Technology Collaboration Programme
by iea

ANNUAL REPORT 2021

HEAT PUMPING TECHNOLOGIES

Technology Collaboration Programme on Heat Pumping Technologies - HPT TCP

IEA HPT

Technology Collaboration Programme on Heat Pumping Technologies

Image sources

Cover

- 13th HPC Conference 2020 (2021)
- Heat Pump Center
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- Jeju, 13th HPC Conference 2020 (2021)
- Screenshot of IEA report on Net Zero by 2050
- Screenshot HPC web page

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Technology Collaboration Programme on Heat Pumping Technologies (p.8-9)

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13th IEA Heat Pump Conference (p.15-18)

- 13th HPC Conference 2020 (2021)
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14th IEA Heat Pump Conference, 2023 (p.19-20)

- Photos from Brian Fricke, IOC Chair, 14th IEA Heat Pump Conference

HPT TCP Annexes

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- p. 29 – Illustrations: Signhild Gehlin
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Content

Message from the Chairman

Heat pumps are the most important heating system to reduce greenhouse gas emissions to Net Zero by 2050. Around 55% of all heating systems worldwide must be equipped with heat pumps by 2050. This translates to a tenfold increase in the number of installed heat pumps. These are the targets set out by the IEA in its "Net Zero by 2050 - A Roadmap for the Global Energy Sector", published on May 18, 2021. This means a strong acceleration in the manufacture and installation of heat pumps.

Heat pumps must be smartly integrated into the "energy system" in order to function efficiently. The "energy system" primarily includes the buildings or industrial processes that are to be heated. However, it also includes the existing heat source, the building technology, the heat storage systems, and the supply of electricity from self-generation or the local grid. Smart means that the heat pump can communicate with the "energy system" and, for example, optimally couple the availability of electricity or the heat source with the heat demand. Achieving "Net Zero by 2050" thus requires not only increasing unit numbers, but also ensuring smart implementation.

In addition to the further development of heat pump technology for heating and cooling (Annex 51, 53, 54 and 55), we are working intensively on the smart integration of heat pumps into the energy system. This includes existing large or new energy-efficient buildings (Annex 49, 50, 52, 60) as well as industrial processes (Annex 58 and 59), but also the local energy system, comprising the power supply as well as thermal grids (Annex 57). The digitization of the energy system plays an important role in this (Annex 56). In discussing the direction of our future strategy, we are also addressing issues of increasing sales, improving industrial production, and training planners and installers. In 2022, we will flesh out these topics and decide our strategy and the associated action priorities for the next five years (for Annex details see page 22-42).

A central element of our activities is the communication of the results and findings of our work. The challenge is to write this information in a way that is appropriate for the target audience. This includes not only the researchers and developers, but also increasingly political and business decision-makers.

An important tool for communicating the latest findings in heat pump technology and application is our triennial International Heat Pump Conference. We were able to have a well-attended hybrid event in April 2021 after having to postpone the event planned for 2020 owing to the Covid-19 pandemic. For four days, 379 people from 26 countries exchanged and discussed the most up-to-date knowledge on heat pumping technologies on-site in Jeju Island, South Korea, and online. The National Organizing Committee did an outstanding job and triumphed over all barriers during the pandemic period.

We also strengthened communication through webinars. These included presentations of completed projects and country reports, as well as discussion forums. The HPT Newsletter, the HPT Magazine, and the reports on our projects, some of which are presented interactively on the website, remain important.

To run a Technology Collaboration Programme is only possible with the highly motivated and experienced people. I, therefore, thank the ExCo delegates, the operating agents and their experts in the Annexes, the staff of the Heat Pump Centre, and of the IEA. I would also like to thank our member countries. Without their financial support, our activities would not be possible.

Stephan Renz, Chairman of the Executive Committee

Highlights 2021

13th IEA Heat Pump Conference

On April 26-29, 2021, the very successful 13th IEA Heat Pump Conference (HPC2020) was organized as a hybrid conference, where both online and onsite participation was possible, by the TCP in collaboration with a national organizing committee. Due to the Covid-19 outbreak, the conference was postponed for one year. Korean domestic participants participated both onsite at Ramada Plaza Hotel Jeju, Korea, and online, but all of the international participants were involved as online participants.

In spite of all the challenging circumstances, ***six plenary speeches from renowned speakers*** and 201 full technical papers enlightened the conference. More than 370 participants from 26 countries attended the conference and had a meaningful time listening to the presentations and having fruitful discussions on scientific, technological and market-related issues on heat pumping technologies with experts from all around the world.

In a ceremony held digitally at the closing session of the 13th IEA Heat Pump Conference, the ***winners of the prestigious Peter Ritter von Rittinger International Heat Pump Award***, the highest international award in the air conditioning, heat pump and refrigeration field were presented. Jussi Hirvonen, Finnish Heat Pump Association, Professor Ruzhu Wang, Shanghai Jiao Tong University and the Center for Environmental Energy Engineering (CEEE) University of Maryland were given the 2021 Rittinger Award for their efforts in the field (for more info, see page 18).

14th IEA Heat Pump Conference

During the closing ceremony of the 13th IEA Heat Pump Conference, the next IEA Heat Pump Conference on the theme "Heat Pumps – Resilient and Efficient" was launched. This will take place in Chicago, US, on May 15-18, 2023 (see page 19-20), and the call for abstract opened in November.

IEA Net-Zero by 2050 Roadmap

The ***special report*** released by IEA on May 18, 2021, shows that the pathway to the critical and formidable goal of net-zero emissions is narrow, but it brings huge benefits. The report shows that **heat pumps and efficient cooling technologies** have an important role in reaching the goal. This is the world's first comprehensive study of how to transition to a net-zero energy system by 2050 while ensuring stable and affordable energy supplies, providing universal energy access, and enabling robust economic growth. It sets out a cost-effective and economically productive pathway, resulting in a clean, dynamic and resilient energy economy dominated by renewables like solar and wind instead of fossil fuels. Building on the IEA's unrivaled energy modeling tools and expertise, the Roadmap sets out more than 400 milestones to guide the global journey to net-zero by 2050. These include, from today, no investment in new fossil fuel supply projects and no further final investment decisions for new unabated coal plants. By 2035, there are no sales of new internal combustion engine passenger cars, and **by 2040, the global electricity sector has already reached net-zero emissions.** In addition, other defined key milestones are **"no new sales of fossil fuel boilers by 2025"** and that **"50% of heating demand is met by heat pumps in 2045, 55% by 2050"**. This means a tenfold increase in the number of heat pumps to 2050 and an increase by a factor of 3 to 4 already to 2030. Facts and data generated within the HPT TCP and provided to the analysts of IEA is an important factor behind that heat pumping technologies were well highlighted within this report.

Member Country Reports

During the year, three Member Country Report workshops were organized within the HPT TCP. ExCo delegates, Operating Agents and Annex participants were invited to the workshops. On each occasion, three to four countries presented the national status for (i) Market statistics, (ii) Policy, and (iii) R&D activities. So far, Austria, Canada, China, France, Germany, Italy, Japan, the Netherlands, UK and US have given their presentations. After the events, the presentations as well as summarizing text were uploaded on the ***website of HPT TCP*** and news were spread on Social Media. These events were well attended and appreciated by the audience, and facts and data from them have been included as input to IEA publications.

Several finalized annexes

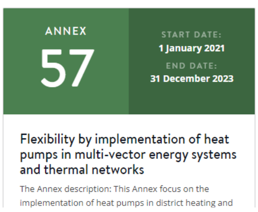
During 2021 the reports from finalized work within the following Annexes were published on the HPT website

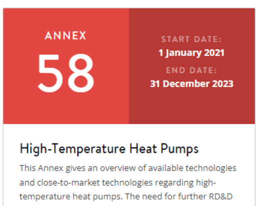
- Design and integration of heat pumps for nZEB ***(Annex 49)***
- Acoustic signatures of heat pumps ***(Annex 51)***

The results from Annex 49 show, among other things, that heat pumps can become the standard building technology for nearly Zero Energy Buildings (nZEB). Due to the high performance of heat pumps, nZEB can be achieved cost-effectively. Further, heat pumps can increase onsite electricity self-consumption and unlock flexibility potentials by smart controls. In this way, heat pumps become the backbone of a future sustainable and renewable built environment and energy system. One of the outcomes from Annex 51 was Round Robin test performed, proved repeatable results for acoustic tests in various measurement chamber type and using different equipment.

Two new Annexes

At the beginning of the year, work actively began on two new annexes, ***Annex 57*** “Flexibility by implementation of heat pumps in multi-vector energy systems and thermal grids”, and ***Annex 58*** “High-Temperature Heat Pumps”. The work has started in early 2021. At the end of 2021, five countries had joined Annex 57, and ten countries had joined Annex 58.





National Experts meetings

On October 28th, the IEA’s Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) hosted a successful National Experts meeting in conjunction with the European Heat Pump Summit. The meeting’s main goal was to generate fresh ideas and proposals for future HPT TCP Annexes (international collaboration projects). The key findings from the mid-term evaluation of the HPT’s Strategic Work Plan 2018-2023 formed the basis for the ideation process and the following topics were discussed, and several ideas for new annexes were the outcome of the meeting.

- Sector coupling
- Solutions that utilize both the cold and warm sides of the thermodynamic cycle
- New or alternative business models
- Digitalization for heat pumping technologies
- Circular economy for heat pumps
- Safety measures on flammable refrigerants

On December 9, a successful digital follow-up meeting was organized, providing a platform for more than 70 participants worldwide to participate, and the generated ideas were discussed further.

Investors’ role in the energy transition

During 2021 the HPT TCP started to explore on investors’ role in the energy transition and the acceleration of deployment of heat pumping technologies. According to IEA, getting the world on track for 1.5 °C requires a surge in annual investment in clean energy projects and infrastructure to nearly 4 trillion USD by 2030. Many investors are interested in sustainable investments and are betting that clean energy technology investments will pay off. In October, a very successful workshop was organized within the HPT TCP, and the ***3rd issue*** of the HPT Magazine was entitled “Climate leap – How investors reach major emission cuts in existing property portfolios”. The topical articles of this issue all addressed the major motivations in investment decisions in combating climate change and speeding the deployment of essential technologies.

WeChat

In October 2021, the account for HPT TCP by IEA was launched at the Chinese Social Media platform ***WeChat***. News are since then been shared on WeChat in the same way that it is on LinkedIn and Twitter.

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 coordinate a collective response to major disruptions in oil supply. 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 energy reliability, affordability, and sustainability. 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 cooperation in energy security, data and statistics, energy policy analysis, energy efficiency, and the growing use of clean energy technologies.

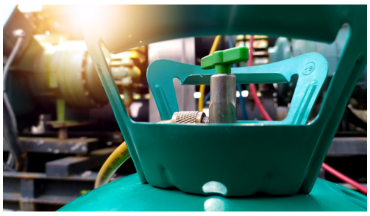
The IEA Global Innovation Network

- 38 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 the 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.

The breadth of the analytical expertise in the Technology Collaboration Programme is a unique asset in the global transition to a cleaner energy future. Currently, there are 39 individual technology collaborations working across several technology technologies 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.

Technology Collaboration Programme on Heat Pumping Technologies



Organized under the umbrella of the International Energy Agency since 1978, the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) is a non-profit organization 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 fulfill 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

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

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 standardization organizations with reliable and independent guidance, data and knowledge about heat pumping technologies, separately or in combination with other technologies

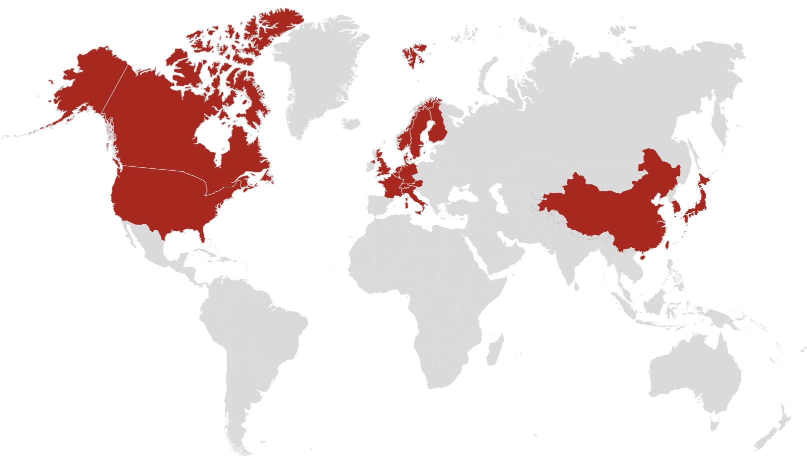
6. Increase activities to attract new members, including IEA key partner and association countries.

Activities

The activities of the Programme include a communication service, the Heat Pump Centre, with a Magazine, Newsletter 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 TCP, 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, the HPT Newsletter, the HPT Website and social media such as ***LinkedIn***, ***Twitter*** and ***WeChat***. 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.
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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.
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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.
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Ola Gustafsson, Technical Specialist
Ola works with research and development of heat pumps. He supports the HPC team with technical expertise.
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Metkel Yebiyo, Editor
Metkel is a researcher, who specializes in refrigeration, air conditioning, and heat pumps, as well as heat transfer, energy efficiency, building performance modeling, and renewable energy technologies. He is the Editor of the HPT Magazine and the HPT Annual Report.
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Anneli Rosenkvist, Communication
Anneli is an experienced marketing and communication professional with knowledge in planning, coordinating, and executing communication strategies. At HPC, she is responsible for and can offer support within graphical design, newsletter, website and social media.
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Activities and achievements

Executive meetings

The year 2021 was like the year before, heavily impacted by the Covid-19 pandemic in many different ways – both in the private and the professional realm. The difference from the year before was that we all were better prepared for and used to online meetings and digital tools. The spring ExCo meeting was organized as a two-day online meeting on May 10-11. After the summer, the possibilities for traveling opened up in some parts of the world, and the intention was to organize a hybrid, online-onsite meeting in Roma on November 10-12. However, since only a few delegates were able to travel, the meeting was transferred to an online meeting only. On November 11, in the morning, the Italian Delegate, together with the Italian National Team, organized an ***Italian National workshop*** with several well recognized invited speakers who gave very interesting presentations.

