Technology Collaboration Programme
by iea

ANNUAL REPORT 2020

HEAT PUMPING TECHNOLOGIES

Technology Collaboration Programme on Heat Pumping Technologies - HPT TCP

Technology Collaboration Programme on Heat Pumping Technologies

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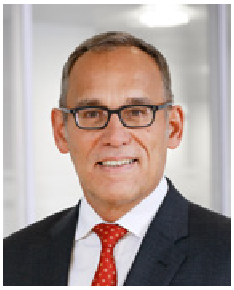
Content

Message from the Chairman



The future challenges of decarbonizing the energy system can only be solved together. This is what the International Energy Agency (IEA) stands for, and we as the Technology Collaboration Programme on Heat Pumping Technologies (HPT) are a part of it.

Our strategic plan for the period 2018–2023 is based on the analyses and forecasts of future political, economic and technological developments that we conducted at the end of 2016. An important driver behind our assumption of the growing importance of heat pumps was the climate conference in Paris in December 2015 (COP21). Today, we can see that the call to decarbonize the energy system has been adopted in the strategic goals and action plans of many countries. Many of them want to reduce greenhouse gas emissions to net zero by 2050. The IEA has also clearly focused on shaping a secure and sustainable energy future. It has announced that it will produce the world's first comprehensive roadmap for the energy sector to reach net-zero emissions by 2050. According to the IEA's analyses, heat pumps, as a highly efficient and renewable energy technology, must make a substantial contribution to this goal. This is true for heating demand but also for the sharply increasing demand for cooling.

We have therefore decided to review our strategy. We are basically well on track and are making relevant contributions to all strategic focus areas. However, we need to place more emphasis on stimulating deployment of heat pumps and, in the case of air-conditioning, affordability of energy efficient equipment. It is also important that heat pumps are perceived as part of the energy system, for example for sector coupling. Communication with stakeholders at all levels is vital.

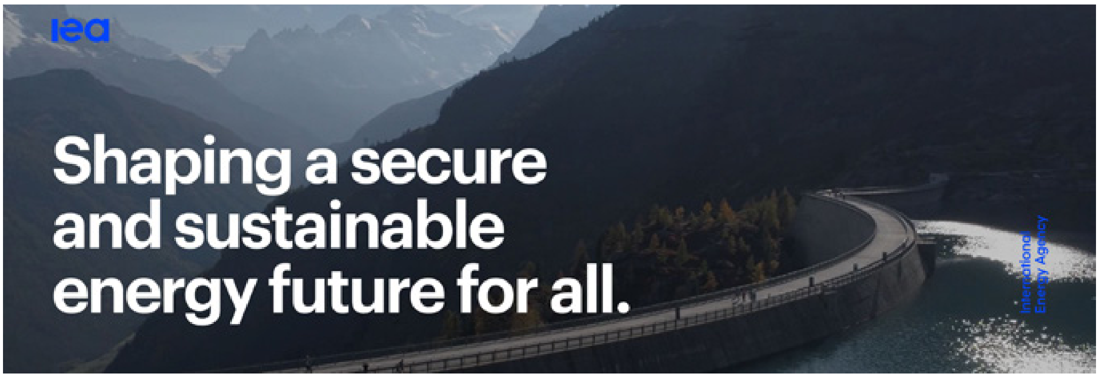
It is therefore gratifying that we have been able to further intensify our cooperation with the IEA and its analysts. We were thus able to make a substantial contribution to Energy Technology Perspective 2020. The article presented on page 6-9 is another outcome. Our network with the experts from our member countries, who are involved in the annexes, shows major potential for knowledge exchange. We need to further develop this network and involve the experts more in the collaboration with IEA analysts. This will bring the advantage of incorporating knowledge in the internationally recognized trend-setting analyses and publications and will generate impact up to the political level.

International cooperation also thrives on the person-to-person exchanges of the participants. Face-to-face meetings were not possible in 2020. We held our meetings online, as did many others. This worked and we also recognized advantages. What was missing, however, was the personal exchange that normally takes place even beyond the meeting room. For the future, face-to-face meetings must be possible again. Virtual meetings can be used to supplement the exchange of information on current topics at short notice. The webinars conducted by some annex teams were useful. It was possible to quickly reach a large number of interested parties worldwide and to disseminate the findings. The pandemic had a substantial impact on the organization of the triennial Heat Pump Conference. It ultimately had to be postponed until 2021 and will be held as a hybrid event on-site in South Korea and online. I would like to express my sincere thanks for the great additional commitment of all those involved.

Running a Technology Collaboration Programme is only possible thanks to highly motivated and experienced individuals. I therefore thank the ExCo delegates, the operating agents and their experts in the annexes, and the staff of the Heat Pump Centre and 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

International Energy Agency



About the International Energy Agency (IEA)
The IEA is at the heart of global dialogue on energy, providing authoritative analysis, data, policy recommendations, and real-world solutions to help countries provide secure and sustainable energy for all.

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

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

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

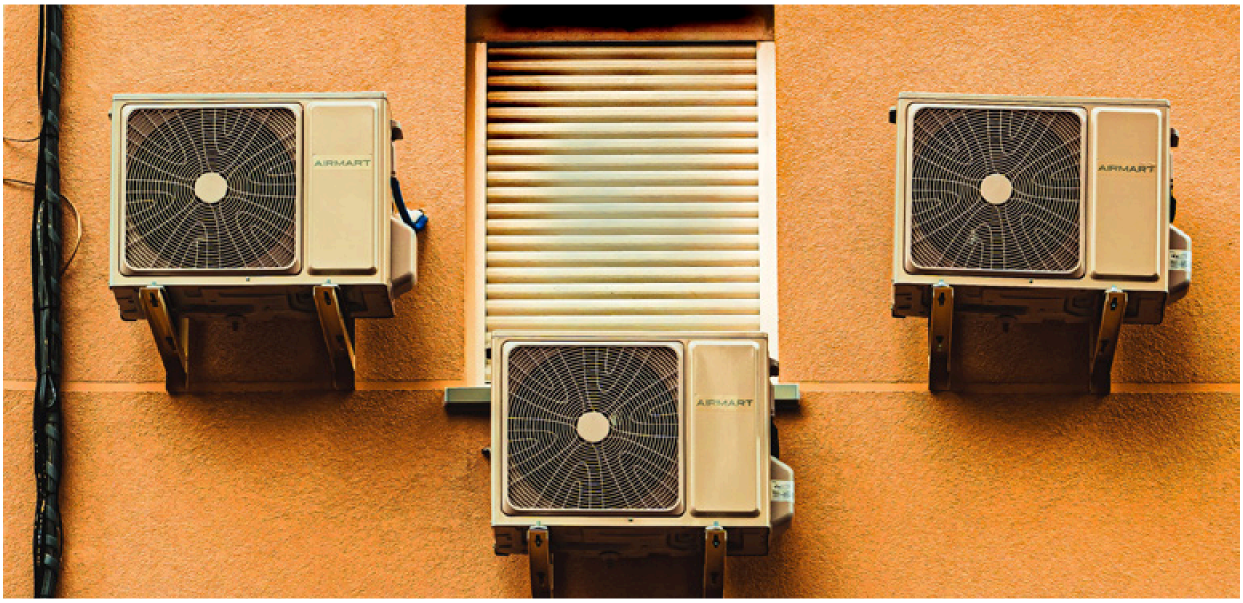
The IEA global innovation network

- 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 a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of thousands of experts across government, academia and industry in 55 countries dedicated to advancing common research and the application of specific energy technologies.

