Risk: Ignition probability			
Life Stage	R32	R1234yf	R290
Logistic	4.1×10^{-17}	4.5×10^{-17}	9.7×10^{-16}
Installation	2.7×10^{-10}	3.1×10^{-10}	3.7×10^{-9}
Use (Indoor)	3.9×10^{-15}	4.3×10^{-15}	5.0×10^{-13}
Use (Outdoor)	1.5×10^{-10}	2.1×10^{-10}	4.9×10^{-13}
Service	3.2×10^{-10}	3.6×10^{-10}	2.8×10^{-7}
Disposal	3.6×10^{-11}	5.3×10^{-11}	4.1×10^{-7}

OBJECTIVES

Annex 54 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.

- Review of available low-GWP refrigerants, their properties and applicable standards, safety and flammability of refrigerants, and safe use of flammable refrigerants (see Figure 1);
- Optimize heat pump components and systems for low-GWP refrigerants;
- Develop design guidelines of optimized heat pump components and system for low-GWP refrigerants;
- Analyze the LCCP impact by the current design and optimized design with low-GWP refrigerants;
- Study 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

This task aims at evaluating design optimization and advancement on the Life Cycle Climate Performance (LCCP) reduction.

Task 4. Outlook for 2030

This task aims at studying market opportunities of heat pumps with low-GWP refrigerants and low-GWP refrigerants availability in different levels for 2030.

Task 5. Report and information dissemination

Aims at reporting work conducted and disseminating information developed in the Annex.

MEETINGS

• Atlanta, GA, USA. Jan 12, 2019. Kick-off Meeting.

• Montreal, Canada. August 26, 2019. Workshop: Heat Pumps for Low-GWP Refrigerant.

• Montreal, Canada, August 26, 2019. Annex 54 Business Meeting.

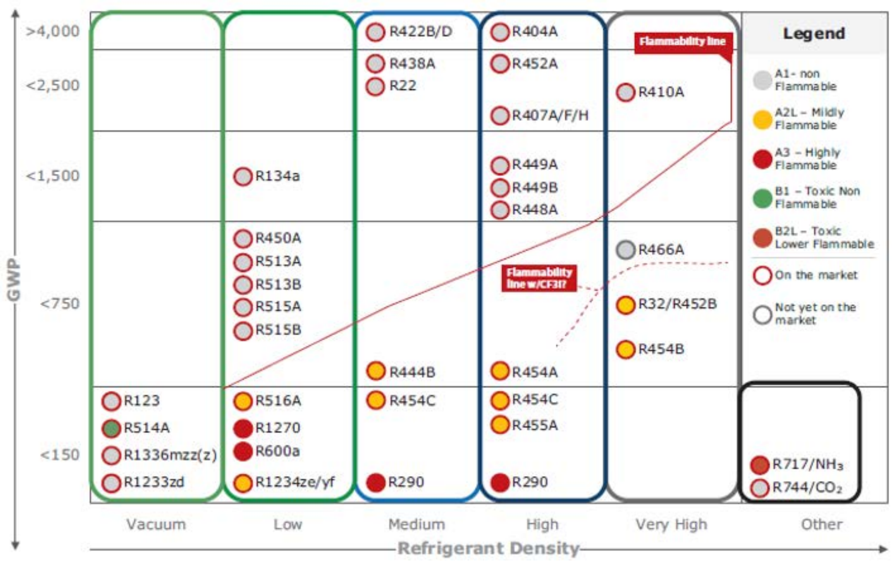

Figure 1. GWP versus Density (pressure) of the main refrigerant groups.

Project duration:
January 2019 – December 2021

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ANNEX

55

COMFORT AND CLIMATE BOX

INTRODUCTION

Integrated systems consisting of heat pumps, storage and controls are considered as an important technological option for deployment of renewable energy in the domestic sector. By combining heat pumps and storage, several issues may be tackled in one and the same process, such as

- Balancing and controlling electricity grid loads;
- Capturing a large(r) share of renewable (local/regional) energy input;
- Optimizing economics, CO_2-emissions, fuel use throughout time;
- Providing optimal supply security to buildings, compactness, reliability, and serviceability.