[Strategy point 2]

Digital workshops and webinars

During the year, the HPT TCP organized several digital workshops and webinars, for example, three workshops when Member Country Reports were presented and discussed and one workshop where Investors' role in the energy transition and deployment of heat pumps was discussed (see page 5-6, Highlights). During the fall, Annex 53, "Advanced cooling/refrigeration technologies development", organized a webinar that attracted more than 80 participants. In conjunction with the 13th IEA Heat Pump Conference, in total, six digital workshops were organized to present and discuss results from ongoing and finalized annexes and to develop ideas for new ones. Finally, in December, a digital follow-up meeting to the National Experts meeting was held (see page 6, Highlights).

[Strategy point 2]

Midterm evaluation

The transition to a more sustainable energy system is ongoing globally, even though further acceleration is needed to reach the climate targets. In addition, many new trends are evolving related to sustainability and digitalization. Therefore, the HPT TCP executive committee decided to perform a midterm evaluation of its HPT TCP Strategic Work Plan 2018-2023 to identify if the direction required adjusting of the plan or if any area required particular focus during its second term.

This work was finalized at the beginning of 2021 and formed the basis for the National Experts meeting organized during the fall and for the Activity plan for 2022. Moreover, the TCP is now well prepared for submitting the request for an extension to IEA during 2022.

For many decades, the HPT TCP, as well as industry and business associations, have been fighting for **recognition** of the technology within the IEA and among policy makers around the world. Now, in 2021, we can conclude that we have succeeded in many ways. The technology is well recognized by IEA as the **future norm for heating** of a decarbonized building sector and for contributing to the decarbonization of the industry sector. In addition, the **legal framework** in many regions of the world, not at least in Europe, is **well prepared for** energy efficiency and electrification of heating and thereby for a **large-scale roll-out of heat pumps**. Although the technology is available and works well, **greater market demand** for this clean, energy-efficient technology must be created.

This midterm evaluation showed that all the identified research areas of the HPT TCP are still very relevant, but that we need to focus on some areas and activities during the second half of our strategy period:

- More focus should be put on stimulating **mass deployment** of heat pumps. Therefore, more **demonstration** and **deployment**-related activities should be performed.
- Annexes should include work packages where **barriers for mass deployment** of efficient heat pumps and air-conditioners are mapped and analyzed how to be overcome.
- We should include **decision-makers (for policy and investments) and (end) users** in the analyses since they are important for the acceptance and the efficiency of heat pumps.
- It is of importance to focus on how to improve **affordability** to stimulate mass deployment of efficient technologies.
- Since **all innovations needed** to obtain the **climatic targets** are not yet developed, activities along **large parts of the TRL-scale** should be performed, **also the lower ones.**
- We should **attract new** performers/players/industry **actors** outside the traditional sectors for heat pumping technologies, e.g. ICT, mobility, industry etc.
- We need to explore and demonstrate the **flexibility potential** of the technology from several perspectives, even more, using the possibilities offered by the developments in the area of **digitalization**.
  - to **balance and stabilize** the electric grid
  - to integrate a **higher share of renewable** energy in the system
  - to enable **sector coupling**
  - to offer **multiple functions** (heating, cooling, grid system services) – flexibility of the use
  - to combine different heat/cold sources, including ventilation
- We should focus to a larger extent on solutions where **both the cold and the warm** sides of the thermodynamic cycle are used.
- We should continue investigating more efficient, **affordable and applicable** cooling and air-conditioning technologies, especially in warm and humid climates, **possible to integrate with other renewable technologies.**

[All strategy points]

Ongoing, new and completed annexes

The international collaboration projects within the HPT TCP, the annexes, form the core of TCP activities.

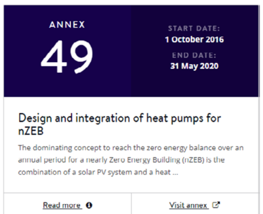
During 2021, the following eight annexes were ongoing:

- Heat Pumps in Multi-Family Buildings for Space Heating and DHW (***Annex 50***)
- Long-term performance measurement of GSHP systems serving commercial, institutional and multi-family buildings (***Annex 52***)
- Advanced Cooling/Refrigeration Technologies Development (***Annex 53***)
- Heat pump systems with low GWP refrigerants (***Annex 54***)
- Comfort and Climate Box (***Annex 55***)
- Internet of Things for Heat Pumps (***Annex 56***)
- Flexibility by implementation of heat pumps in multi-vector energy systems and thermal grids (***Annex 57***)
- High-Temperature Heat Pumps (***Annex 58***)

See further pages 22-42.

Reports from these finalized Annexes were published on the HPT website during the year:

- Design and integration of heat pumps for nZEB (***Annex 49***)
- Acoustic Signature of Heat Pumps (***Annex 51***)



In addition, many reports from Annex 52, "Long-term performance measurement of GSHP systems serving commercial, institutional and multi-family buildings", were uploaded on the HPT website.

During the two ExCo meetings and the two National Experts meetings arranged during the year, several ideas and proposals for potential new annexes were presented, discussed and further developed in the meetings. More information about these ideas and proposals can be found on page 43-44, Outlook into the future.

[Strategy point 2]

The IEA Heat Pump Conference

Much attention and efforts had to be put on the postponement, due to the Covid-19 pandemic, of the 13th IEA Heat Pump Conference, which should have taken place on Jeju Island in South Korea, first in May, thereafter in September 2020. Finally, it was postponed to April 2021 and arranged as a hybrid online-onsite event (see page 15-18).

13th IEA HEAT PUMP CONFERENCE
2020 | JEJU KOREA

Thorough information campaigns were made, on the websites, on social media and directly to the authors to keep everyone updated about the changes and to maintain their interest in presenting their papers at the conference. Because of the hybrid format and different time zones around the world, the conference program needed to be adapted. The Peter Rittinger von Rittinger Award Ceremony was also adopted to an online format since none of the awardees could be present on-site (see page 5-6, Highlights).

At the same time, the work to plan the next IEA Heat Pump Conference in 2023 was initiated, and it was launched during the closing ceremony of the conference in Jeju.

In conjunction with the 13th IEA Heat Pump Conference, the day before the official opening of the conference in total, six digital workshops were organized to present and discuss results from on-going and finalized annexes and to develop ideas for new ones. Workshops on the following topics were arranged:

- Heat Pumps in Smart Grids (***Annex 42)*** and Hybrid Heat Pumps (***Annex 45***)
- Comfort and Climate Box Solutions for Warm and Humid Climates – new annex idea
- Heat Pumps for Low GWP Refrigerants (***Annex 54***)
- Comfort and Climate Box - Heat Pumps, Energy Storage and Integrated Control (***Annex 55***)
- Design and Integration of Heat Pumps for nZEB (***Annex 49***)
- Large Demonstration project for Flexibility by Heat Pumps (***Annex 57***)

Overall, thanks to high skills and much efforts, not at least from the Korean National Organizing Committee, the conference was a very successful and well-appreciated event! The ***conference proceedings*** can be ordered from the HPT website.

[Strategy point 4]

HPT communications: magazine, newsletter, website, social media and more

One of Heat Pump Centre's (HPC) main activities is publishing the Heat Pumping Technologies Magazine. Each issue covers a specific topic and contains articles, news, events, and a contribution from a guest columnist. Three issues of the HPT Magazine were published in 2021 on the topics "***Heat pumps in multi-family buildings***", "***Heat Pumps with Thermal Storage***", and "***Climate Leap – how investors reach major emission cuts in existing property portfolios***". They were published together with an electronic newsletter with short versions of selected articles.

The HPT TCP website is continuously updated with news, information, new annex sub-sites and new publications. The Heat Pump Centre has been active on social media, publishing news and retweets on ***LinkedIn*** and ***Twitter***. In October 2021, the HPT TCP launched an account on ***WeChat***, as a Chinese social media platform, to increase the spread of news in this part of the world. It continuously follows the web traffic and number of readers on our communication channels and has noted a considerable increase in both from year to year. As a result of these analyses, the center focused on updating some Wikipedia pages and putting together information from the TCP for publication on the IEA website. As an example, the Heat Pump Centre supported two of the Operating Agents for the annexes, "***Heat Pumps in Multi-Family Buildings for Space Heating and DHW" (Annex 50)*** and ***"Advanced Cooling/Refrigeration Technologies Development" (Annex 53),*** to produce films for IEA's campaign "Today in the Lab – Tomorrow in Energy".

The Heat Pump Centre has continued to support the operating agents (project leaders for the annexes) to improve and update annex pages on the website with new information, such as publications and links to webinars. This is important, as annex pages are the most visited ones on the HPT TCP site every month.

During 2021 presentations and summaries from Member Country Report workshops have been published on the website. This offers website visitors a good source for information regarding market development and the present status and conditions for the deployment of heat pumps in different parts of the world.

Heat Pump Centre (HPC) continued to send out the "HPC 60 seconds" e-mail, a monthly overview in bulleted format of HPC activities for people actively involved in the TCP. As a complement, a more detailed information letter, the HPC letter, is distributed to the ExCo delegates between the ExCo meetings.

[Strategy point 4]

Collaboration with IEA

Representatives from the HPT TCP and Heat Pump Centre have had a continuous dialogue with the IEA secretariat and participated in meetings, all of them online during 2021. At the end of the year, a cross-TCP project was launched, which shall result in an online article to be published on the website of IEA and promoted in their various communication channels, in which a deep-dive will be made for the building-related milestones of the IEA Net-Zero by 2050 Road-map, published by IEA in May (see page 5-6 Highlights). Different TCPs contributes to different parts of the article, and the HPT TCP is responsible for the milestone "600 million heat pumps are in operation in buildings by 2030". The article will be published during the summer of 2022.

[Strategy point 5]

International collaboration and promotional activities

During the European Heat Pump Summit, which took place in October in Nuremberg, Germany, the HPT TCP had a booth at the physical exhibition where the TCP promoted its activities and products. This was the first time in over one-and-a-half-year Heat Pump Centre representatives could meet and reach out to its network in real life. The day after the summit, the HPT TCP National Experts meeting was organized in the same venue (see page 6, Highlights).

Besides this event, due to the Covid-19 pandemic, physical outreach activities were very limited during 2021. Several bilateral online meetings were arranged between the Heat Pump Centre and representatives from associations in different parts of the world. Moreover, HPC representatives were interviewed by surveying parties with interest in the conditions for accelerated deployment of heat pumping technologies. As an example, an interview was made for an episode on ***Heat Pumps on the UK channel #ITVTonight and "Saving the Planet: Saving Money?"*** during the week of COP26 in Scotland.

[Strategy point 5]

Mission Innovation Challenge

Mission Innovation 2.0 was launched on May 31, 2021. HPC is following the development of #IC7 Affordable Heating and Cooling and the overall development of Mission Innovation 2.0. The most important activity is the ongoing HPT TC ***Annex 55 Comfort and Climate Box*** with an aim to accelerate market development of Climate and Comfort box solutions for the heating market and is expected to be finalized in 2022. The Annex is a joint Annex with ECES TCP and in collaboration with Mission Innovation #IC7 Affordable Heating and Cooling. HPC has supported the work with the development of a second project, this time with a focus on affordable comfort and climate box solutions for warm and humid climates. In connection to the HPT TCP conference, a second global workshop was arranged by HPC with invited speakers from IEA, US, India, and China.

[Strategy point 5]

The 13th International Energy Agency Heat Pump Conference "Mission for the Green World"

Under the difficulties of the Covid-19 outbreak, the 13th IEA Heat Pump Conference was held in Jeju Island at the end of April after a year of postponement. Considering the situation and the preference of the participants, the conference was served in a hybrid way both with offline events and with online platforms. Most of the Korean participants participated offline, but all of the international participants have participated through the online conference due to the limitation of international travel.

Despite the enormous risks from the pandemic, the conference was successful with a full of communication and information. The conference had an extensive program with six plenary speeches from the renowned speakers and 201 full technical papers that enlightened the conference. More than 370 participants attended the conference from 26 countries and had a meaningful time listening to the presentations and having fruitful discussions on scientific and technological issues on heat pumping technologies with experts from all around the world.

To prepare for the hybrid conference, the National Organizing Committee (NOC) made all the efforts with 24 online and offline meetings along with 10 online meetings with the International Organizing Committee (IOC). The conference was a big challenge more than ever, but in the end, the rewards of the delegates showing their appreciation to the NOC was a great honor.

Objectives of the 13th IEA Heat Pump Conference

The objective of the conference was to share the state-of-the-art heat pumping technologies with engineers, to promote the advanced technologies of leading companies, and to inform politicians and the public of the superiority of heat pumps. As heating and cooling play a great role in our daily lives, the future energy systems should be greener with heat pumps which are always recommended as promising technologies against climate change.

With this in mind, the 13th IEA Heat Pump Conference was held with the theme 'Heat Pumps – Mission for the Green World'; we aimed to address global climate change and discuss necessary actions. Considering the varied applications of heat pump systems in the residential, building and industrial fields, this major conference with hundreds of participants definitely broadened the horizons of our heat pump community. The theme, "Heat Pumps – Mission for the Green World", have made all the researchers proud that we are creating a Green World together through research and development for a better future.