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

Is cooling the future of heating?



This commentary from IEA, starts with pointing out that high-efficiency heat pump technology is the cornerstone of sustainable buildings. Heating and cooling systems, the two main end-uses in building operations, are particularly critical areas to address to curb buildings emissions.

Heating is currently responsible for around 45% of building emissions, and still relying on fossil fuels for supplying more than 55% of its final energy consumption. Building floor area is expected to double by 2070. At the same time, space cooling will expand more rapidly than any other building end-use, with access provided to an additional 5 billion people by 2070 - a cold crunch is looming behind the buildings heat decarbonisation challenge.

Meeting buildings sector space cooling needs only required 15% of the energy used for heating in 2019 and generated about 1 Gt CO_2 from the use of electricity. Yet, space cooling is the fastest-growing building end-use and is expected to remain so over the coming decades, according to this commentary. On the basis of stated policy intentions, cooling demand is growing at more than 3% a year for the next three decades, 8-times faster than demand for heating in the last 30 years.
It is also stated that there are multiple drivers for space cooling demand growth. First, there are stark differences in air-conditioner ownership today across household income ranges. For example, ownership levels in high-income urban households in India range from 75%-85%, compared to the 5% or lower for low-income rural households. Air-conditioner ownership exceeds 90% in the United States and Australia, while it remains under 10% in India, Indonesia and close to 20% Brazil, despite the number of cooling-degree-days - a metric used to assess needs for cooling services – being about twice as high in those countries. Of the 35% of the global population that live in areas where it is hot every single day, only around 15% own an air conditioner. As a result of improving living standards, climate change and policies to broaden access to essential energy services, this share is projected to jump to 60% by 2050 and 70% by 2070. Another major factor in cooling demand growth is a significant expansion in buildings floor area, which is expected to double by 2070. More than 70% of that growth will occur in places with high space cooling demand, driven by a growing population in developing regions. Overall, the global stock of air conditioners could increase to 7 billion units by 2070, the equivalent of selling almost 10 air conditioners every second from now to 2070. Average temperature rise also contribute to increasing cooling service demand. The average global temperature on land and ocean surfaces has risen every decade by 0.15°C on average since 1980. Despite the growing momentum to raise efficiencies of air conditioners, stated policies will not be able to curb electricity use for cooling, which is set to grow threefold by 2070 relative to 2019, or more than twice the level reached in the Sustainable Development Scenario.

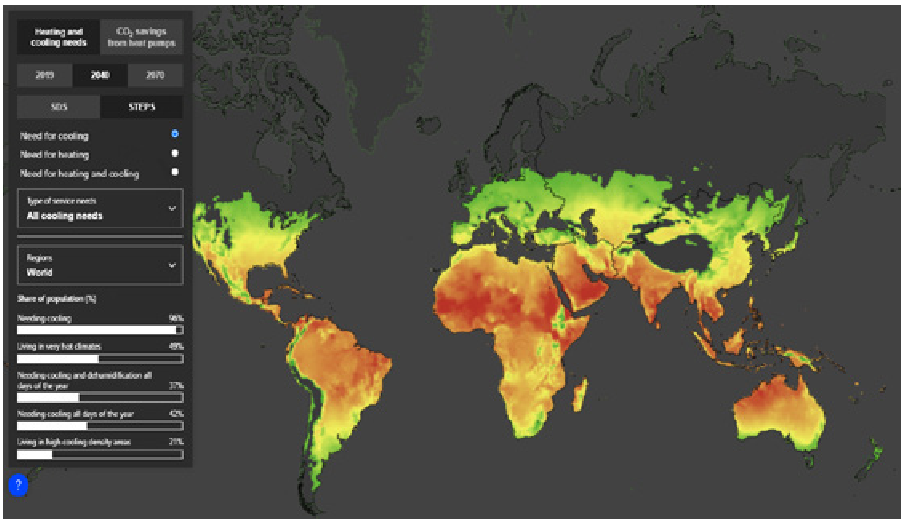
It is pointed out that low-carbon heating and cooling in buildings need a common strategy. Decarbonising the buildings sector will benefit from prioritizing solutions focused on heating, cooling or both heating and cooling. Heat pumping technologies are an important technology solution as they can be deployed in a broad range of climates, and tailored to provide both heating and cooling, cooling only or heating only. In fact, a third of the global population requires heat pumps for both heating and cooling. In year-round hot and humid climates, advanced cooling technologies are needed to meet the challenge of rapid growth in air-conditioning demand. In both cases, accelerating deployment of high-efficiency products and continued innovation will be essential to meet decarbonisation goals. Within the heating market, already today, heat pumps are effective for decarbonisation and could provide more than 90% of heating needs globally, emitting less CO_2 than the most efficient fossil-fuel alternative, according to this publication. In major heating markets such as the European Union, the United States, Canada, Russia or China, the high seasonal performance factor of heat pumps (ranging from 300% to 400% or more depending on the region) is enough to halve CO_2 emissions related to the electricity consumed under what gas combustion in an efficient condensing boiler would emit. They already make up for more than 40% of heating equipment sales in the United States for the new builds market.