However, commercial development of this type of solution is progressing very slowly. In order to address that, Annex 55 was initiated. Under the combined direction of the IEA TCPs on energy storage (ECES) and heat pumping technologies (HPT), Annex 55 started in 2019, and will focus on improving combined systems of heat pumps, storage and controls.

> ***The goal of this combined annex is to develop improved Comfort and Climate Boxes in existing buildings to speed up local market development.***

The central concept in Annex 55 is the Comfort and Climate Box (CCB). This denotes a combined package, consisting of a heat pump, an energy storage module and controls. This package may form an actual physical unit, or may consist of separate modules that form an integrated 'virtual package', where all components of the CCB should be designed to work together in a modular fashion and should be operated under a dedicated and optimal integrated control strategy, see Figure 1.

PROGRESS

There have already been several attempts to put CCBs on the market. However, market uptake is slow and hesitant. We analysed market access and potential success by looking at nine design criteria that play a role in developing CCBs, see Figure 2.

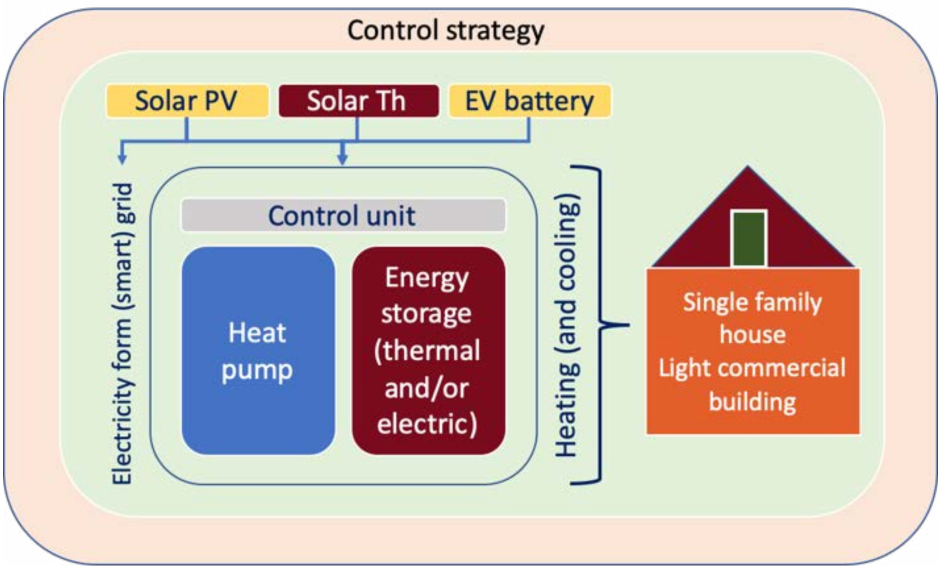

Figure 1. Outline of a Comfort and Climate Box.