Conference Program

Workshops

On Monday 26th May, the first day of the Conference, six workshops were held. The workshops was held fully online, around 200 participants were actively discussing through the workshop. From the workshop, ongoing and recently finished HPT Annex projects were introduced. As up-to-date technologies, heat pumping technologies related to smart grid connection, energy storage, and nZEB integration were discussed. Also, low GWP refrigerant issues, cooling Comfort and Climate Box (CCB) solutions, and large demo-projects held participants' focus.

The topics and the numbers of participants were:

- "Annex 42/45 on HPs and Smart Grids, and Hybrid" (Workshop A1: 34 participants)
- "Heat Pumps for Low GWP Refrigerants (Annex 54)" (Workshop A2: 22 participants)
- "Annex 55 on HPs and Energy Storage" (Workshop B2: 15 participants)
- "Design and Integration of Heat Pumps for nZEB (Annex 49)" (Workshop C2: 19 participants)
- "Comfort and Climate Box Solutions for Warm and Humid Climates"(Workshop D1: 42 participants)
- "Large Demonstration Project for Flexibility by Heat Pumps" (Workshop D2: 27 participants)

Welcome speech from Stephan Renz (IEA HPT TCP Chair) (left) and opening remark from NOC Chair Minsung Kim (right)

Opening Ceremony

On Monday 27th May, the second day of the Conference, the HPC2020 was officially held with the opening speech from the HPT Chair and NOC Chair. Both speeches were broad-casted in hybrid ways.

Plenary Speakers

For the plenary speech, the six influential speakers presented their vision on the heat pump industry. The first three influential speakers introduced global heat pump markets and policy, followed by three eminent speakers providing excellent summaries on key technologies of heat pump systems.

- Mechtild Worsdorfer, Director for Sustainability, Technology and Outlooks, the International Energy Agency (IEA), "Heat Pumping Technologies in Clean Energy Transitions"
- Martin Forsén, President of EHPA (European Heat Pump Association), "The European Legal Framework is Well Set for a Massive Roll-out of Heat Pumps - but More Efforts are Needed!"
- Min Soo Kim, President of Society of Air-conditioning and Refrigerating Engineers of Korea, "Korean Policy for a Green World and Heat Pumping Technologies"
- Saikee Oh, Vice President of LG Electronics, Korea, "Heat Pump System Technology Trend"
- Xudong Wang, Vice President of Air-Conditioning, Heating, and Refrigeration Institute (AHRI), "Ensuring a Safe Refrigerant Transition"
- Noboru Kagawa, Professor of National Defense Academy, Japan, "Clean and Safe Air by HVAC systems – Laws and Advanced Technologies in Japan"

Live captures at the workshops

Online discussion with Martin Forsén (EHPA president) after his plenary speech (left).
Video presentation of Mechtild Worsdorfer from IEA (upper right).
Online discussion with Saikee Oh (Vice President, LG Electronics Inc.) after his plenary speech (right bottom).

Technical sessions

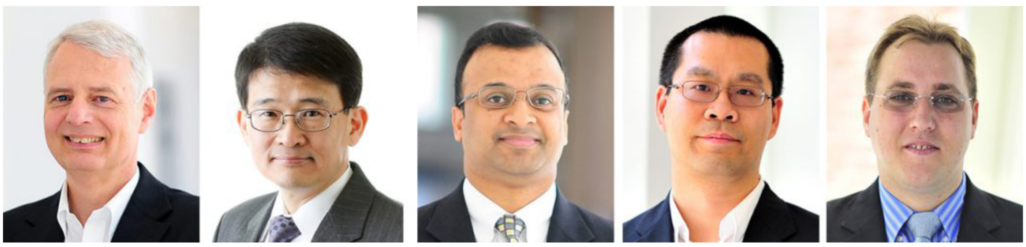
After the plenary session, general technical sessions were opened until the conference closing. In spite of the hybrid operation of the conference, the call for papers were successful and resulted in 201 high-quality papers of 175 oral presentations and 26 poster presentations. The majority of papers were from Europe (91) and Asia (79). The topics covered the entire issues in heating and cooling, directly related to the work under the HPT TCP. Technical sessions were provided in 36 parallel oral sessions with a keynote speech in each oral session. The total number of participants were 379 from Asia (168), Europe (156), America (52), Africa (2) and Oceania (1). 81 participants from Korea were registered as offline participants.

Considering the time difference between the continents, American presentations were assigned majorly in the morning sessions, and European presentations were in the afternoon sessions. The hybrid technical sessions were well organized, with questions and answers online and offline. During the conference, presenters were ready to

The winners of the 2021 Rittinger Award

M.Sc. Jussi Hirvonen

Prof. Ruzhu Wang



The team from Center for Environmental Energy Engineering: Dr. Reinhard Radermacher, Dr. Yunho Hwang, Dr. Vikrant Aute, Dr. Jiazhen Ling, Mr. Jan Muehlbauer.

Photos at online/offline hybrid technical sessions.

answer the online/offline questions. The presenters of 121 papers chose the live Q&A. Online discussion was very active during the conference.

Global Student Video Competition

To promote the active participation of student attendees, we promoted a global student video competition. This competition provided an excellent opportunity to create a video that were awarded at the conference. The aim were to exchange creative ideas and relevant knowledge on the topic, such as heat pump application, environmental issues, energy, or what students do in the laboratory. 11 teams were participated, and 6 teams received awards.

Closing Ceremony

In the closing ceremony, an award ceremony for Ritter von Rittinger Award and Global Student Video Competition was served. The awardees are listed as below.

Ritter von Rittinger Award

- Jussi Hirvonen, Finnish Heat Pump Association, Finland
- Ruzhu Wang, Shanghai Jiao Tong University, China
- Center for Environmental Energy Engineering (CEEE), University of Maryland, USA

Closing remark

The country sponsors and twelve corporate sponsors supported the preparation of the conference very much. Also, eleven international organizations related to heat pump technologies endorsed the conference for promotion. During the hybrid conference transition, NOC faced unexpected difficulties in budgets and promotions. Without their support, it would not have been possible to organize the conference successfully.

Now the conference is over, but the website is still alive. NOC wish to express our sincere thanks for your proactive participation and involvement in the conference. Despite the enormous challenges from the pandemic, the conference was successful, and attendance exceeded our expectations. We wish you the best, and until the next time we meet, please be safe and healthy. Thank you.

See you in Chicago!

Welcome to the 14th IEA Heat Pump Conference, 2023 "Heat Pumps – Resilient and Efficient"

The United States is proud to announce that it will be hosting the upcoming 14th IEA Heat Pump Conference, which will be held in **Chicago on 15-18 May 2023**. The theme for the Conference is **"Heat Pumps – Resilient and Efficient"**.

Conference goals

Clean, efficient, and reliable energy systems are essential to meeting basic needs for comfortable, secure, and environmentally friendly building environments, food processing, transport, storage; and industrial processes. Many analysts estimate that it will not be possible to achieve long-term climate, security, and energy goals without increasing the use of renewable heating and cooling technologies in conjunction with large-scale refurbishment and renovation of the world's existing buildings and industrial infrastructure. Heat pumps, driven with renewable power sources, are the key technical solution for meeting these challenges.

The upcoming 14th IEA Heat Pump Conference will serve as a forum to discuss the latest heat pumping technologies and applications, and exchange valuable knowledge in research, market, policy, and standards information on related technologies. Exhibitions will be held during the Conference to share heat pumping products and technologies.

Conference program highlights

The National Organizing Committee (NOC), chaired by Brian Fricke, looks forward to providing conference attendees with an exceptional conference experience, in keeping with the tradition of excellence established by all 13 of the preceding conferences.

14th IEA HEAT PUMP CONFERENCE

Conference program highlights include the following:

» High level invited speakers for the opening plenary sessions
» High level invited keynote speakers leading each major conference oral technical session
» Poster presentation sessions associated with each oral technical session
» Exhibition of equipment and information kiosks
» Technical visits
» Social and sight-seeing program

The Conference will start on Monday (15 May 2023) with a series of Workshops on international collaborative projects (Annexes) within the HPT TCP by IEA and other related topics. After the main plenary opening sessions on Tuesday morning (16 May 2023), the remaining two and one-half days will consist of oral and poster technical sessions organized in parallel tracks, featuring a number of heat pump related topics including, but not limited to, the following:

» Residential and commercial building comfort conditioning, focusing on topics such as: space heating, air-conditioning, net-zero buildings, renovation, hybrids, domestic hot water, and multifamily buildings.

- Non-residential applications, focusing on industrial heat pumps, waste heat, district heating, commercial refrigeration, and transport air conditioning and refrigeration.
- Innovation and Research and Development (R&D), focusing on aspects such as ground sources, advanced storage systems, working fluids, sorption technologies, advanced vapor compression, non-vapor compression technologies, smart grids/energy, cold and hot climate applications, advanced air conditioning technologies, gas-driven heat pumps and combinations with other renewable technologies.
- Policy topics and market status, trends, strategies, and future opportunities.

Who should attend?

The wide variety of heat pump related discussions that will take place during the Conference is intended to attract a diverse group of attendees, including:

- Policy makers, government officials, energy efficiency program leaders
- Executives and representatives from industry, utilities, and the public sector
- Manufacturers, distributors, and technology supporters
- Designers and developers of heat pump systems and components
- Researchers from industry, utilities, academia, and private and public R&D institutes

Call for papers

Abstracts (250 words maximum) covering the conference theme may be submitted on the conference website until 15 May 2022. The abstracts will be screened, and authors will be advised of acceptance by 15 June 2022.

Important conference dates:

- Abstract submission opened 15 November 2021
- Abstract submissions due 15 May 2022
- Authors advised of acceptance 15 June 2022
- Full paper submissions due 15 November 2022
- Final paper submissions due 15 February 2023

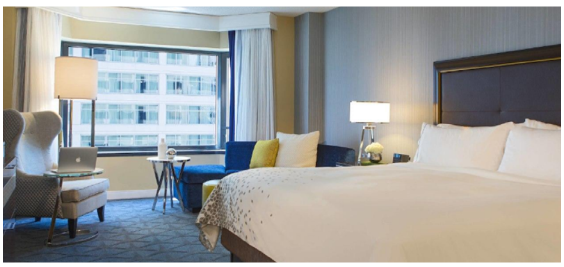
Conference information

Those wishing to attend the Conference should visit the conference website: ***www.hpc2023.org***. Detailed information, including registration and hotel accommodation forms, will be available together with a second announcement in autumn 2022.

Conference venue

The Renaissance Chicago Downtown Hotel is excited to welcome the 14th IEA Heat Pump Conference attendees, "Resilient and Efficient." Located in the prime area of the Theater District, the venue provides attendees with easy access to Chicago's vibrant cultural infrastructure, including a wide variety of traditional pubs, eclectic bars, and clubs. Chicago is also home to a wide variety of restaurants satisfying most any culinary desire. The Chicago O'Hare International Airport (ORD) and Midway International Airport (MDW) are international and domestic arrival hubs offering light rail service to downtown Chicago, and ground transportation such as taxis and rideshare services are readily available.

Additional updates and details will be provided on the website of the conference ***www.hpc2023.org*** and via ***www.heatpumpingtechnologies.org.***



Chicago Venue

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), China (CN), 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).

Finalized 2021

NEW

Letters A-F in right column, indicates which of the selected RDD&D areas in the strategy of HPT TCP the Annex is linked to, see below.

HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW	50	AT, CH, **DE**, DK, 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	AT, DE, FR, IT, JP, KR, SE, **US**	F
COMFORT AND CLIMATE BOX	55	AT, BE, CA*, CH*, CN, DE, IT, **NL**, SE, TR*, UK, US	A, B
INTERNET OF THINGS FOR HEAT PUMPS	56	**AT**, CH, DE, DK, FR, NO, SE	D
FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI-VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS	57	AT, DE, **DK**, FR, NL SE	C
HIGH-TEMPERATURE HEAT PUMPS	58	AT, BE, CA, CH, DE, **DK**, FR, **NL, NO, JP**	E

*) Participates from ECES TCP

Selected areas for RDD&D activities in HPT TCP

RDD&D - Research, Demonstration and Deployment

A. Affordable and competitive technologies for heating
B. More efficient cooling and air-conditioning
C. Flexible, sustainable and clean system solutions
D. Digitalization and Internet of Things
E. New or special markets and applications
F. New, alternative or natural refrigerants with lower global warming potential

ANNEX
50

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

INTRODUCTION

The building sector is highly important for energy consumption in every country. Regarding the emission of greenhouse gases, it is one of the three most important sectors. Therefore, the massive reduction of CO_2 emissions from buildings and the long-term achievement of a climate-neutral building sector can be considered inseparable.

Applying heat pump technologies and renewable energy is more complex for multi-family buildings (MFB) than for newly built apartments, as multi-family houses bring along a range of heat demand characteristics. Firstly, the share of domestic hot water demand on the overall heat demand varies due to varying building standards as well as different climates. Secondly, the temperature level of the heating system is influenced by these aspects as well as by the installed heating transfer system. Henceforth, dealing with the variety of heat demand characteristic bears the challenge on the way to a broader spread of heat pumps in multifamily buildings.

Thus, Annex 50 focus on solutions for multi-family houses with the attempt to identify barriers for heat pumps on these markets and how to overcome them. In respect to the demand of the participating countries, new buildings and retrofit will be considered as well as buildings with higher specific heating demand.

OBJECTIVES

- Enhancement of HP systems and/or HP components for their adaptation in multi-family buildings
- Categorization of possible concepts for application of HP in all types of MFB with diverse energetical standard of the building envelope
- Collecting and visualizing the realized projects

MEETINGS

Due to the pandemic, no face-to-face meetings took place in 2021. Instead, a series of online meetings were organized and held. The work during the meeting focused on all components of the "solution matrix", from the completion of the classification of solutions, through the description of each solution, to the identification and preparation of real examples (case studies).