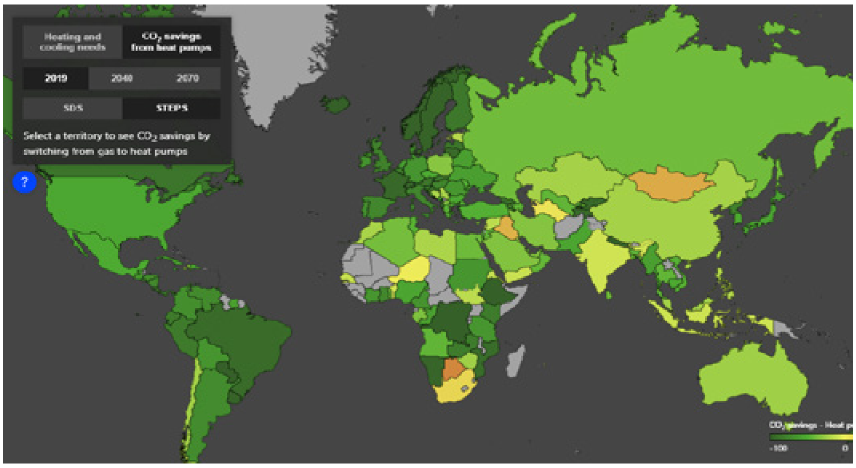
However, despite their growing penetration within the heating market, the overwhelming majority of heat pumps sold today are used for space cooling. Total cooling equipment capacity is 17 times the one for heating. While the most efficient heat pumps used for space cooling (e.g. air conditioners) could reach an energy performance rating of up to 12, the average energy efficiency rating of the products available on the market is close to 4. To be aligned with the objectives of the Sustainable Development Scenario, the average performance of air conditioners needs to increase by more than 50% by 2030 and almost double by 2070. Without such efficiency improvements, under stated policies, electricity demand for cooling could nearly triple by 2070. The authors recommend to exploit synergies across heating and cooling strategies to lower the cost, since this can accelerate the deployment of more efficient reversible heat pumps, help to phase out fossil fuel equipment and therefore support buildings sector decarbonisation objectives. In particular, heat pump sales for heating need to triple by 2030 and become the leading technology in the long-term. They reach more than 50% of heating equipment stock by 2050 for both residential and commercial applications in the Sustainable Development Scenario.

An estimated 33% of households worldwide have both space heating and cooling needs, and in some regions the share is much higher. In these regions, it is particularly important that technology progress in reversible heat pump units is steered towards simultaneously achieving decarbonisation objectives associated with both heating and cooling provision for buildings. Many applications can take advantage of synergies between heating and cooling.

An interactive map on heating and cooling needs.

See more at iea website:
www. iea.org





An interactive map showing CO_2 savings by switching from condensing gas boilers to heat pumps by country.

See more at iea website:
www. iea.org

To exploit this opportunity, governments and industries could focus on:

- Stimulating market uptake with the provision of new services (e.g. cooling) in favour of heat pumps for new builds and renovations.
- Exploiting simultaneous heating and cooling generation in vapour compression cycles. (This is the topic of HPT Annex 54, page 34.)
- Reaping technology spillovers. Technology learning could be transferred across various types of heat pumps and air conditioners because they share multiple components and thermodynamic principles. Synergetic technology areas include the use of next-generation components such as electrochemical compressors or more compact heat exchangers.

A number of heat pump technology designs are ready for deployment. However, the diversity of building types, end-use service demand patterns and climate conditions require further enhancement for them to adapt to a variety of working environments. Therefore, innovation is a must to further accelerate heat pump deployment.

In particular, additional innovation in vapour-compression equipment to penetrate the heating market are needed to:

- Tailor heat pump designs to specific market segments or operating conditions.
- Enhance heat pump integration to other parts of the energy system, such as electricity grids, renewable assets (off-site or on site such as solar PV), storage, micro-grids, etc.
- Improve heat pumping technology designs and control systems to adapt to end-user demand patterns, such as part load.

(The topics above are investigated in several HPT Annexes, e.g. Annex 49, 50, 52 and 55, see pages 24-36.) In addition to innovations in vapour compression technologies, there is a significant market opportunity to develop affordable alternative or hybrid cooling solutions, especially for hot climate developing countries with no need for heating. (This is for example investigated in HPT Annex 53, page 32).

- Hybrid membrane-based solutions (TRL 3-5) would open up the possibility of controlling both humidity and temperature by decoupling latent and sensible heat loads.
- In addition, solid-state cooling technologies exploiting caloric effects of specific materials are today a prototype of what could be a new approach to refrigeration.

The benefits of non-vapour-compression cooling technologies also include the accelerated phase out of high-global warming potential refrigerants such as hydro-chlorofluorocarbons (HCFCs). (This is the topic of HPT Annex 54, page 34.) To date, more than 195 countries have committed to reducing their use by 80% by 2050 as part of the Kigali amendment to the Montreal Protocol. The article is concluded by stating that governments hold the key to low-carbon heating and cooling.

Government stimulus packages represent an opportunity to increase the adoption of more efficient equipment. The European Commission introduced "Next Generation EU", a recovery instrument supporting the EU strategy for the Clean Energy Transition. In particular, the package will support energy efficiency, the use of local resources and direct electrification, which is expected to lead to increased adoption of heat pumps and other renewable heating solutions for new builds and renovations.

The rapid advancement and innovation in heat pumping technologies holds the promise of providing cost-effective, energy-efficient heating and cooling services to meet the challenges of decarbonisation in the building sector. However, key measures for implementation may only prove successful if a wide array of countries and stakeholders act together, and collaboratively, on the aforementioned critical research areas.

This is a summary, made by Heat Pump Centre, of the Commentary "Is cooling the future of heating?" written by the IEA analysts **Thibaut Abergel** (the desk officer of HPT TCP at the IEA secretariat) and **Chiara Delmastro**, published in December 2020 at iea.org. The commentary is one of the outcomes of an intensified cooperation between the IEA secretariat and the HPT TCP during 2020 and several of the HPT Annexes are referred to in the commentary.

Read the whole Commentary text at iea.org >

Actions to support heat pumping technologies

	Near-term measures	**Innovation needs**
Deploy	Incentives for low-carbon heating technologies (examples include China's Control Action Plan for air-source heat pumps, Japan's Energy Conservation Plan, the United States' ground-source heat pump support scheme)	Optimal balance between investment and CO_2 savings. Promoting testing for application of innovative heat pump designs specific to critical market segments (e.g. for building renovation), given building types (e.g. multi-family buildings) and climate zones (e.g. cold, hot and humid)
	Performance-based labels (e.g. in the European Union).	International collaboration to catalyse cost reductions from technology spillovers
	Remove fossil fuel subsidies	
Integrate	Ensure a reliable and non-intrusive use of end-user data along with the deployment of metering infrastructure.	Support to the development of integrated heating, cooling and storage solutions, as well as with on-site renewable production
	Exploit district energy infrastructures to recover waste heat, integrate renewable power-to-heat and other low-carbon resource.	Regulatory changes to reward innovative business models and market designs that integrate flexibility services to the power systems
	Plan new low-temperature networks, exploiting large scale heat pumps and/or heat pump boosters when waste heat resources are in excess	Demonstration of heat pump integration through sector coupling

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

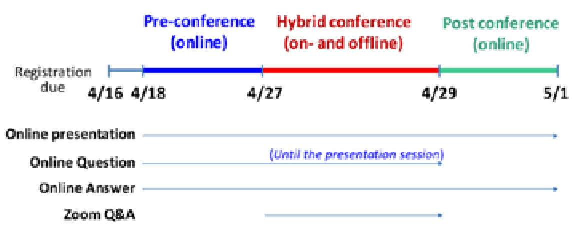
The 13th IEA Heat Pump Conference will take place on April 26-29, 2021, a year later than originally scheduled. Due to the corona virus outbreak, the conference is held as online-on-site hybrid.