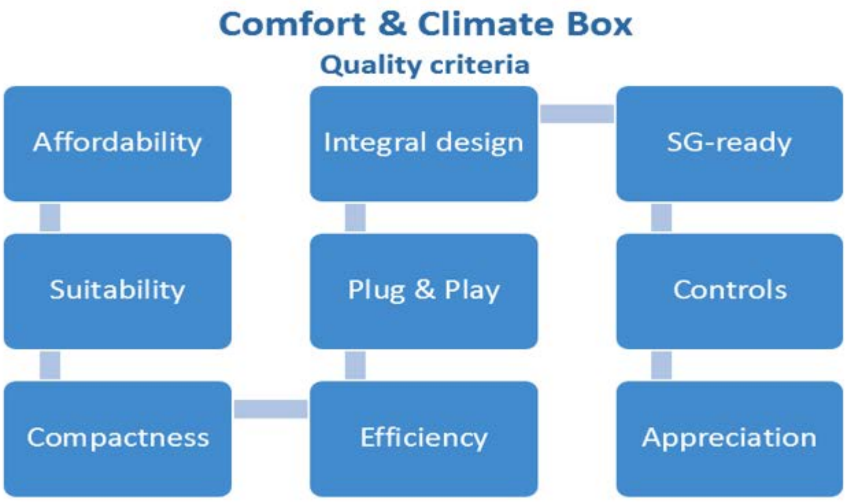

Figure 2. Design criteria for the development of CCBs

Depending on the local market, available systems may need to improve performance with respect to one or several of these criteria. These criteria form our central reference to describe and measure CCB development and quality. Overview schemes based on scores on these criteria per country give an impression at a glance how CCB developments proceed within the participants' countries.

OBJECTIVES

Annex 55 is not meant to be a classic theoretical 'research and dissemination Annex'. All contributing projects in the participating countries should aim to focus on developments that are 'almost market ready'. The goal of this combined annex is to develop improved CCBs in existing buildings to speed up local market development. The work will be oriented around the nine quality criteria, mentioned above, to define the concept of improved quality.

Annex 55 is entwined with the global Mission Innovation program Task # 7. This functions as a non-hierarchical platform to enhance technology development within the building envelope.

OVERVIEW OF TASKS

Task 1: Investigate the present market status. For each participating country separately: available systems, case histories, requirements for local market.

Task 2: Testing of prototypes, controls and standardization. System specification, control strategy development, assembling prototypes.

Task 3: Develop or assemble market prototypes. Develop comparison metrics, make measurements under lab conditions.

Task 4: Provide input for the roadmap. Identify boundary conditions for optimal market development; recommendations and guidelines for various stakeholders, etc.

Task 5: Knowledge dissemination and communication. Information exchange / input from other sources, outcomes expert workshops.

MEETINGS

• Utrecht, Netherlands, January 2019. Kick-off.

• Paris, France, June 2019. International team meeting

• Freiburg, Germany, October 2019. International team meeting

Project duration:
April 2019 – September 2021

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Further information:
https://heatpumpingtechnologies.org/annex55/

ANNEX 56

INTERNET OF THINGS FOR HEAT PUMPS

INTRODUCTION

The increasing spread of digitalization will enable heat pumps, equipped with electronics, software, sensors and network connectivity, to participate in the Internet of Things (IoT). This can be at domestic building level or in an industrial plant. The ability to collect and exchange data and make use of it wisely will open new potential for optimization and flexibility. Together, heat pumps and digitalization can thereby play a major role to increase energy efficiency and introduce renewable energy into buildings and industry.

> ***The ability to collect and exchange data and make use of it wisely will open new potentials for optimization and flexibility***

With heat pumps and their components becoming connected devices participating in the Internet of Things, a variety of new use cases and services will be enabled. Such services and applications can be related to any part of the lifecycle of the heat pump. IoT-enabled heat pumps for household and commercial applications are serial products that are sold in large quantities. They provide data that can be used for preventive analytics, such as what-if analyses for operation decisions, predictive maintenance, fine-tuning of operation parameters, and benchmarking. They can be used for smart demand response to reduce peak load and to optimize electricity consumption, e.g. as a function of the electricity price (Figure 1). In contrast, industrial heat pumps are usually planned, manufactured and installed on a project-specific basis by contractors and installers. Digitalization in industry can range from automated equipment and advanced process control systems to connected supply value chains. IoT-enabled heat pumps allow for integration in the process control system as well as a higher-level energy management system, which can be used for overall optimization of the process.

Each level of participation of a heat pump in a connected world (Figure 2) is also associated to various significant risks and requirements for connectivity, data analysis, privacy and security for a variety of stakeholders. Therefore, this Annex will have a broad scope, looking at different aspects of digitalization to analyze heat pump specific challenges and opportunities.