> ***"The holistic approach of the Annex 50 provides for a "big picture"– from the theoretical categorization of possible solutions to realized case studies."***

RESULTS

The approach of the Annex 50 was to find a way to create a holistic (integrated) method of presenting its results, as well as to work on all Tasks simultaneously. The result of this approach is a "solutions matrix". Each part of the matrix can be used or presented as a standing alone component and is connected to a specific Task of the Annex.

The first part of Task 1 consists of the country reports from all participating counties. The second part builds an overview of various heat pump solutions in MFB. The broad scope of possibilities, combined with numerous types of multi-family buildings, showed the need for a categorization system, which would allow for a simplified but systematic way of structuring the information gathered. As a result, five "solutions" families have been identified, reaching from a fully centralized system to a completely decentralized system (each-room solution). Most of the "families" consisted of several "family members", which are sub-solutions of the general categorization. Altogether, 13 general solutions have been identified.

The next step, and at the same time the main work within Task 3, was a deeper analysis and description of each solution. This part took place with a significant time-investment of each Annex partner. Several discussions about this topic took place, not only between the Annex partners but also during national workshops organized specifically for this purpose.

The work within Task 4 (demonstration and monitoring) resulted in the collection of case studies representing the implementation of heat pumps in multi-family buildings. Case studies collected in countries participating in the Annex 50 show a wide variety of possibilities with heat pumps. The cases varied as to the energetical standard of the building, its number of apartments, heat source of the heat pump and further characteristic.

To fulfill the holistic approach and to illustrate the practice, each case study is connected to the corresponding theoretical example described in Task 3.

The work group believes that this innovative way of reporting will help disseminate the outcomes from the Annex 50 in an attractive and user-friendly way. The central achievement connected to Task 5 is the multi-functional website of the project ***Annex 50***.

PUBLICATIONS

Miara, M. *Wärmepumpen – warum und wie sie auch im Bestand geeignet sind – Fokus Mehrfamilienhäuser* Online-Fortbildung für Energieberater*innen, 2021

Miara, M. *Heat Pumps. Potential of heat pumps in existing buildings* GIZ Workshop Argentina, Uruguay, Paraguay, 2021

Miara, M. *Wärmepumpen in Mehrfamilienhäusern, Possible solutions and examples of implementation* European Heat Pump Summit, Nuremberg, Germany, 2021.

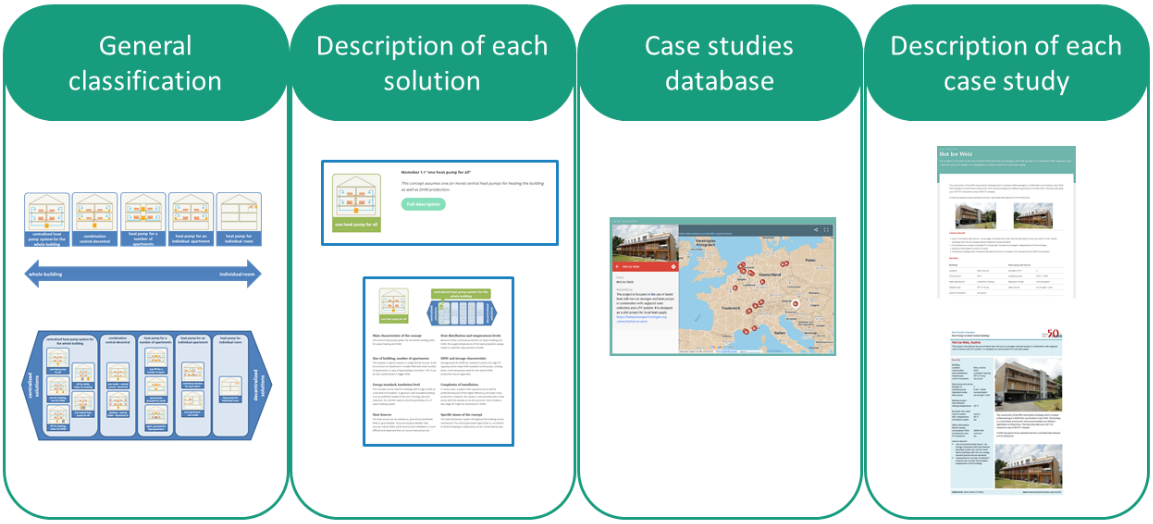


Figure 1. Main elements of the "solutions matrix", the holistic result of the Annex 50, Source: Annex 50.

Project duration:
January 2017 – June 2021

Operating Agent:

Marek Miara, Fraunhofer ISE, Germany
marek.miara@ise.fraunhofer.de

Participating countries:
Austria, Denmark, France, Germany, Italy, the Netherlands and Switzerland.

Further information:
www.heatpumpingtechnologies.org/annex50

ANNEX

51

ACOUSTIC SIGNATURES OF HEAT PUMPS

INTRODUCTION

The work in this Annex targets heat pumps used in single-family and multi-family houses. Their acoustic emissions are both relevant as outdoor and indoor noise negatively affects the acceptance of this technology. Outdoor noise is an issue for both the owner and his/her neighbours.

To increase the acceptance while keeping the high energy savings linked to that technology, emphasis must be put on several levels including components of heat pumps and their best combinations, control algorithms including acoustic parameters as well as unit placement and clever use of sound absorption measures. Acoustic perception is an important aspect of the acceptance and thus has to be included in future standards to an increased level.

Thus, the following sectors are targeted within the Annex: (1) heat pump components, (2) heat pump units and control, (3) unit placement and (4) acoustic perception and its importance for standardization. In all these sectors the Annex will influence future developments by generating guidelines for designers, manufacturers, installers, end-users and public authorities.

OBJECTIVES

- The primary aim is **to increase the acceptance of heat pumps** (as air-to-water, water-to-air, air-to-air and brine-to-water units) for comfort purpose with respect to the noise and vibration emissions.
- A second focus is placed on **increasing knowledge at different levels** (manufacturers, acoustic consultants, installers, legislators).
- To reach this goal, first different reasons to reduce sound emissions depending on countries (legislation), locations and applications have been gathered and understood. The main influencing factors to the acoustic signature of these units have also been identified. Collecting and combining research results in these fields on the different implementation levels (component, unit and application) have lead to directions for improved components, units and control strategies including guidelines, as well as training and inputs to future standards. The aim was to gather the knowledge and the expertise of the participants on the different levels in order to forward this knowledge and establish recommendations and advice.

> ***Please visit the IEA HPT Annex 51 website to view the webinar and to download the presentations and eleven task documents.***

ACHIEVEMENTS

- Increased the adoption of heat pumps
- Increased knowledge and expertise at different levels
- Provided input to national and international standardization bodies
- Prepared seven annex meetings – five physical meetings have been held (Austria *Vienna* June 2017, France *Lyon* January 2018, Sweden *Borås*, June 2018, Denmark *Aarhus*, January 2019, Germany *Freiburg* October 2019), and two meetings were held online (March 2020 and September 2020)
- Workshop on the acoustics of heat pumps held at the ICR2019 in Montreal, presentation published on the IEA HPT Annex 51 website
- Concluding international workshop and compilation of proceedings realized as a webinar in November 2020
- Worldwide dissemination to heat pump manufacturers
- Generated and distributed Acoustic Guidelines for the different levels (Component Level, Unit Level, Application Level) via the annex website

RESULTS

The following documents are available for free download on the IEA HPT Annex 51 website:

- IEA HPT Annex 51 Executive Summary and Document Guide – ***IEA HPT Annex 51 Executive Summary and Documents Guide***
- IEA HPT Annex 51 Umbrella Report – ***IEA HPT Annex 51 Umbrella Report***
- Deliverable 1.0 – Introduction – ***IEA HPT Annex 51 D1.0***
- Deliverable 1.1 – Measurement Techniques – ***IEA HPT Annex 51 D1.1***
- Deliverable 1.2 – Regulations – Countries overview – ***IEA HPT Annex 51 D1.2***
- Deliverable 1.3 – Regulations – Synthesis – ***IEA HPT Annex 51 D1.3***
- Deliverable 2.1 – Selection of Heat Pumps for Round Robin Tests – Market figures – ***IEA HPT Annex 51 D2.1***
- Deliverable 2.2 – Round Robin Tests – Air-to-Water Heat Pump – Heat Pump Water Heater – ***IEA HPT Annex 51 D2.2***
- Deliverable 2.3 – Seasonal Sound Power Level – Air-to-Water Heat Pump – ***IEA HPT Annex 51 D2.3***
- Deliverable 3 – Overview on Heat Pump Component Noise and Noise Control Techniques – ***IEA HPT Annex 51 D3***
- Deliverable 4 – Analysis of the Effect of Operating Conditions of Heat Pumps on Acoustic Behaviour – ***IEA HPT Annex 51 D4***
- Deliverable 5 – Report on heat pump installation with special focus on acoustic impact – ***IEA HPT Annex 51 D5***
- Deliverable 6 – Annoyance rating and psychoacoustical analysis of heat pump sound – ***IEA HPT Annex 51 D6***
- Deliverable 7.1 – Educational material on acoustics of heat pumps – ***IEA HPT Annex 51 D7.1***
- Deliverable 7.2 – Workshop material and conference contributions – ***IEA HPT Annex 51 D7.2***

Annex 51 Webinar "Acoustic Signatures of Heat Pumps". The webinar consisted of an introduction, a panel discussion and seven technical contributions. The presentations are available for download at the IEA HPT Annex 51 website.

- ***Introduction Annex 51 webinar*** – Caroline Haglund Stignor (Heat Pump Centre)
- ***Annex 51 overview*** – Christoph Reichl (AIT, Austria)
- ***European Standards and Legislation*** – Roberto Fumagalli (Polimi, Italy)
- ***Noise and seasonal variations based on interlaboratory results*** – Francois Bessac (CETIAT, France), Thomas Gindre (ISE, Germany)
- ***Effect of different heat sinks and operation modes on acoustic emissions*** – Kamal Arumugam (DTI, Denmark)
- ***(Transient) Noise of Heat Pumps*** – Thore Oltersdorf (Fraunhofer ISE, Germany)
- ***Heat pump installation and effects on surrounding environment*** – Christoph Reichl (AIT, Austria)
- ***Annoyance rating and psychoacoustical analysis of heat pump sound*** – Henrik Hellgren (RI.SE, Sweden)

PUBLICATIONS

C.H. Kasess, C. Reichl, H. Waubke, P. Majdak, *Perception Rating of the Acoustic Emissions of Heat Pumps*, e Forum Acusticum, Lyon, France, December 7-11, 2020.

Christian H. Kasess, Christoph Reichl, Holger Waubke, Piotr Majdak, Beurteilung derWahrnehmung der Schallemission von Wärmepumpen, submitted to DAGA 2020, 46. Jahrestagung für Akustik, online 2020, Hannover, Deutschland.

Christoph Reichl, Johann Emhofer, Peter Wimberger, Felix Linhardt, Norbert Schmid-bauer, Gerwin H.S. Drexler-Schmid, Brigitte Blank-Landeshammer, Andreas Sporr, Christian Köfinger, Thomas Fleckl, *Akustische Optimierung von Wärme-pum-pen (IEA HPT Annex 51),* 26. Tagung des BFE-Forschungsprogramms «Wärmepumpen und Kälte», online BFH Burgdorf, 24.06.2020.

Christoph Reichl, Brigitte Blank-Landeshammer, Andreas Sporr, Gerwin Drexler-Schmid, Johann Emhofer, Mirza Popovac, Peter Wimberger, Camilla Sandström, Christian Köfinger, Andreas Zottl, Thomas Fleckl, *Acoustics of heat pumps with special focus on icing, defrosting and placement,* Chillventa eSpecial Congress, online, 13.11.2020.

Christoph Reichl, Johann Emhofer, G. Drexler-Schmid, Peter Wimberger, Felix Linhardt, Brigitte Blank-Landeshammer, Andreas Sporr, Thomas Fleckl, *Acoustic behaviour and placement of heat pumps*, The perception of sound and heat pumps" in The Essence of Heat Pumps Series, EHPA Webinar, 02.09.2020.

E. Wasinger, *Sound field simulations of air-water heat pumps in a terraced housing estate*, Bachelor

Thesis, Austria 2017, translated to English.
Christoph Reichl, Johann Emhofer, *SilentAirHP - Advanced methods for evaluating and developing noise reduction measures for air heat pumps*, final report of Austrian research project.

François Bessac, Roberto Fumagalli, Henrik Hellgren, Thore Oltersdorf, Svend Pedersen, Thomas Fleckl, Christoph Reichl, *Acoustic Characterisation of an Air-To-Water Heat Pump for Different Operating Conditions: Inter-laboratory Results*, submitted to the 13th IEA HPC, Jeju Island, South Korea, April 26-29, 2021.

Gerwin H.S. Drexler-Schmid, Christian H. Kasess, Brigitte Blank-Landeshammer, Christian Köfinger, Johann Emhofer, Holger Waubke, Christoph Reichl, *Augmented reality acoustics of air heat pumps – App development and methods*, submitted to the 13th IEA HPC, Jeju Island, South Korea, April 26-29, 2021.

Christian Vering, Jonas Klingebiel, Christoph Reichl, Johann Emhofer, Markus Nürenberg, Dirk Müller, *Simultaneous energy efficiency and acoustic evaluation of heat pump systems using dynamic simulation models*, submitted to the 13th IEA HPC, Jeju Island, South Korea, April 26-29, 2021.

Blank-Landeshammer Brigitte, Sporr Andreas, Drexler-Schmid Gerwin, Kasess Christian, Köfinger Christian, Emhofer Johann, Waubke Holger, Reichl Christoph, *Noise Propagation Modelling and Mapping using Augmented Reality for HVAC Sound Sources*, submitted to ICSV27, 27th International Congress on Sound and Vibration, Prague, July 12th-16th, 2020, accepted.