The on-site conference is held at Ramada Plaza Hotel Jeju in Korea, and the online conference is held along with offline for those who cannot attend the conference physically. The upcoming conference will be the 13th of the series of conferences held by the International Energy Agency (IEA) Heat Pumping Technologies TCP (HPT TCP). It is the fourth Heat Pump Conference to be held in Asia, and the first to be held in the Republic of Korea.

Heat pumping technologies, as a reliable and confirmed technology, is the key equipment for energy savings and green-house gas reductions with its wide range of application to various energy sources. With the theme 'Heat Pumps – Mission for the Green World', we aim to address global climate change and discuss necessary actions. Since heat pumps have been renowned an efficient tool for combating climate change, many countries are acting to replace the conventional fossil-based heating facilities with heat pump systems. And in line with the trend of electrification, we are confident that such a transition will be accelerated for the 'Greener World'. The 13th IEA Heat Pump Conference will serve as a forum to discuss the latest developments in heat pumping technologies, and exchange valuable knowledge in market, policy, and standards information on related technologies. Exhibitions will be held at the conference, to share products and technologies from domestic and foreign companies.

Hybrid conference organization – How it works

For the online participants, online conference platform will be provided. The conference program will be a generous online platform, which will give attendees the possibility to take part of the presentations over an ex-



tended amount of time. Register in advance and you will have the opportunity to take part of all the highlights of the 13th IEA Heat Pump Conference between the 18th of April until the 1st of May – on-demand when it suites you.

The Conference will be organized to offer as much value as possible to "offline" (on-site) as well as online attendees. The presentations will be pre-recorded, broadcasted online and shown at the conference venue in accordance with the conference program. However, in order to make it possible for the conference attendees to select and take part in as many presentations as possible, it is recommended to watch the pre-recorded presentations on-demand before the conference start. The whole online conference plan in accordance with the scheme is shown in below.

When it comes to questions & answers, there will be two separate schemes for the attendees as well as for the authors. It will be possible for the conference attendees to pose their questions online during the whole pre-conference as well during the conference period. The author is responsible for answering the questions until 1st of May at the latest. During the offline program slot for the presentation, the authors will be encouraged to attend online via Zoom, or physically at the venue, to be able to answer questions from the audience live.

Conference program

During the first day of the conference the plenary session is scheduled, beginning with the conference opening speeches. During the plenary session, six invited speakers from three continents will give their vision on heat pump industry. The first three influential speakers will introduce global heat pump markets and policy.

» Mechthild Worsdorfer, IEA Director of Sustainability, Technology and Outlooks
» Martin Forsén, President of EHPA (European Heat Pump Association)
» Min Soo Kim, President of SAREK (Society of Air-conditioning and Refrigerating Engineers of Korea)

This is followed by three eminent speakers providing excellent summaries on key technologies of heat pump systems.

» Saikee Oh, Vice President of LG Electronics, Korea
» Xudong Wang, Vice President of AHRI (The Air-Conditioning, Heating, and Refrigeration Institute), USA
» Noboru Kagawa, Professor of National Defense Academy, Japan

After the plenary opening session, the conference will continue for three days in three parallel tracks of presentation.

Papers

The call for papers has successfully generated more than 206 high quality papers. To guarantee a high level quality, the papers are evaluated, screened and reviewed by the Scientific Committee. The presentations will be given as oral or poster presentations. In the technical sessions, participants will encounter numerous cutting-edge presentations.

The authors of the full papers that have passed the review process were asked to confirm participation. And the total 206 papers of 237 were confirmed and accepted for the conference program. Currently, the preliminary program is ready with 180 oral presentations and 26 poster presentations.

Conference venue - Ramada Plaza Hotel Jeju

Ramada Plaza Hotel Jeju is 5 star hotel located near the beautiful ocean at the center of Jeju city. The hotel is located just five minutes away from Jeju International Airport and Jeju Port. The Jeju Island is a famous holiday destination in Southeast Asia, with beautiful beaches, volcanic mountains, and extra-ordinary cuisine. Home to the natural World Heritage Site, Jeju Volcanic Island and Lava Tubes, participants and those accompanying will certainly enjoy visiting the beautiful island. In addition to sightseeing opportunities, a variety of technical tours are planned.

The conference program can be found on the website of the conference *www.hpc2020.org* or via *www.heatpumpingtechnologies.org.*

The 13th International Energy Agency
HEAT PUMP CONFERENCE
KAL HOTEL JEJU, KOREA | APRIL 26-29, 2021

Technology Collaboration Programme on Heat Pumping Technologies


Organised under the umbrella of the International Energy Agency since 1978, the Technology Collaboration Programme on Heat Pumping Technologies (HPT TCP) is a non-profit organisation funded by its member countries. The scope of the Programme covers heat pumps, air conditioning and refrigeration, commonly denoted as heat pumping technologies. We continuously observe the development and requirements of our energy system and revise our strategy every five years, according to the objectives of the IEA.

Strategic Work Plan 2018 - 2023

Vision of HPT TCP*

Heat pumping technologies play a vital role in achieving the ambitions for a secure, affordable, high-efficiency and low-carbon energy system for heating, cooling and refrigeration across multiple applications and contexts.

The Programme is a key worldwide player in this process by communicating and generating independent information, expertise and knowledge related to this technology as well as enhancing international collaboration.

Mission of HPT TCP

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

Strategic Objectives

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

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

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

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

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

Strategy

1. Advance the RDD&D* of heat pumping technologies through creation of research opportunities, networking possibilities and meeting places for academia, industry, private sector markets and policy makers to collaborate under new Annexes (projects) and activities within the HPT TCP.

2. Perform RDD&D activities within the areas of heating, cooling and refrigeration for the building, community, transport and industrial sectors while widening the scope to include to a larger extent:

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

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

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

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

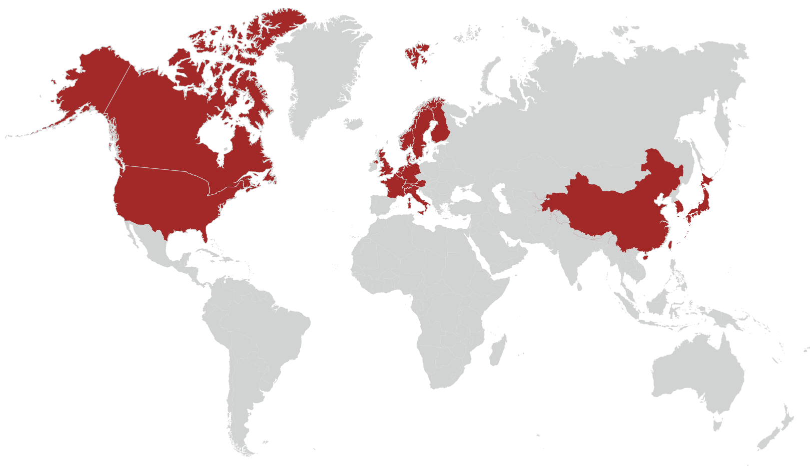
6. Increase activities to attract new members, including IEA key partner and association countries.