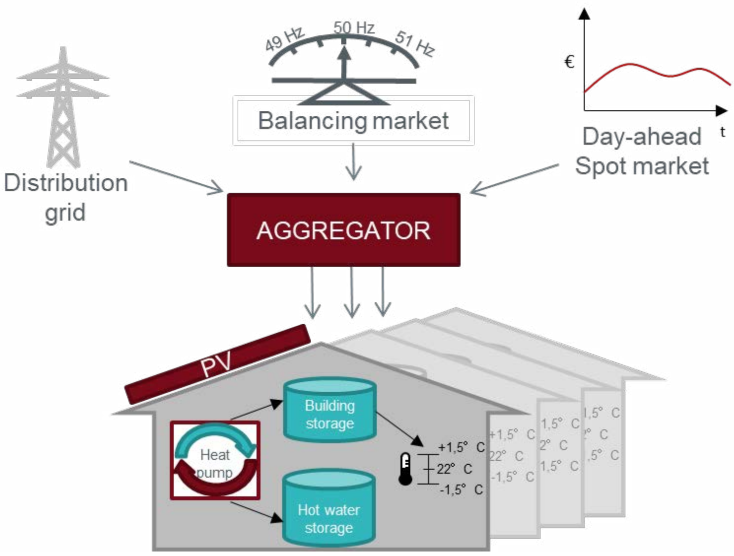

Figure 1. A pool of connected heat pumps participating on the energy market.

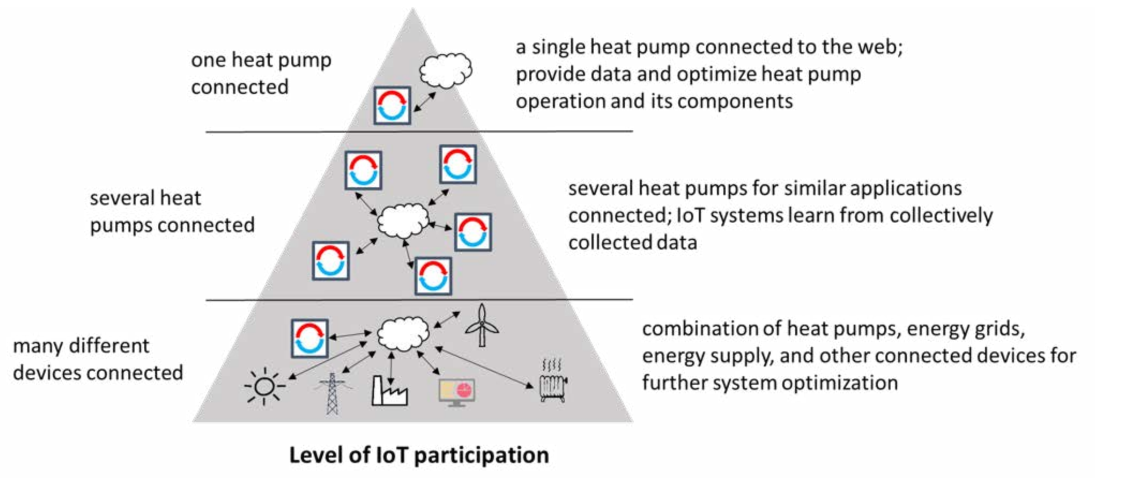

Figure 2. A heat pump can be part of the Internet of Things at different levels.

OBJECTIVES

The Annex focuses on 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 results of the Annex will be disseminated to relevant target groups, such as component manufacturers, heat pump manufacturers, associations and regulatory authorities, by means of tailored messages. The Annex will thereby

- provide guidance, data and knowledge about heat pump technologies regarding IoT applications;
- increase knowledge at different levels (component manufacturers, heat pump manufacturers, consultants, installers, legislators, etc);
- contribute to the development of future standards.