A concluding webinar guiding participants through the results of IEA HPT Annex 51

Project duration:
April 2017 – December 2020

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www.heatpumpingtechnologies.org/annex51 and Research Gate

ANNEX
52

LONG-TERM PERFORMANCE MEASUREMENT OF GSHP SYSTEMS SERVING COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS

INTRODUCTION

Carefully instrumented and analyzed long-term performance measurements from large Ground Source Heat Pump (GSHP) systems are highly valuable tools for researchers, practitioners and building owners. Analyses of good quality long-term performance measurements of GSHP systems are sparse in the literature, and there is no consensus on key figures for performance evaluation and comparison. Within Annex 52, a bibliography on long-term measurement of GSHP systems has been compiled, and the participants have measured performance of more than 30 GSHP systems. Based on this experience, the annex is revising the current methodology to better characterize the performance of larger GSHP systems. These systems have a wide range of features and are considerably more complex than single-family residential GSHP systems. The case studies provide a set of benchmarks for comparisons of such GSHP systems around the world, using an extended system boundary schema for calculation of system performance factors. This schema is a further development of the ***SEPEMO*** system boundary schema developed for non-complex residential heat pump systems.

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.

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 and ground heat exchangers 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.

> ***21 case study reports and two guideline documents are completed and published on the Annex 52 website.***

MEETINGS

» 7th Expert meeting - June 17th-18th 2021, online. Case study progress reports, final drafts of instrumentation and uncertainty analysis guidelines, key performance indicators guideline draft.
» 8th Final Expert meeting – Nov 8th-10th 2021, Sweden. Case study final results; instrumentation guideline final editing. Key performance indicator guideline document discussions.

RESULTS

Annex 52 finished in December 2021. 21 case study reports are completed and published on the Annex 52 website. An additional 6-10 reports will be uploaded at the beginning of 2022. Results for 26 projects with 116 years of data in total have been collated. Not all projects can measure at the same boundaries, but 12 projects with 59 years of data have measurements for boundary 2, which includes the ground heat exchanger and heat pump(s). Seasonal performance factors within this boundary for heating and cooling together (SPF_{HC2}) are in the range 1.4-12.6, with an average of 4.6. 80% of the project years have SPF_{HC2}

of 3 or higher, and 34% of the project years have SPF_{HC2} of 5 or higher. One German building with 14 years of data that makes significant use of direct cooling from the ground has an average SPF_{HC2} of 8.2, and it has increased over time from an SPF_{HC2} of about 6 to 12.8 for the last two years of measurements.

Two guideline documents, for instrumentation and data and for calculation of uncertainties, have been completed and published on the website. Compilation and systematization of key performance indicators other than SPF and COP will be completed at the beginning of 2022. The annotated bibliography that has been compiled within the Annex contains some 80 publications describing more than 55 buildings where long-term performance monitoring of larger GSHP systems have been performed, and some form of measured SPF has been reported.

Two open-access journal papers presenting results from case studies within Annex 52 have been published in late 2021, in addition to the five previously published journal papers. The journal paper by Todorov et al. (2021) covers the long-term performance of the Aalto University borehole storage system in Helsinki, while Abuasbeh et al. (2021) report on an aquifer thermal energy storage serving an office building in Stockholm. Four Annex 52-related conference papers were presented and published at the hybrid conference HPC2021 in Jeju, South Korea. A conference paper with results from five years of measurements from the Studenthuset building in Stockholm has been submitted to the Clima 2022 conference in May, and a paper concluding the entire Annex 52 work is being written for the European Geothermal Congress 2022 in October. A webinar presenting the overall results from ***Annex 52*** is planned for the spring of 2022.

PUBLICATIONS

Davis, M.J., Martinkauppi, I., Witte, H., Berglöf, K., Vallin, S. (2021). ***Guideline for Instrumentation and Data – Final Document.*** IEA HPT Annex 52 – Long-term performance monitoring of GSHP systems serving commercial, institutional and multi-family buildings. ***https://doi.org/10.23697/tgr4-qn89***

Spitler, J.D., Berglöf, K., Mazzotti-Pallard, W., Witte, H. (2021). ***Guideline for Calculation of Uncertainties – Final Document.*** IEA HPT Annex 52 – Long-term performance monitoring of GSHP systems serving commercial, institutional and multi-family buildings. ***https://doi.org/10.23697/m2em-xq83***

Todorov, O., K. Alanne, M. Virtanen, R. Kosonen. (2021). A Novel Data Management Methodology and Case Study for Monitoring and Performance Analysis of Large-Scale Ground Source Heat Pump (GSHP) and Borehole Thermal Energy Storage (BTES) System. Energies 2021; 14(6):1523. ***https://doi.org/10.3390/en14061523***

Figure 1. Two new guideline documents on instrumentation and calculation of uncertainties are completed. Illustration: Signhild Gehlin

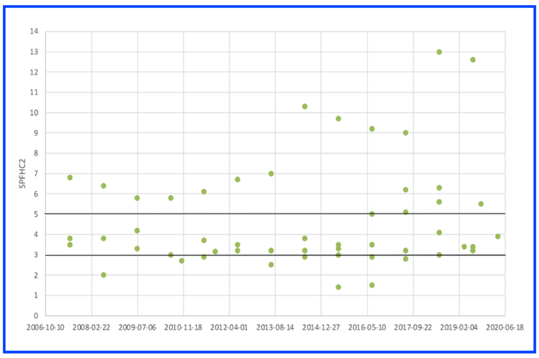

Figure 2. SPF_{HC2} for 12 projects with totally of 59 years of data. 80% of the project-years have SPF_{HC2} of 3 or higher, and 34% of the project years have SPF_{HC2} of 5 or higher. Illustration: Signhild Gehlin

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 (Figure 1). 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 under investigation include the vapor compression (VC) based systems, thermal compression-based systems (absorption and adsorption), and non-traditional cooling approaches. Advanced VC R&D underway by participant teams includes a combined absorption/VC/thermal storage concept, a large chiller based on water (R-718) as refrigerant, a novel pressure exchange (PX) concept for expansion work recovery, and enhanced source and sink stream matching using zeotropic refrigerants. Significant efforts are also underway aiming at advancing the state of development of systems based on magnetocaloric (MC), elastocaloric (EC), and electrocaloric effect (ECE) cooling cycle concepts. This includes work on identifying materials with improved fatigue performance, etc., for MC, EC, and ECE concepts.

> ***"Research results show promise to improve the cost-effectiveness (reduced size & weight) of EC-based cooling systems."***

OBJECTIVES

- Annex 53's main objective is longer-term R&D and information sharing to push the 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;
- 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.

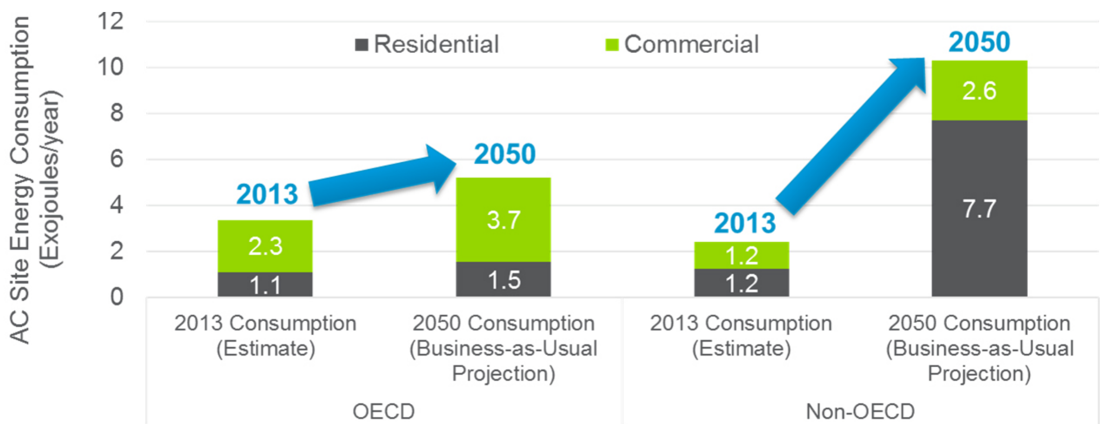

Figure 1. Current and projected space cooling site energy consumption for OECD and Non-OECD countries. Courtesy W. Goetzler, Guidehouse, Inc.; Source: IEA ETP 2016.

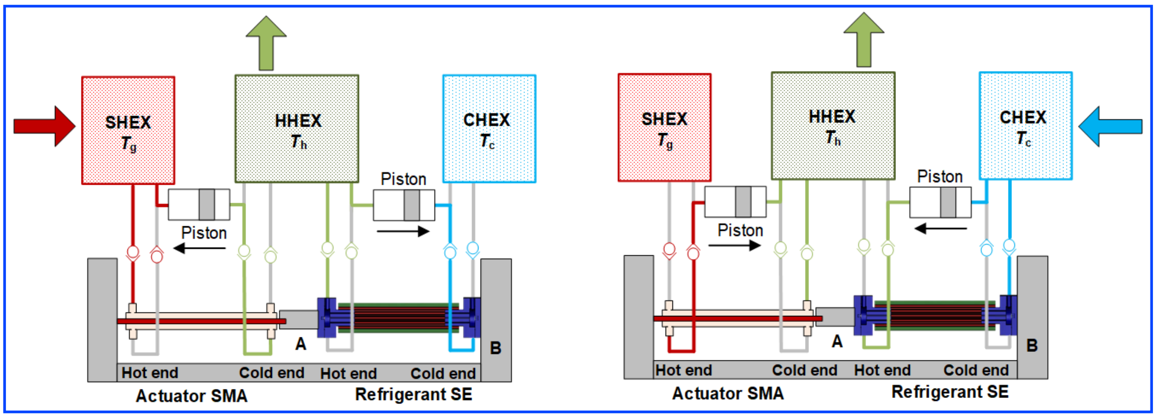

Figure 2. Schematic of the heat-driven EC cooling cycle.

MEETINGS

- A working meeting (virtual) was held on June 14, 2021.
- An Annex 53 workshop was held on June 9 as part of the virtual IIR THERMAG IX Conference.
- An online webinar featuring video presentations from all Annex participant teams was held in Sept./Oct. There were over 80 registrants for the webinar. The presentations were available for viewing from 9/20 – 10/29. A live, virtual Q&A workshop was held on October 5 with 24 participants.

PROGRESS HIGHLIGHTS

China's Annex 53 team at Xi'an Jiaotong University aims to develop a heat-driven elastocaloric (EC) cooling system. The latest progress is the development of a regenerative shape memory alloy (SMA) actuator that could harvest low-grade thermal energy by using hot water at 80 to 110°C. Figure 2 illustrates the operation of the system. The actuator shrinks upon heating and thus converts thermal energy to mechanical energy that drives the super elastic (SE) cooling material. Simulation results indicated a thermal to cooling efficiency of 1.08 with a heat source temperature of 100°C when assuming the actuator could shrink by 3% upon heating. Lab test results with the prototype SMA actuator achieved up to 4% stroke. Modifications to the SMA actuator are underway to improve heat transfer effectiveness so that higher operating frequency can be achieved. If successful, this heat actuated EC concept could significantly reduce the size and weight of EC systems. This technology has the potential to be used for residential-scale solar-driven air conditioners and off-grid refrigerators.

PUBLICATIONS

Bachmann, N., Fitger, A., Maier, L.M., Mahlke, A., Schäfer-Welsen, O., Koch, T., Bartholomé, K. Long-term stable compressive elastocaloric cooling system with latent heat transfer. Communications Physics **4**, 2021.

Elatar, A., Fricke, B., Sharma, V., Nawaz, K. Pressure exchanger for energy recovery in trans-critical CO2 refrigeration system. Energies **14**, 2021.

Griffith, L.D., Alho, B.P., Czernuszewicz, A., Ribeiro, P.O., Slaughter, J., Pecharsky, V.K. Toward efficient elastocaloric systems: Predicting material thermal properties with high fidelity. Acta Materialia **217**, 2021.

Qian, S., Wang, Y., Xu, S., Chen, Y., Yuan, L., Yu, J. Cascade utilization of low-grade thermal energy by coupled elastocaloric power and cooling cycle. Applied Energy **298**, 2021.

Sapienza, A., Brancato, V., Aristov, Y., Vasta, S. Plastic heat exchangers for adsorption cooling: thermodynamic and dynamic performance. Applied Thermal Engineering **188**, 2021.

Wu, W., Zhai, C., Huang, S.-M., Sui, Y., Sui, Z., Ding, Z. A hybrid H2O/IL absorption and CO2 compression air-source heat pump for ultra-low ambient temperatures. Energy **239,** 2022.

Yang, X., Wang, B., Cheng, Z., Shi, W., Yu, Y. Upper-limit of performance improvement by using (quasi) two-stage vapor compression. Applied Thermal Engineering **185**, 2021.

Yang, Z., Zhao, J., Wang, B., Zhuang, R., Li, X., Xiao, H., Shi, W. Experimental performance analysis of hybrid air conditioner in cooling season. Building and Environment **204**, 2021.


Reinhard Radermacher

Project duration:
October 2018 – December 2022

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ANNEX

54

HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS

INTRODUCTION

Low-GWP refrigerants are considered long-term solutions for environmentally friendly heat pump systems. Considerable studies have shown that design modifications are necessary to optimize low-GWP refrigerants. In particular, system-level design, analysis, and optimizations are much needed.

Annex54 aims to address the challenge via:

» a comprehensive review of recent R&D progress on component- and system-level design, analysis, and optimization using low GWP refrigerants,

» in-depth case studies of system-level optimization, which can provide design guidelines and real-world experiences.