Activities

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

HPT TCP MEMBER COUNTRIES

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



* Research, Development, Demonstration and Deployment

Organization of the HPT TCP

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

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

National Teams (NTs) are important for promotion of the HPT TCP at the national level. The National Teams are experts on their countries' needs regarding industry, markets, deployment, research and development activities. It is a forum for discussion, networking and creation of new ideas. Thus, an interactive process where the National Team shares information with the ExCo delegates, the Heat Pump Centre, and other National Teams is highly important. **Annexes** are the cooperative projects within the HPT, and are a central activity of the HPT TCP. Within these, new knowledge is elaborated through collaborative RDD&D work. They are conducted on a combination of cost sharing and task-sharing basis by the participating countries. They are often conceived at the joint National Experts' meetings.

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

This is the HPC Staff :

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

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

Christina D-Nordström, Coordinator/Administrator
Christina is an experienced administrator, who is used to handling large and complicated projects. She is the person to contact for general issues regarding the HPT TCP and HPC.
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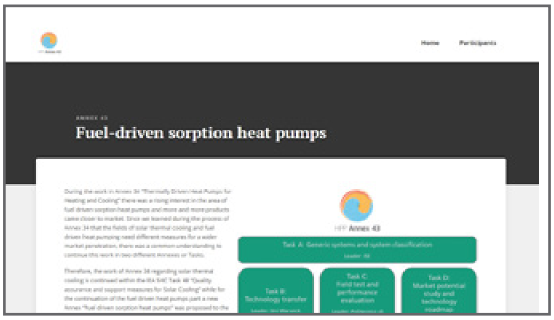
Ulrica Örnemar, Communication
Ulrica's communication skills cover the esthetics of producing all kinds of publications, as well as how to catch the readers' eyes on social media.
Has been replaced by Johanna Gisslén (*johanna.gisslen@ri.se*) in 2021

Johan Berg, Magazine, Annual report, statistics, Member country report
Johan enjoys streamlining texts received from authors within or outside the TCP, for HPT publications.
Has been replaced by Sara Skärhem (*sara.skarhem@ri.se*) in 2021.

Kerstin Rubenson, Communication
With a background as a scientific journalist, Kerstin is the ideal writer of condensed appealing texts for publications.
kerstin.rubenson@ri.se

Highlights 2020



Several finalized annexes
During 2020 work was finalized in the following four international collaboration projects, called annexes:

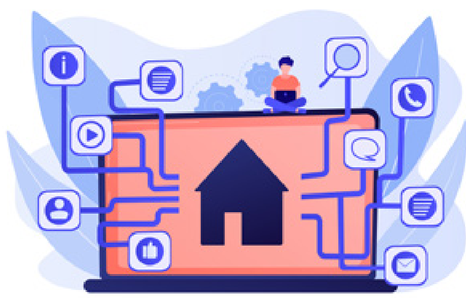
- » Fuel-driven Sorption Heat Pumps (Annex 43)
- » Domestic Hot Water Heat Pumps (Annex 46)
- » Industrial Heat Pumps, Second Phase (Annex 48)
- » Design and integration of heat pumps for nZEB (Annex 49)

The results from Annex 43 show that fuel-driven sorption heat pumps are a competitive option in, for example, multi-family homes with higher heating supply temperatures.

The share of domestic hot water (DHW) production in the total heat consumption of buildings is increasing with the deployment of new low-energy buildings as well as “deep” renovation of existing buildings. Thus, DHW production is becoming a more important factor in building heating systems. Results from Annex 46 show that DHW heat pumps can offer substantial energy and CO_2 emission savings, but focused governmental support will be needed for the market for this type of heat pump to develop to its full potential.

The results from Annex 48 show that major CO_2 emission reductions in the industry sector can be obtained by application of industrial heat pumps (IHPs). IHPs are ideal in many processes which will be electrified in the future, for example drying or distillation.This is a mature technology – well integrated, IHPs are highly reliable and enhance process efficiency. The IHP is a key technology in almost all industrial sectors for gaining energy savings and mitigating greenhouse gas emissions.

Outcomes from simulations and field measurements performed within Annex 49 proved 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. Furthermore, heat pumps can increase on-site electricity self-consumption and unlock flexibility potentials through smart controls. In this way heat pumps become the backbone of a future sustainable and renewable built environment and energy system.



New annexes
In the beginning of the year, work actively began in a new annex, Annex 56, “Internet of Things for Heat Pumps”. In addition, several countries confirmed participation in the newly launched Annex 57 “Flexibility by implementation of heat pumps in multi-vector energy systems and thermal grids” and in Annex 58 "High Temperature Heat Pumps". The work will start in early 2021.

New relations with stakeholders from India

During 2020 relations between HPT TCP and stakeholders from India, governmental as well as non-governmental, were established and strengthened, and HPC performed activities to increase awareness of the technology and the HPT TCP in India. A round table discussion on the theme "Implementing India's cooling action plan: Partnerships for low-GWP refrigerants and low-energy technologies" was arranged in conjunction with the ACREX fair. Thereafter, representatives from India were invited to and participated both in the fall ExCo meeting and a workshop to outline a new annex addressing "Comfort and Climate Box Solutions for Warm and Humid Climates".

Contributions to IEA publications

During the year the HPT TCP contributed to several IEA publications, with data as well as review of draft reports, such as the Energy Technology Perspectives report, ETP2020, the Tracking of Clean Energy Progress (TCEP) websites 2020 for heating and heat pumps, IEA's Renewable Energy Markets report 2020, and their analysis and forecast for Renewables 2020. From their analyses, IEA concluded that high-efficiency heat pump technology and efficient air-conditioning technology must become the norm in sustainable buildings. They also published an article titled "Is cooling the future of heating?"
[See page 6]

Midterm evaluation of HPT TCP Strategic Work Plan 2018-2023

Since the HPT TCP is halfway in its strategy period and yet the world around us is changing rapidly in many respects, the TCP performed a midterm evaluation in 2020 to identify the main focus and whether any necessary changes were needed. The evaluation mainly concluded that the HPT TCP should continue to conduct RDD&D activities along much of the TRL scale. More focus should be placed in the higher range in order to stimulate a large-scale roll-out of heat pumps. Still, many of the innovations needed to reach the climate targets do not yet exist, according to IEA. Therefore, projects at low TRL levels are important to have in the portfolio. Another conclusion is that investors have become a much more important stakeholder for clean energy solutions like heat pumping technologies.