OVERVIEW OF TASKS

Task 1 - State of the Art

This task aims at reviewing the status of currently available IoT-enabled heat pumps, heat pump components and related services. A common glossary for the most important digitalization topics will be compiled.

Task2 – Interfaces

Identify requirements for data acquisition from new built and already implemented heat pump systems, considering types of signals, protocols and platforms for buildings and industry applications and related privacy issues and ongoing standardization activities.

Task3 – Data analysis

Evaluate data analysis methods and applications (digital twins) for one or many heat pumps and sensors. Including machine learning, semantic models, Building Information Modeling (BIM) and soft sensors.

Task4 – Services

Evaluate market opportunities created by IoT-connected heat pump devices and identify success factors and further demands to software and hardware infrastructure.

Task5 – Dissemination

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

MEETINGS

• Nuremberg (DE). 21 October. Annex definition workshop. Outline of Tasks and presentation of relevant research activities and infrastructure of Annex participants and interested countries.

Project duration:
January 2020– December 2022

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Outlook into the Future

In 2020 the HPT TCP will continue its work with implementing the strategic work plan for 2018-2023 for the TCP (see page 8) which was launched in 2018.

For 2020, 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

Four overarching priorities for TCP enhancement have been set up by IEA, which were used as guidance when outlining the Activity Plan for 2020 for HPC.

» Increase collaboration with external partners;
» Deepen integration of TCP inputs into IEA work;
» Deepen engagement with emerging economies;
» Streamline administrative processes and procedures.

In order to progress towards the objectives above, the TCP has some prioritized achievements to be reached during 2020, e.g.:

» Successful Conference organization and defined procedures for next conferences;
» Greater knowledge about the HPT TCP and heat pumping technologies among prioritized target groups, i.e. policy makers, investors, possible new member countries in warm and humid climates, and new and broader network to widen the scope of the research, development, demonstration and deployment (RDD&D);
» To be the first and foremost source for information regarding heat pumping technologies;
» New ideas and proposals for Annexes according to our strategy plan.

During 2020, much of the attention of the work of HPC will be put on supporting, promoting, attending and reporting from the 13th IEA Heat Pump Conference, which will take place on Jeju, South Korea, since this is one of the most important activities arranged by the TCP.

In addition to the priorities above, a central part of the strategy plan is also the advancement of the RDD&D of heat pumping technologies. This will be accomplished through creation of research opportunities networking possibilities and meeting places for academia, industry, private sector markets and policy makers. They will then be able to collaborate under new Annexes (projects) and activities within the HPT TCP. 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 strategy plan, two new Annexes were approved during 2019 with start during 2020. The first one was Annex 56 "IoT for Heat Pumps" (see page 40) and the second one was "Flexibility by implementation of heat pump in multi-vector energy systems and thermal networks", which has not yet been designated an Annex number.

This annex will be a continuation of Annex 47. Since the implementation and the focus on CO_2 reductions have increased, the energy market analysis will be updated, and new participating countries will be included. Further, the interaction with the electrical grid and the flexibility will be taken into account, and it will specifically be described how heat pumps in domestic heating grids can be an actor on the electrical energy market.

In order to be in line with the strategic work 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 was initiated during 2019 and has so far resulted in a proposal for a new annex about High Temperature Heat Pumps, for industrial and other types of applications.

Other Annex ideas that have been discussed within the TCP concerns heat pumps for drying, Comfort and Climate Box solutions, i.e. combinations of air conditioners, heat pumps, energy storage and integrated control, for warm and humid climates and large demonstration projects to show the flexibility potential of a large population of heat pumps that could be externally controlled.

Concerning engagement worldwide, the countries where the demand for comfort cooling is expected to grow strongly during the coming decades are of high concern for the HPT TCP. One of these countries is China, which joined the HPT TCP during 2019. Another one is India. During 2020, the TCP is planning to participate in several activities in India to learn more about their situation - challenges and possibilities - and to create contacts with parties in India who could benefit from a collaboration with the HPT TCP.

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