All the efforts are accomplished from academic and industrial participating countries. The work can be a valuable reference for researchers, engineers, and policymakers across the HVAC industry. It is of particular interest for those to dive deep into the R&D of heat pump systems.

OBJECTIVES

Annex 54 promotes the application of low-GWP refrigerants to air-conditioning and heat pump systems with the following objectives:

» a comprehensive review of recent R&D progress on system-level design, analysis, and optimization using low-GWP refrigerants (fulfilled),

» in-depth case studies of system-level optimization, which can provide design guidelines and real-world experiences (partially fulfilled),

» optimization of heat pump systems for low-GWP refrigerants (partially fulfilled),

» analysis of the LCCP impacts by the current design and optimized design with low-GWP refrigerants (partially fulfilled), and

» making an outlook for heat pumps with low-GWP refrigerant for 2030 (planned).

"Significant progress has been made on case studies and design guidelines for optimizing heat pump systems using low GWP refrigerant, review of design optimization, and advancement impacts on life cycle climate performance (LCCP) reduction."

MEETINGS

Workshop

» Hosted three online workshops on 1) April 26 during the 13th International Energy Agency Heat Pump Conference, 2) June 16 during the 2nd IIR International Conference on HFO Refrigerants and Blends, and 3) September 1st during the 6th IIR Conference on Thermophysical Properties and Transfer Processes of Refrigerants.

» During the workshops, experts from Annex 54 participating member countries presented low-GWP refrigerants utilizing technologies for residential heat pumps (air-to-air, water-to-water, and ground source heat pumps), and heat pump water heaters. Details of workshops presentation materials are available from the ***Annex 54*** website

Business meeting

» Hosted one online business meeting on 1) April 27th during the 13th International Energy Agency Heat Pump Conference

» During the meeting, we discussed the overall Annex schedule, two-year extension, and future workshops.

RESULTS

In 2021, we achieved considerable progress in the following two areas: 1) Task 2: case studies and design guidelines for optimizing heat pump systems using low GWP refrigerants. 2) Task 3: a review of design optimization and advancement impacts on life cycle climate performance (LCCP) reduction. The work can be a valuable reference for researchers, engineers, and policymakers across the HVAC industry. The progress accomplished by participating countries is described below.

The research groups in the U.S.A. summarized the activities related to establishing a detailed database of alternative lower GWP refrigerants for various HVAC&R applications, including thermodynamic and transport properties. The goal is to identify the most suitable candidates for the replacement of traditional refrigerants based on thermodynamic performance and environmental benefits. The study also considers the extent of potential system adjustments required to accommodate the new alternative refrigerants. University of Maryland research group provided a comprehensive investigation of the LCCP of unitary air conditioners. The review focused on LCCP methodologies, impacts of parameter and methodology selections, and a few representative case studies.

The teams in Italy carried out significant advances in the use of low GWP refrigerants in heat pumps. Three research entities reported their progress on low GWP refrigerants and their applications in various heat pump systems. The activities cover condensation and flow boiling heat transfer coefficients measurements and multiple experimental-oriented projects on long-term evaluations of novel heat pump systems using low GWP refrigerants.

Research groups in Japan mainly focus on the first step of a two-step process on LCCP evaluation of heat pumps with next-generation refrigerants. They also presented an overview of a project to establish a new concept and hypothesis for LCCP evaluation, in which field data related to air conditioners is adopted.

The French research group conducted studies on finned-tube heat exchangers using low GWP refrigerants. The study assessed the heat transfer performance during evaporation and condensation of R410A, R454B, and R32 in a finned-tube heat exchanger. A 30-kW experimental setup was built to assess the heat exchanger performance with these three refrigerants. The simulations show that the same design of the finned tube heat exchanger can be used for R410A and R454B, but a design optimization is necessary with R32.

Several research groups in German collaboratively summarized the most recent large-scale heat pump monitoring project, a review of ongoing heat pump projects based on an analysis of the EnArgus database, and a survey on heat pumps and their refrigerants as part of the market incentive program coordinated at the Federal Office for Economic Affairs and Export Control. Further, they presented a high-level summary of R&D progress across multiple institutions in Germany. Within the last five years, the activities for heat pump research have changed. The activities cover more fundamental research up to the application of deployable heat pump demonstrators for white goods (e.g., dishwashers), mobile systems for electric-driven buses, or large capacity heat pumps systems for multi-family houses.

PUBLICATIONS

Journal:

» Azzolin M., Bortolin S., 2021a. Condensation and flow boiling heat transfer of a HFO/HFC binary mixture inside a mini channel, International Journal of Thermal Sciences, Vol. 159, 106638.

» Wan, H., T. Cao, Y. Hwang, S. Andersen, S. Chin, 2021a, A Comprehensive Review of Life Cycle Climate Performance for Air Conditioning Systems, Int. J. of Refrigeration, 130, 187-198, October 2021. ***DOI: https://doi.org/10.1016/j.ijrefrig.2021.06.026.***

» Wan, H., T. Cao, Y. Hwang, R. Radermacher, S. Chin, 2021b, Comprehensive Investigations on Life Cycle Climate Performance of Unitary Air-Conditioners, Int. J. of Refrigeration, 129, 332-341, September 2021. ***DOI: https://doi.org/10.1016/j.ijrefrig.2021.04.033.***

Conference:

» Azzolin M., Berto A., Gaion M., Bortolin S., Del Col D., 2021b, Heat transfer coefficient measurements and flow pattern visualizations of R1234ze(E) condensation inside a 3.4 mm diameter channel, 2nd IIR Conference on HFOs and Low GWP blends (HFO2021), Osaka, Japan (online), June 16-18, 2021, Paper ID: 1027.

» Azzolin M., Berto A., Bortolin S., Del Col D., 2021c, Two-phase heat transfer of low GWP ternary mixtures, 18th International Refrigeration and Air Conditioning Conference at Purdue, West Lafayette, IN, USA (online), Paper #210049, May 24-28, 2021.

» Clemens Dankwerth, Timo Methler, Thore

Oltersdorf, Peter Schossig, Lena Schnabel, Evalution of A Low Charge Heat Pump Circuit using Propane, 13th IEA Heat Pump Conference, April 29, 2021.

» Ehsan Allymehr, Torsten Will, Lena Sschnabel, Geir Skaugen, Comparison of Refrigerant Charge Requirements in an Optimized Fin and Tube Evaporator Versus Plate Heat Exchangers, 6th IIR TPTPR Conference, September 1-3, 2021.
» Höges, C., Venzik, V., Müller, D., Theoretical Assessment of Binary Mixtures as Working Fluids in Heat Pump Cycles, 34th International Conference On Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems.
» Laura F., S. Bobbo, D. Menegazzo, An update on the thermosphysical properties data available for pure low GWP Refrigerants, 6th IIR Conference on Thermophysical Properties and Transfer Processes of Refrigerants, The Sixth IIR TPTPR Conference, September 1-3, 2021 - Vicenza, Italy.
» Menegazzo, D., S. Bobbo, L. Fedele, M. De Carli, G. Emmi, F. Poletto, A. Tarabotti, D. Mendrinos, G. Mezzasalma, A. Bernardi, Selection of Low GWP Refrigerants for Ground Source Heat Pumps within UE GEO4CIVHIC project, Purdue 2020 Conferences in Compressor Engineering, Refrigeration and Air Conditioning, and High Performance Buildings, May 24-28, 2021.
» Vering, C., Stopp, D., Klebig, T., Venzik, V., Müller, D., Optimal Designed Experiments for Reliable Model Calibration of a fixed-speed Scroll Compressor with R410A and R32, Materials Science and Engineering, Volume 1180, 12th International Conference on Compressors and their Systems (Compressors 2021) September 6-8, 2021, London, United Kingdom.

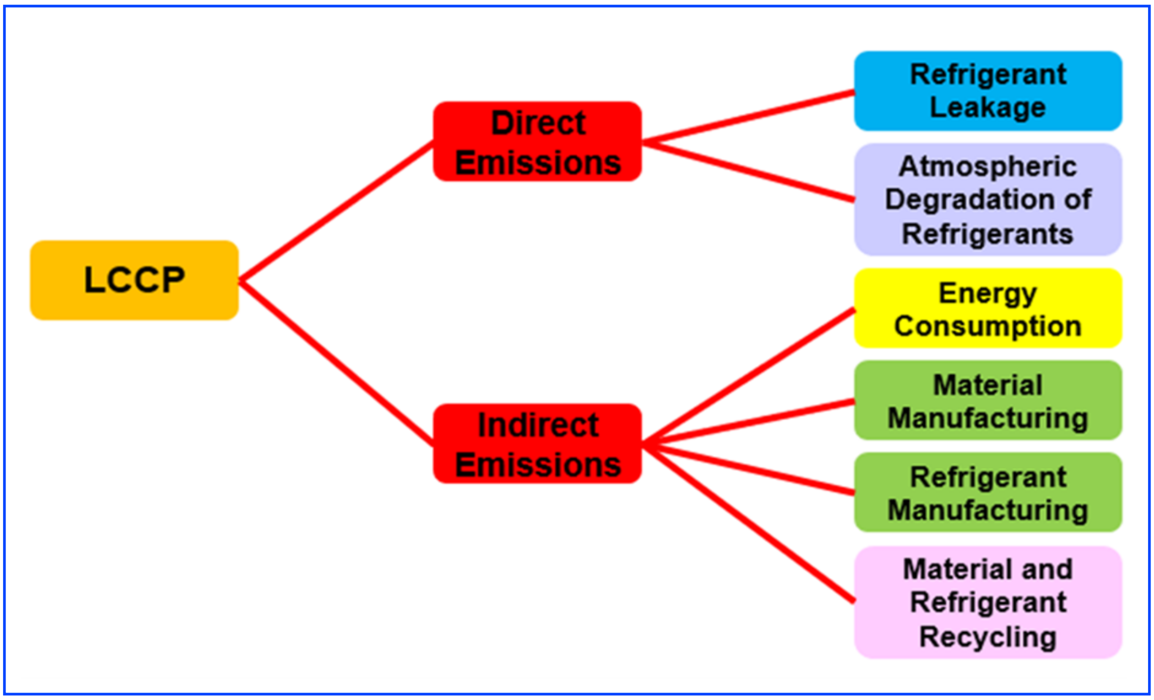

Figure 1. LCCP Components (IIR, 2015) Reference: Hwang, Yunho, 32nd Informatory Note on Refrigeration - Harmonization of Life Cycle Climate Performance. International Institute of Refrigeration (IIR) 2015.

Project duration:
January 2019 – December 2023

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Further information:
www.heatpumpingtechnologies.org/annex54/

ANNEX

55

COMFORT AND CLIMATE BOX

INTRODUCTION

Integrated systems consisting of heat pumps, storage and controls are in general considered as an important technological option to accelerate the deployment of renewable energy in the domestic sector. Improving the coordination and integration of heat pump operation and storage, performance of the system can be enhanced in several ways: price, compactness, reliability, efficiency, serviceability etc. Meanwhile, a better smart-grid integration and a larger share of direct renewable energy use becomes feasible.

Under the combined direction of the IEA Technology Collaboration Programs (TCPs) on energy storage (ECES) and heat pumping technologies (HPT), HPT Annex 55 started in early 2019 and focused on improving combined systems of heat pumps, storage, and controls.

Integrated systems consisting of heat pumps and storage are an important technological option to accelerate the use of renewable energy for heating and cooling. By combining heat pumps and storage, several issues may be tackled in one and the same process, such as:
Balancing & controlling electricity grid loads; Capturing a larg(er) share of renewable (local/regional) energy input; Optimizing economics, CO_2 emissions, fuel use throughout time; Providing optimal supply security to buildings.

Commercial development of this type of solution is progressing very slowly, so the aim of the combined Annex 55 (ECES Annex 34) is to accelerate market development of combined heat pump/storage packages (working title “Comfort and Climate Box”, or ‘CCB’). This is the first Annex to integrate the work from the TCPs HPT and ECES, building upon the earlier work in the fields of Heat Pumps and Storage systems.

COMFORT & CLIMATE BOX (CCB)

The central concept in Annex 55 is the Comfort and Climate Box, (see figure 1), a concept that denotes the combined package, consisting of a Heat Pump, an Energy Storage Module and Controls.

> ***To achieve a good match between optimized CCBs and market conditions, it is important for policy makers to consider which goals are to be met.***

This package may form an actual physical unit, but can also consist of separate modules that form an integrated ‘virtual pack-age’, 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.

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 market development. We focus on systems that are close to market availability, i.e. technology readiness level (TRL ladder) upwards from 7, and have a high quality adopted for their local market requirements.