One of many digital HPT TCP meetings held during 2020.

Activities and achievements

Executive meetings

The year 2020 was heavily impacted by the Covid-19 pandemic in many different ways – both in the private and the professional realm. As a consequence, the activities planned within the HPT TCP needed to be greatly modified. The original plan had been to organize the spring ExCo meeting in conjunction with the 13th IEA Heat Pump Conference at Jeju Island in May. But since the conference was postponed (see page 10) and travel restricted for most people around the world, the HPT TCP spring ExCo meeting was successfully organized as on online meeting, on May 12-13. Since the situation had not considerably improved during the fall, the fall ExCo meeting also took place online, on November 3-5. Since the fall ExCo meeting had originally been planned to take place in Rome, several Italian guests were invited to the first day of the ExCo meeting. The Italian delegate gave an extensive presentation about ongoing RDD&D activities in Italy within the field of heat pumping technologies. In addition, representatives from the Indian Ministry were invited to the meeting and described Indian policies and research related to sustainable heating and cooling.

Digital workshops and webinars

To partly compensate for the postponed 13th IEA Heat Pump Conference, several online meetings were arranged by the TCP during the fall. Some of them were internal meetings, such as workshops for ExCo delegates and dialogue meetings for operating agents (project leaders of international collaboration projects) and information meetings for new delegates. Others were also open to external participants, for example a webinar for presenting the final results from Annex 51, Acoustic Signatures of Heat Pumps, a digital workshop discussing the content of a future annex within the TCP, "Comfort and Climate Box Solutions for Warm and Humid Climates", and another discussing the role of heat pumps and hydrogen in the future building energy sector. Online meetings proved to be an efficient meeting form that could nicely complement in-person meetings even in a future without travel restrictions.

[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 or any area required particular focus during its second term. One of the activities was to review and analyse relevant IEA reports and policy documents which are related to heat pumping technologies in different regions of the world.

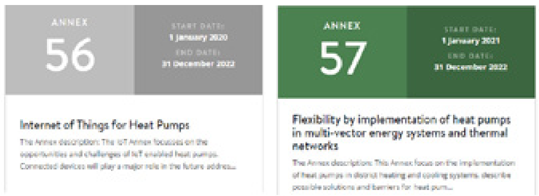
For many decades, the HPT TCP as well as industry and business organizations have been fighting for recognition of the technology within the IEA and among policy makers around the world. Now, in 2020, we can conclude that we have succeeded in many ways. The technology is well recognized by IEA as a cornerstone for decarbonization of the 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.

Therefore, focus should be put on activities to stimulate mass deployment of the technology within the upcoming decade. This includes research and development related to what is needed to reach the tipping point for large-scale 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 heat pumping technology in an energy system in transition. As a complement to the activities around high TRL levels above, the ETP points out that all innovations needed to obtain the 2070 climate targets do not yet exist. Therefore, research on low TRL levels are also crucial.

In addition, channelling private investments to complement public funding for the transition to a climate-neutral economy would accelerate the energy transition, the innovation rate and the deployment of heat pumping technologies. Because sustainability has become an important consideration for many investors, they are a key stakeholder in the deployment of sustainable solutions like heat pumping technologies. Another topic which has garnered much attention from the IEA in recent years is the expected increase in cooling demand in many parts of the world, primarily in rapidly developing countries that have warm and humid climates. More energy-efficient cooling equipment is needed to dampen the projected increase in energy demand for this service. During the midterm evaluation process, the delegates of the executive committee were able to discuss and rate the importance of the different objectives, the defined areas for RDD&D, and the strategy points during a digital workshop. They assessed that these objectives were still relevant and important, even though some of them should gain additional focus during the second term.
[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 2020, the following seven annexes were ongoing:

- » Heat Pumps in Multi-Family Buildings for Space Heating and DHW (Annex 50)
- » Acoustic Signature of Heat Pumps (Annex 51)
- » Long-term performance measurement of GSHP systems serving commercial, institutional and multi-family buildings (Annex 52)
- » 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)



These four annexes were completed during the year:

- » Fuel-driven Sorption Heat Pumps (Annex 43)
- » Domestic Hot Water Heat Pumps (Annex 46)
- » Industrial Heat Pumps, Second Phase (Annex 48)
- » Design and integration of heat pumps for nZEB (Annex 49)

Several countries confirmed participation in the newly launched Annex 57, “Flexibility by implementation of heat pumps in multi-vector energy systems and thermal grids”. In addition, the legal text of Annex 58, “High Temperature Heat Pumps”, was approved. Work on these two new annexes started in early 2021.
[Strategy point 2]

Generation of new potential annexes
During the two ExCo 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 42, Outlook into the future.
[Strategy point 2]

The IEA Heat Pump Conference

Unfortunately, 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 Sout Korea in May. As a first step it was postponed from May to September and in a next step it was postponed to April 2021 (see page 10). Thorough information campaigns were made, on the websites, in 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. At the same time, the work to plan the next IEA Heat Pump Conference in 2023 was initiated and it was decided to be arranged in the US.

[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 2020 on the topics "Integration of Heat Pumps into the Future Energy System", "Heat pumps for the retrofit and renovation market", and "Digitalization as an enabler for a robust, flexible and sustainable energy system". 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 subsites and new publications. The Heat Pump Centre has been active on social media, publishing news and retweets on LinkedIn and Twitter. It continuously follows the web traffic and number of readers on our communication channels, and has noted a considerable increase in both. As a result of these analyses, the centre focused on updating some Wikipedia pages and putting together information from the TCP for publication on the IEA website.

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 2020, the centre continued to publish 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

The Heat Pump Centre team and the ExCo Chairman have continuous contact with the IEA secretariat regarding various issues, and participate actively in workshops and meetings representing the TCP. In the spring, the Heat Pump Centre had a continuous dialogue with the desk officer of HPT TCP and provided IEA with comments and proposals of revised input data to the models, which was taken into consideration. In addition, the centre completed a thorough review of the first draft of the ETP2020, coordinated the review of ExCo delegates and operating agents, and provided the Energy Technology Perspectives (ETP) team at IEA with extensive comments, which were well received. Heat pumping technologies were highlighted much more in the published version of the ETP2020 compared with the draft version. The message of the final report is that heat pumps and other renewable equipment need to become the norm for heating buildings. High-efficiency heat pump technology (including heat pumps and air-conditioning) is a cornerstone for decarbonization of the building sector and can make a major impact on decarbonizing the industry sector.

The Heat Pump Centre reviewed and coordinated the review of the updated pages of the 2020 TCEP (Tracking of Clean Energy Progress) websites for heating and heat pumps and collected input from the delegates and OAs for the IEA's Renewable Energy Markets report, which was published in May. They then also reviewed the analysis and forecast for Renewables 2020 which was published during the fall. As a result of this fruitful collaboration, heat pumping technologies were also highlighted well in the IEA's World Energy Outlook and their Sustainable Recovery Plan.

Another action taken in collaboration with the IEA secretariat was a social media campaign from IEA called "Today in the Lab – Tomorrow in Energy", which took place in 2020. It aims to give visibility to RDD&D performed by the TCPs. As part of this work, the Heat Pump Centre has, in collaboration with the operating agents and IEA secretariat, created one-page summaries about some of the ongoing and recently finalized annexes published by IEA late in the fall of 2020.·

- Turning up the dial on heating and cooling innovation (Annex 55 – Comfort and Climate Box), at *https://www.iea.org/articles/turning-up-the-dial-on-heating-and-cooling-innovation*
- Heat Pumps in District Heating and Cooling systems (Annex 47), at *https://www.iea.org/articles/heat-pumps-in-district-heating-and-cooling-systems*
- Meeting the increasing global demand for cooling (Annex 53 – Advanced Cooling/ Refrigeration Technologies Develop-ment), at *https://www.iea.org/articles/meeting-the-increasing-global-demand-for-cooling*

[Strategy point 5]

International collaboration

Due to the Covid-19 pandemic, HPT TCP had to rethink the way it participated in international events and promoted itself. However, it was still very active. In February, the Heat Pump Centre co-arranged a round table discussion together with CEEW (Council for Energy, Environment and Water) and ISHRAE (Indian Society for Heating Refrigeration and Air Conditioning Engineers), on the theme "Implementing India's cooling action plan: Partnerships for low-GWP refrigerants and low-energy technologies" in conjunction with the ACREX fair in New Dehli, India. It invited representatives from the Indian government's Department of Science and Technology to deliver an opening speech at the round table. Since representatives from the Heat Pump Centre could not travel, they participated in the event online and gave a presentation about the HPT TCP to increase awareness about the potential for international collaboration offered by this TCP. Representatives from India's government then participated both in the fall ExCo meeting and a workshop to outline a new annex titled "Comfort and Climate Box Solutions for Warm and Humid Climates".

In addition to these events, other online meetings open for external participants were arranged by the HPT TCP. A well-attended webinar which presented the final results from Annex 51, "Acoustic Signatures of Heat Pumps" was held. The Heat Pump Centre arranged a digital workshop to discuss the role of heat pumps and hydrogen in the future building energy sector. Outcomes from several of the HPT TCP annexes, for example Annex 48 "Industrial Heat Pumps – Second Phase", were presented at the Chillventa Congress, an online event that took place in October 2020. In December, HPT TCP representatives participated in the EUWP (End-Use Working Party) Industry online workshop, and the Heat Pump Centre gave a presentation about the activities performed with the TCP.

[Strategy point 5]

Mission Innovation Challenge

The Heat Pump Centre is following Mission Innovation progress in #IC7, Affordable Heating and Cooling, and the overall progress of Mission Innovation with an aim to investigate valuable collaboration for HPT TCP. One joint Annex between HPT TCP and ECES TCP (Annex 55/Annex 34) is already running with an interconnection to Mission Innovation #IC7, see page 36. There are already ongoing discussions about continuing Mission Innovation after 2021.

[Strategy point 5]

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).

NEW

Finalized 2020

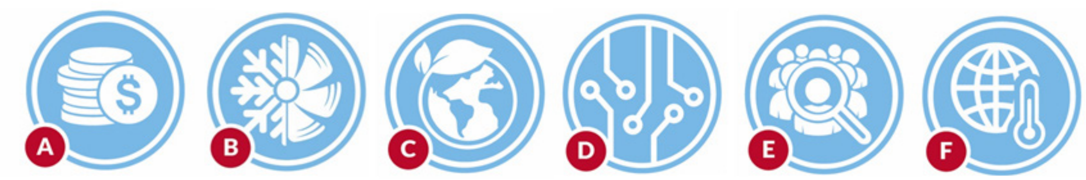
Letters A-F in right column, indicates which of the selected RDD&D areas in the strategy of HPT TCP the Annex is linked to, see page 13.

DESIGN AND INTEGRATION OF HEAT PUMPS FOR NZEB	49	AT, BE, **CH**, DE, NO, SE, UK, US	A, C
HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW	50	AT, 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

*) 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. Digitalisation and Internet of Things
E. New or special markets and applications
F. New, alternative or natural refrigerants with lower global warming potential

Selected Publications 2020

Annex 49
Wemhoener, C. (Editor)
IEA HPT Annex 49 - Design and integration of heat pumps for nZEB, Final Report IEA HPT Annex 49, IEA HPT, December 2020

Wemhoener, C., Ochs, F., Betzold, Ch., Dentel, A.
Heat pump integration for nZEB - results of IEA HPT Annex 49
13th IEA Heat Pump Conference, Jeju (KR), 26-29 April 2021

Annex 50
Calame, N. et al 2019
Air to water heat pumps for heating system retrofit in urban areas: understanding the multi-faceted challenge
Journal of Physics: Conference Series 1343, 2019

Suárez, A., Miara, M.
Nachrüsten mit Wärmepumpen.
Phase 5, 04-2020, 58-63, 2020.

Miara, M.
Wärmepumpen in Mehrfamilienhäusern, Lösungsvorschläge international (IEA HPT Annex 50).
26. Tagung des BFE-Forschungsprogramms „Wärmepumpen und Kälte“ Burgdorf (CH), 2020.

Annex 51
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 der Wahrnehmung 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 Wärmepum-pen (IEA HPT Annex 51),
26. Tagung des BFE-Forschungsprogramms «Wärmepumpen und Kälte», online BFH Burgdorf, 24.06.2020

Annex 52
Liu, H., Zhang, H., and Javed, S.
Long-Term Performance Measurement and Analysis of a Small-Scale Ground Source Heat Pump System.
Energies 2020, 13, 4527;
https://doi.org/10.3390/en13174527

Naicker, S. S. and Rees, S. J.
Long-term high frequency monitoring of a large borehole heat exchanger array.
Renewable Energy 145 (2020) 1528–1542. 2020.
https://doi.org/10.1016/j.renene.2019.07.008
Measurement data available as open access at:
http://archive.researchdata.leeds.ac.uk/272/

Annex 53
Slaughter, J., Czernuszewicz, A., Griffith, L., Vitalij, V.
Compact and efficient elastocaloric heat pumps - is there a path forward?
Journal of Applied Physics, 2020;127:194501.

Wu, W., Leung, M.
Transient and seasonal performance evaluation of a novel flexible heat pump for solar cooling.
Energy Conversion and Management 223, 2020, 113269.

Shi, J., Li, Q., Gao, T., Han, D., Li, Y., Chen, J., Qian, X.
Numerical evaluation of a kilowatt-level rotary electrocaloric refrigeration system.
International Journal of Refrigeration, 2020.