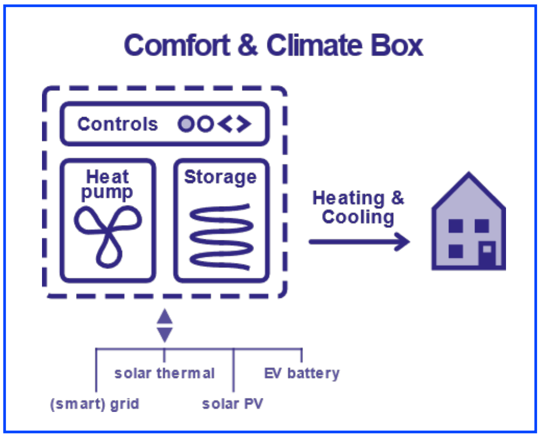

Figure 1. The possible components of a CCB

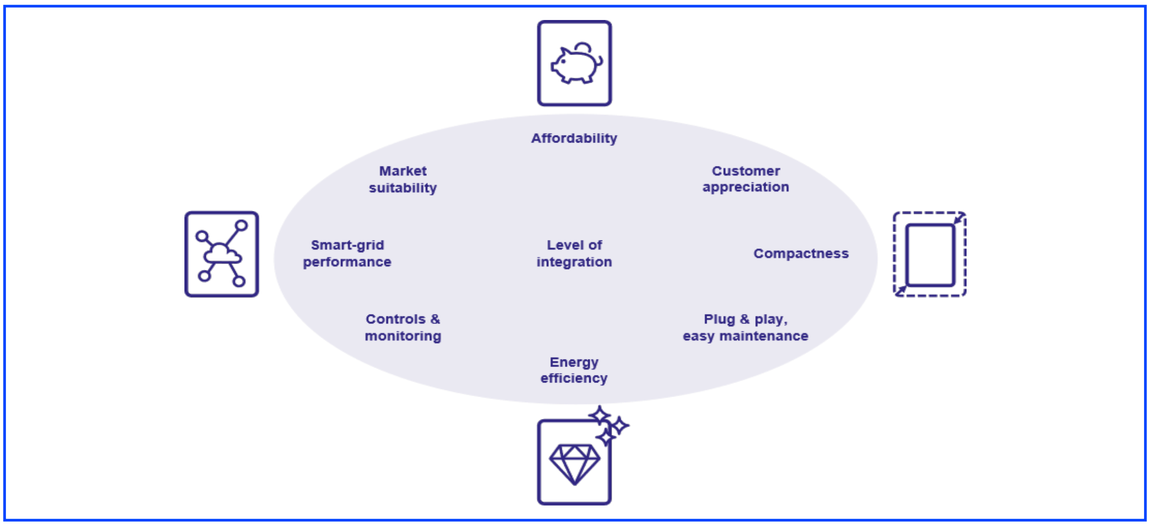

Figure 2. The four implementation strategies for a CCB and the associated quality criteria

The work is oriented around the nine quality criteria as mentioned to define the concept of improved quality. The underlying drive is to accelerate the market development for CCBs to enable rapid growth of the application of these systems in various climate zones. By exchanging the lessons learned from the separate developments in each participating country, we aim to enable the participants to help each other to speed up their local market development. Annex 55 is also in twined with the global Mission Innovation program Task # 7. MI -7 functions as a non-hierarchical platform to enhance technology development within the building envelop.

MEETINGS

- » March 2021, Online video meeting - General meeting, focusing on the contents of the final report; what will the work packages deliver, what is already done and what needs to be done in the coming period.
- » May 2021, online video meeting - Discussion of the draft versions of all the work packages final reports.
- » October 2021, online video meeting - Discussion of the final report.

RECENT PROGRESS

CCB, or integrated systems of heat pumps and storage units, can achieve much better performance if they are designed to function as a single unit, with a specific optimization goal in mind. Therefore it is important to realize that there is no single 'perfect CCB'. Depending on the circumstances, system performance may be very different across performance criteria, such as SPF, compactness, investment, or ease of installation. To achieve a good match between optimized CCBs and the local market conditions, it is very important for policy makers to consider which goals are to be met. High market volume? Excellent performance of single systems? Or maximum flexibility and grid balancing capacity?
We have developed a set of four CCB 'archetypes' that should help policy makers to design appropriate support mechanisms to achieve their policy goals within the local market context.

1. **'Budget CCB'** – Focus on lowest investment, and, consequentially, rapid market growth and high volume.
2. **'Flexible CCB'** – Maximum flexibility, to allow optimal grid balancing and auto-consumption of renewable energy.
3. **'Compact CCB'** – Small components and easy installation, to allow the use of heat pumps in densely populated areas where space constraints are dominant.
4. **'Top quality CCB'** – Maximum performance in terms of energy efficiency. This comes with a higher investment, less flexibility and a large installed footprint.

Project duration:
April 2019 – September 2021 (Final delivery has been postponed to January 2022).

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Participating countries:
Austria, Belgium, Canada, China, France, Germany, Italy, the Netherlands, Sweden, Switzerland, Turkey (from ECES TCP), UK and USA.

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

ANNEX

56

INTERNET OF THINGS FOR HEAT PUMPS

INTRODUCTION

Today, more and more devices are connected to the Internet and can interact due to increasing digitalization – the Internet of Things (IoT). In the energy transition, digital technologies are intended to enable flexible energy generation and consumption in various sectors, thus leading to greater use of renewable energies. This also applies to heat pumps and their components.

Annex 56 explores the opportunities and challenges of connected heat pumps in household applications and industrial environment. There are a variety of new use cases, and services for IoT enabled heat pumps. Data can be used for preventive analytics, such as what-if analysis for operation decisions, predictive maintenance, fine-tuning of the operation parameters and benchmarking. Connected heat pumps allow for demand response to reduce peak load and to optimize electricity consumption, e.g. as a function of the electricity price. Digitalization in industry can range from automated equipment advanced process control systems to connected supply value chains. IoT enabled heat pumps allow for integration in the process control system and 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 1) is also associated with different important risks and requirements to connectivity, data analysis, privacy, and security for various stakeholders. Therefore, this Annex has a broad scope looking at different aspects of digitalization and will create a knowledge base on connected heat pumps. The Annex will provide information for heat pump manufacturers, component manufacturers, system integrators and other actors involved in IoT.

OBJECTIVES

- Provide guidance, data and knowledge about heat pump technologies with respect to IoT applications
- Review the status of currently available IoT enabled heat pumps, heat pump components and related services
- Identify requirements for data acquisition from newly designed or already implemented heat pump systems considering types of signals, protocols and platforms for buildings and industrial applications and related privacy issues and ongoing standardization activities
- Evaluate data analysis methods and applications (digital twins), including machine

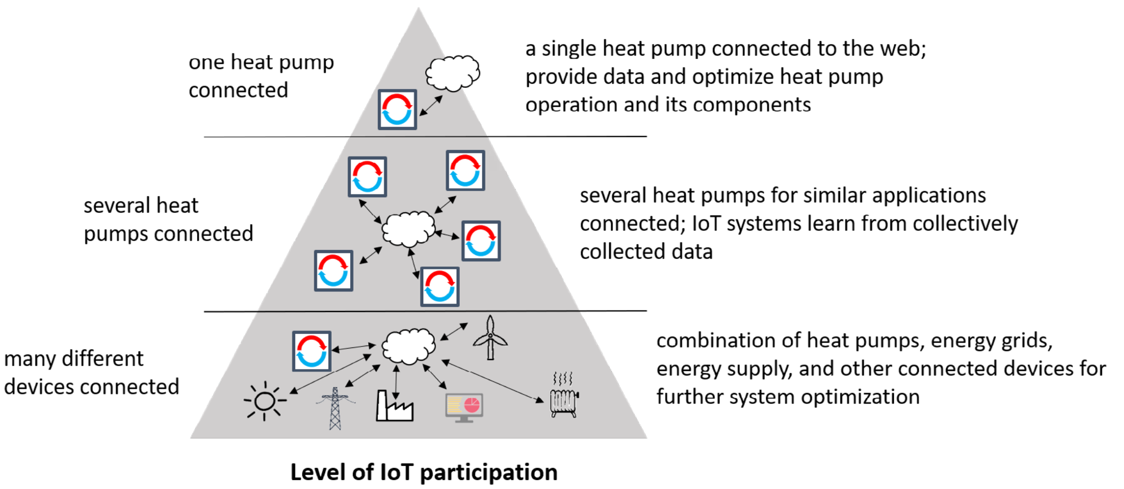

Figure 1. Heat pumps as a part of the Internet of Things (source: AIT Austrian Institute of Technology GmbH)

learning, semantic models, hybrid models, data-driven models and soft sensors
- Analyze business models for IoT enabled heat pumps (strengths, weaknesses, opportunities, threats)
- Evaluate market opportunities created by IoT enabled heat pumps and identify success factors and further demands to software and hardware infrastructure.

MEETINGS

- 19.01.2021, online meeting, 2nd Deep Dive Session on data-driven modeling and machine learning, refinement of the framework to categorize IoT use cases
- 18.03.2021, online meeting, 3rd Deep Dive Session on hybrid modeling including data-driven models as well as physical models, refinement of the framework to categorize IoT use cases
- 01.06.2021, online meeting with 4th Deep Dive Session on connected heat pumps in industrial applications, refinement of the framework to categorize IoT use cases
- 23.06.2021, online working meeting, discussion of the structure and content of the different task reports
- 25.10.2021, working dinner in Nuremberg prior to the European Heat Pump Summit
- 26.11.2021, online meeting with 5th Deep Dive Session on Heat as a service and user engagement in the context of connected heat pumps, further shaping of the work for the tasks on State of the Art and on Data analysis

RESULTS

Modeling is a key element in the field of IoT and heat pumps, as the model allows to infer information and to predict on collected real-world data. In three Deep Dive sessions consisting of presentations by the participants on completed, ongoing and planned research work in the field of IoT and heat pumps, different aspects of heat pump modeling were analyzed:

Semantic models contain information on how data relates to the real world; an example is Building Information Modeling (BIM). It was developed to consolidate the large number of different information sources throughout the life-cycle of a building. Standardization, which is key for efficient data exchange and interoperability, and integration of HVAC components in BIM, are still ongoing.

Data-driven models and machine learning approaches make use of large quantities of data, e.g., by supervised or unsupervised learning, clustering and classification. These methods can also be transferred to building and heat pump applications.

Hybrid models or grey box models combine analytical models with detailed physical relations with data-driven models based on statistics to find a good compromise on complexity and accuracy. Grey-box models are applied, e.g. for advanced system monitoring and fault detection. The task of correctly recording environmental influences on the observed system to be able to distinguish a fault from an observed change was identified as an important issue for HVAC systems.

Industrial applications: Two different scales of applications for connected heat pumps were discussed in the Deep Dive Session:

- large scale heat pumps for district heating that interact with different markets with optimization based on price signals, that also provide flexibility to the electric grid
- an energy demand control system that allows for optimal process control for small and medium industrial companies.

For industrial applications, digital twins for operation, maintenance and grid flexibility services are in the focus of research and demonstration activities and have become considerably more important in the last years.

Networking: We reached out to related annexes in other technology collaboration programs, such as Electric Motor Systems Annex of 4E Energy Efficient End-use Equipment TCP and Users TCP: TCP on User-Centred Energy Systems

PUBLICATIONS

V. Wilk "IoT and heat pumps: opportunities and challenges", European Heat Pump Summit, Nuremberg, 27.10.2021.

Project duration:
January 2020– December 2022

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ANNEX 57

FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI-VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS

INTRODUCTION

The CO_2 reduction goals means that the need for using excess heat from industries, the commercial sector and other sources are increasing as well as thermal solar power. In combination with District Heating, heat pumps are a way to make these energy sources available to use in buildings. At the moment, the interest in heat pumps for district heating and processes is growing.

Annex 57 focuses on coming technologies and the possibilities of heat pumps to increase the flexibility in energy systems with different sources such as PV, wind-power, and biomass and where end users can be consumers or prosumers or both (Multi-Vector). Heat pumps in DH systems provide many benefits since they enable the possibility of running DH systems at lower temperatures, which increases the possibilities of using waste heat. Thus, the grid can run more efficiently as the heat losses can be reduced.

OBJECTIVES

This Annex focuses on implementing heat pumps in district heating and cooling systems, describing possible solutions and barriers for heat pumps on these markets. The creation of the possible flexibility in the thermal network and the electrical grid is a main part of the annex.

The possibilities of increasing a larger share of renewable energy and excess heat as well as reducing the CO_2 emission in the used heating systems by using heat pumps will be a focus area of the Annex. In addition, minimizing the system losses by using heat pumps will also be an objective, as will the reduction of CO_2 emissions.

RECENT PROGRESS

The participants got their funding in place; the Annex had a kick-off meeting in January and task 1 start-up meeting in February. A workshop for the IEA Heat Pump Conference was set up in April.

At ExCo meeting in spring, it was decided that flexibility from individual heat pumps should be a part of the annex. This means that we are working on the implementation of that part in Task 1.

Task 2 is at the moment in the preparation phase, where we are going to find cases where heat pumps are bringing flexibility to the electrical and thermal grid.

ACHIEVEMENTS

- Meetings: Kick-off meeting in January, Task 1 meeting in February, Task 1 meeting in September.
- Workshop: Preparation and coordination of a workshop at the IEA Heat Pump Conference in April.

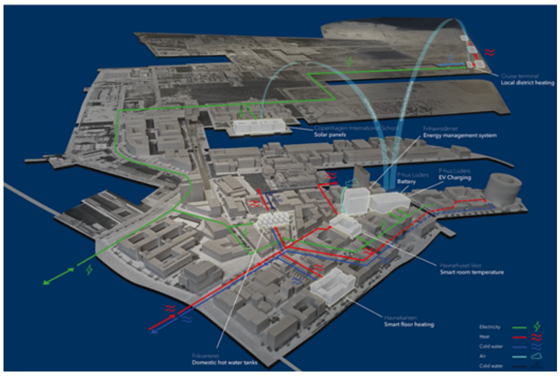

Figure 1. Integrated energy sytems in EnergyLabs Nordhavn

Project duration:
January 2021 – December 2022

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ANNEX 58

HIGH-TEMPERATURE HEAT PUMPS

INTRODUCTION

Heat pump-based heat supply at high temperatures has considerable potential for decarbonizing the industrial process heat supply but is often facing various challenges. Exploiting the full potential of high-temperature heat pumps (HTHP) requires a common understanding of the technology, its potentials, and its perspectives at a variety of stakeholders. High-temperature heat pumps are considered a key technology for decarbonizing industrial process heating towards 2030, while a successful wide-scale implementation of the technology will require the consideration of technologies that are currently approaching the market and still under development.

Therefore, this Annex gives an overview of available technologies and close-to-market technologies and outlines the need for further RD&D developments. In order to maximize the impact of high-temperature heat pumps, this Annex also looks at process integration by developing concepts for heat pump-based process heat supply, and the implementation of these concepts see Figure 1.

> ***Exploiting the full potential of high-temperature heat pumps requires a common understanding of the technology, its potentials, and its perspectives at a variety of stakeholders.***

OBJECTIVES

The overall objective of the Annex is to provide an overview of the technological possibilities and applications as well as to develop best practice recommendations and strategies for the transition towards heat pump-based process heat supply. The intention is to improve the understanding of the technology's potential among various stakeholders, such as manufacturers, potential end-users, consultants, energy planners and policy makers. In addition, the Annex aims to provide supporting material to facilitate and enhance the transition to a heat pump-based process heat supply for industrial applications.

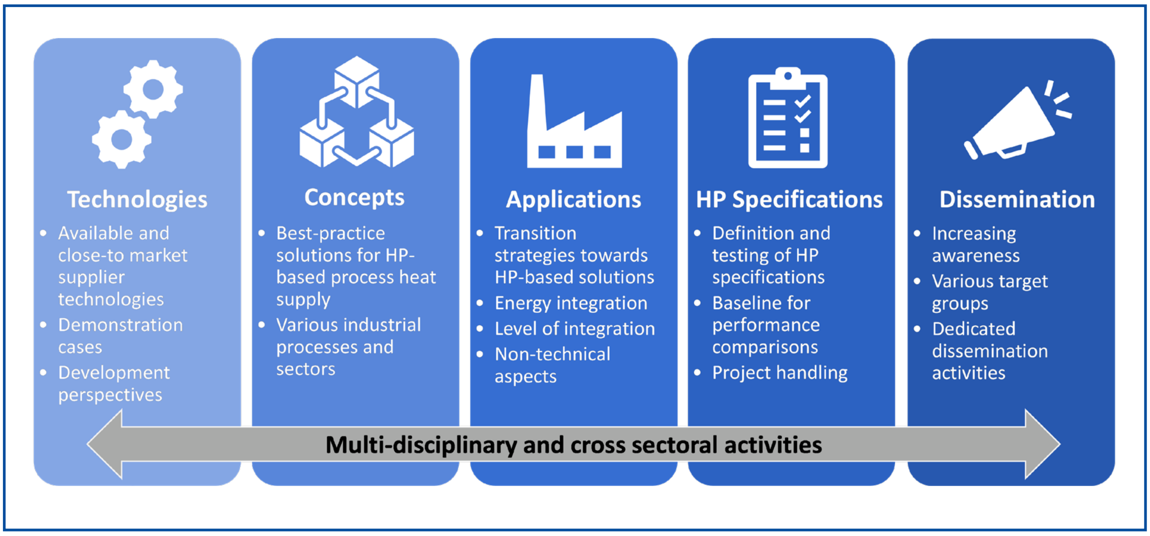

Figure 1. Overview of activities in Annex 58.

This will be achieved by the following sub-objectives:

- Provide an overview of the technology, including the most relevant systems and components that are commercially available and under development (Task 1 – Ongoing).
- Identify technological bottlenecks and clarify the need for technical developments regarding components, working fluids and system design (Task 1 – Ongoing).
- Present best practice system solutions for a range of applications to underline the potential of HTHPs (Task 2 – Ongoing).
- Present strategies for the transition to heat-pump based process heat supply (Task 3 – Planned).
- Enhance the information basis about industrial heat pumps, potential applications and potential contribution to the decarbonization of the industry (Task 1, 2 & 3 – Ongoing).
- Develop guidelines for the handling of industrial heat pump projects with a focus on the HP specifications and the testing of these specifications (Task 4 – Planned).
- Disseminate the findings to various stakeholders and add to the knowledge base for energy planners and policy makers (Task 5 – Ongoing).

MEETINGS

The Annex work was organized by various online working meetings with the national representatives from each participating country. During the last year, the following working meetings were held:

- Kick-Off Meeting, 04.03.2021, Online Teams Meeting. The meeting provided an update about the formal participation, established a working structure, and initiated the work for Task 1 – Technologies in a group session.
- 1st Status Meeting, 19.05.2021, Online Teams Meeting. The meeting was used to continue the work on Task 1 and for aligning the expectations. Review schemes for collecting information about supplier technologies and demonstration cases were developed.
- 2nd Status Meeting, 08.07.2021, Online Teams Meeting. The meeting focused on getting an overview of the ongoing collection of information using the review templates and discussing first examples from suppliers.
- 3rd Status Meeting, 30.08.2021, Online Teams Meeting. A preliminary analysis of the collected information was presented, and the report outline of Task 1 was discussed.
- 4th Status Meeting, 01.10.2021, Online Teams Meeting. The meeting was used to distribute and coordinate the contributions from the national teams for the Task 1 report.
- 5th Status Meeting, 29.11.2021, Online Teams Meeting. The meeting was used to coordinate the work on Task 1 and to kick-off work on Task 2.

These working meetings were supplemented by various online Deep Dive sessions, which comprised presentations from selected speakers focusing on a specific topic. These Deep Dive sessions were open to all participants from the national support groups represented in the Annex.

- Deep Dive about medium- and large-scale HTHP systems, 19.05.2021, Online Teams Meeting. Presentations from German Aerospace Center about their development activities and from MAN ES, Turboden, EPCON, Olvondo and Hybrid Energy about their technologies.
- Deep Dive about medium-scale HTHP systems, 08.07.2021, Online Teams Meeting. Presentations from Sustainable Process Heat, Star Refrigeration and ECOP about their technologies.
- Deep Dive about steam generation and MVR, 30.08.2021, Online Teams Meeting. Presentations from AIT, Ostschweizer Fachhochschule OST, CRIEPI and SINTEF about steam generation using heat pumps and analysis of different systems and technologies.
- Deep Dive about working fluid and cycle optimization for high-temperature heat pumps, 29.11.2021, Online Teams Meeting. Presentations from DTI, DLR, NTNU, Johnson Controls, and RWTH Aachen University about working fluid and cycle optimization for high-temperature heat pumps. This includes both the evaluation of refrigerants as well as the simultaneous optimization of working fluid, cycle layout and components.

RESULTS

High-temperature heat pumps (HTHP) are attracting growing interest and are considered a key technology for decarbonizing industrial process heating. The recently published IEA report "Net Zero by 2050 – A Roadmap for the Global Energy Sector" outlined the importance of industrial heat pumps and concluded that heat pumps should cover 15% of the process heat demand of light industries at temperatures up to 400 °C in 2030, while this share should increase to 30% by 2050. This corresponds to a required installation capacity of 500 MW per month over the next 30 years. The majority of these systems are expected to have supply temperatures above 100 °C and are accordingly considered high-temperature heat pumps.

The relevance of high-temperature heat pumps is confirmed by the large interest in the Annex 58. Ten countries have already confirmed their participation, and in total, up to twelve participating countries are expected to join the Annex. The national support groups comprise R&D institutes and universities, technology suppliers, consultants, and others and are accordingly supplemented with knowledge from various national and international R&D projects.

As part of Task 1, the activities focused on summarizing the state of the art, including available and close-to-market technologies. In this activity, information about supplier technologies and demonstration cases were collected using review templates. In the general perception of the industrial heat pump industry, supply temperatures of commercially available equipment seem to be limited to around 100 °C, while first technologies are becoming commercially available for higher temperatures. In order to communicate the availability of technologies, the Annex has collected information about supplier technologies and demonstration cases in informative two-page brochures, as shown in Figure 2.

By now, 25 supplier technologies were described, while more than 30 are expected in total. This is in contrast to the 9 demonstration cases for which information has been gathered. The review is still ongoing and will be concluded in the coming month before being published during the first half of 2022. If you are aware of any technologies or demonstration cases that should be included in the review, please reach out to the operating agent (Benjamin Zühlsdorf, ***bez@dti.dk***).

PUBLICATIONS

B. Zühlsdorf, High-temperature heat pumps – Developments and perspectives, European Heat Pump Summit, Nuremberg, Germany, 2021.

Figure 2. Two-page information brochures of high-temperature heat pump systems.

Project duration:
January 2021 – December 2023

Operating Agent:

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Participating countries:
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Further information:
www.heatpumpingtechnologies.org/annex58/

Outlook into the Future

In 2022, HPT TCP will continue implementing the strategic work plan (SWP) for 2018-2023 for the TCP (see page 8-9). Based on the outcomes from the midterm evaluation (MTE) of this plan (see page 11-12) performed during 2020/2021, we will focus on the following strategies in the SWP during 2022:

- Advancing the RDD&D of heat pumping technologies through the creation of research opportunities, networking possibilities, and **meeting places for academia, industry, private sector markets, investors and policy makers**, to collaborate under new Annexes (projects) and activities within the HPT TCP. **(Strategy point 1)**
- **Perform RDD&D activities** within the areas of heating, cooling and refrigeration for the building, community, transport and industrial sectors **(Strategy point 2)** and focus on the areas defined to be **prioritized** during the **midterm evaluation**; see achievement 5 below.
- Contribute to advanced and/or disruptive innovations through **cross-cutting networking** and collaboration with other TCPs and relevant organizations. **(Strategy point 3)**

Moreover, much work in 2022 will be focused on preparation for the upcoming **request for extension** of the TCP to IEA for the next strategy period 2023-2028, and the strategic work plan will be reviewed and possibly revised or renewed.

The TCP has prioritized some selected achievements to be reached in 2022. These were selected based on the conclusions from the midterm evaluation of the strategic work plan finalized during 2021. Examples include a sharper focus by the TCP on affordability and replication aspects of the technology, capacity building by using digital tools, outreach to key individuals within our prioritized target groups, and additional emphasis on improving some parts of the annex life cycle.

The selected achievements for 2022 are:

- Request for Extension of HPT TCP
- Strategic relations/partnership with individuals and organizations within our prioritized target groups and new member countries
- Implementation of improved existing procedure to start new annexes and make trials of new procedures
- Information, knowledge and data from HPT TCP is used and implemented by key actors important for the energy transition
- New ideas and proposals for Annexes (international collaboration projects), according to the SWP and MTE, which clearly contributes to accelerated deployment of the technology
- Enforcement of the conference as a meeting place for different actors (market, research, industry, policy, investors).

Throughout 2022, a considerable part of the HPT TCP's work, especially that of the Heat Pump Centre and the conference committees, will be aimed at preparing for the 14th IEA Heat Pump Conference. The conference will take place in Chicago, USA, in May 2023.

Based on the conclusions from the midterm evaluation (MTE) of the strategic work plan (SWP), the TCP will continue initiating and performing RDD&D within all the prioritized areas (see page 12). The aim will be to continue to have RDD&D activities along large parts of the TRL scale. More focus should be placed in the higher range to stimulate the large-scale roll-out of heat pumps. This includes research and development related to what is needed to accelerate the roll-out, not only for single-family houses and other building types, but so industry at large can improve affordability in multiple solutions and best integrate the heat pumping technology in an energy system in transition. Moreover, it includes demonstration and deployment related activities. At the same time, many of the technical innovations needed to reach the climate targets do not yet exist, according to IEA. Therefore, research projects at low TRL levels are important to have in the portfolio as well.

At the end of 2021, Annex 59 "Heat Pumps for Drying" (Strategy area 2e), was approved to be started, and the activities will start in early 2022. The overall objective of the Annex is to evaluate potentials on energy savings in drying processes in several applications, industrial as well as in household applications, that can be unlocked with the use of heat pumps.

In addition, Annex 60 "Retrofit Heat Pump Systems in Larger non-Domestic" Buildings" (Strategy area 2a) was approved to be stated. In this case, the work will start in early 2022 as well. The objective of this project is to develop evidence of the practical feasibility and satisfactory operation of a range of installed retrofit systems in large non-domestic buildings in a number of countries, together with insights into the thinking that led to the choice of system. In addition, simple to use, accessible advice to support the initial selection of system options for specific circumstances will be developed. These will be signposted to evidence and summaries of the relative strengths of each option.

The scope, objectives and content of the Annex proposal "Heat Pumps in Positive Energy Districts" (Strategy area 2a,b,c) was approved at the end of 2021, and the Annex will start as soon at least two countries have confirmed participation in the Annex. The development of the Annex idea "Comfort and Climate Box Solutions for Warm and Humid Climates" (Strategy area 2b) will continue during the year, taking the output of the recently finalized Annex 55 "Comfort and Climate Box", with more emphasis on heating applications, (see page 35-36) into consideration. Moreover, a follow-up annex to Annex 50, "Heat Pumps in Multifamily Buildings", (see page 23-24), with a focus on applications for cities, is also during preparation as well as on a follow-up project on Annex 51 "Acoustic signatures for heat pumps", (see page 25-27).

In 2021, two National Experts meetings were arranged (one physical and one online), where the main purpose was to develop new ideas and proposals for future Annexes within the HPT TCP. The outcome from the midterm evaluation (MTE) of the strategic work plan SWP) formed the basis for the meeting. The outcome from the meeting was several annex ideas within the following areas, which will be further developed during 2022:

- Sector Coupling
- Solutions where both the cold and the warm sides of the thermodynamic cycle are used
- Alternative and new business models
- Digitalization for heat pumping technologies
- Heat pump and circular economy
- Safety measures on flammable refrigerants

In 2022 we will continue the work started in 2021 to explore in the field of investors' role in accelerating the energy transition. The most important types of investors for stimulating accelerated deployment of heat pumping technologies will be identified, alongside with information about what would create awareness among them, which type of facts they would need to take investment decisions and in which channels and networks we could reach them. This will form valuable input to the revised strategic work plan (SWP) for 2023-2028, which will be elaborated during 2022.

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