Annex 54
Wan, H., Cao, T., Hwang, Y., Chang, Y., Young-Jin, Y.,
Machine-Learning-Based Compressor Models: A Case Study for Variable Refrigerant Flow Systems,
International Journal of Refrigeration, Vol.123 (2021), 23-33.

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

Berto, A., Azzolin, M., Bortolin, S., Guzzardi, C., Del Col, *D., Measurements and modelling of R455A and R452B flow boiling heat transfer inside channels,*
International Journal of Refrigeration, Vol. 120 (2020), pp. 271-284.

Annex 56
Fleckl, T. (workshop participation)
The Internet of Things for Heat Pumps.
IEA CERT Thematic discussion on Energy Efficiency and Digitalisation, Paris (FR) 18.02.2020.

ANNEX 49

DESIGN AND INTEGRATION OF HEAT PUMPS FOR nZEB

INTRODUCTION

The EU requires all new buildings as of January 1, 2021 to be nearly-zero energy buildings (nZEB), according to the recast of its Energy Performance of Buildings Directive (EPBD). In the US and Canada as well as in Japan and China, nZEB targets are to be introduced from 2020 to 2030. Achieving the high-performance levels of nZEBs requires both the building and the system technology to be high-performing and renewable energy production to take place on-site or nearby.

Thus, nZEB building technology is a compelling solution for building designers and companies, the heating industry and other stakeholders to meet the high-performance requirements. Moreover, policy makers need performance data from actual buildings to shape the requirements.

Heat pumps have already proven successful for nZEBs due to their unique features. In high-performance buildings with low heating loads, heat pumps reach high seasonal performance factors and thus enable cost-effective nZEBs. Moreover, nZEB loads change to higher domestic hot water (DHW) shares and space cooling/dehumidification needs, and heat pumps can cover all building loads with one generator even simultaneously, e.g. for combined DHW and space cooling. Therefore, integrated heat pumps yield even higher performance in nZEBs. Furthermore, heat pumps can

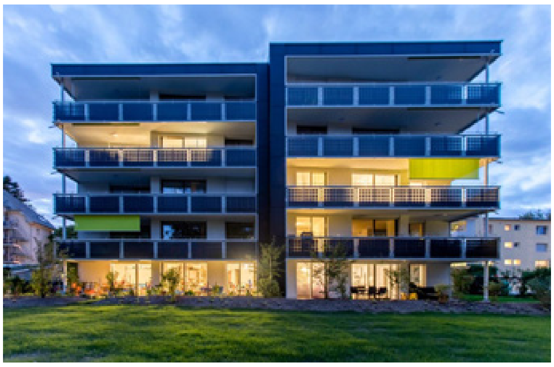


Figure 1: Five-storey multi-family plus-energy building monitored in Annex 49 (Source: arento AG)

> ***Heat pumps enable cost-effective nZEB that also unlock energy flexibility for grid support. Thus, heat pumps in nZEB are a backbone for a future renewable energy system.***

increase on-site self-consumption of the renewably generated electricity and unlock energy flexibility potentials for grid support through storage integration and smart controls.

Annex 49 has investigated the heat pump application in nZEB in more than 15 partly long-term monitored nZEBs and accompanying simulations. Figure 1 shows a five-storey energy-plus building that was monitored in Annex 49. Moreover, several compact and highly integrated prototypes also including DHW and space cooling/dehumidification functions have been developed and tested within Annex 49. A façade-integrated prototype for PV-driven space heating and cooling is depicted in Figure 3.

OBJECTIVES

- Integration options for heat pumps in connection with other building technologies like storage for multi-functional operation and energy flexibility
- Real-world performance characterization by monitoring nZEB in the participating countries, partly accompanied by simulations for optimizing building and heat pump performance
- Design and control of heat pump systems for various applications in residential and office buildings in terms of achievable performance and reduced cost
- Recommendations for integrated heat pump systems and prototype development and testing, as well as heat pump design and control in single-family and larger nZEBs

Simulation combination	Basis								
buffer expansion							x	x	x
PV-control strategy					x	x	x	x	x
battery (7 kWh or 27 kWh)			7	7		7		7	27
night temperature set back		x		x	x	x	x	x	x
total power consumption	11.227 kWh	- 2,4 %	0 %	- 2,4 %	+ 1,3%	+ 1,3%	+ 4,5%	+ 4,5%	+ 4,5%
direct use of PV-output	27 %	28 %	31 %	31 %	34 %	37 %	38 %	41 %	48 %
fraction on power consumption	34 %	36 %	37 %	39 %	42 %	45%	45 %	48 %	54 %
grid power	7.420 kWh	- 5,4%	- 4,6%	- 9,9%	- 11,2%	- 15,5%	- 13,3%	- 17,0%	- 28,0%

Figure 2: Results of storage integration and control variants concerning PV self-consumption and grid support (Source: IGS, TU Braunschweig)

RESULTS

Heat pumps reach high performance levels in nearly zero-energy building applications. More than 15 partly long-term monitoring projects in Annex 49 confirm high seasonal performance factors up to an SPF of 5.5 for all building services, enabling the achievement of the nearly zero-energy requirements cost-effectively. In turn, nZEB requirements can become a market driver for heat pumps to help even larger buildings achieve high performance.

Results from the simulation studies of heat pump and storage integration in Annex 49 based on the monitoring projects show that self-consumption of on-site renewable electricity production can be notably increased through smart controls, both with rule-based or more advanced model predictive control strategies as depicted in Figure 3. In this way, heat pumps in nZEBs can also provide energy flexibility to support electrical grids.
Highly integrated heat pump prototypes developed and tested in Annex 49 for all building services, such as space heating and cooling as well as domestic hot water, can become future standardized system solutions for nZEB applications where loads shift to higher domestic hot water and space cooling fractions.

MEETINGS

IEA HPT Annex 49 was concluded in 2020. One meeting was held in late February 2020 in Brussels to discuss the final results and presentation of results in the final reports of Annex 49.

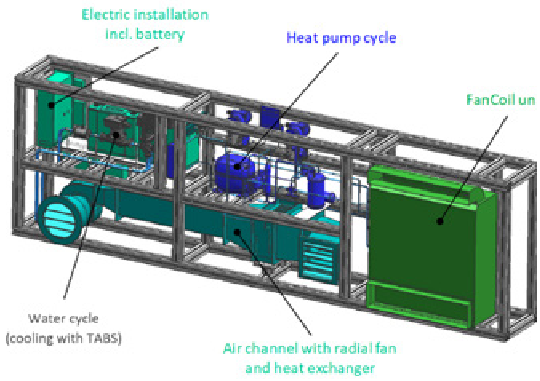


Figure 3. Façade-integrated heat pump prototype for PV-driven space heating and cooling (Source: IWT, TU Graz)

Project duration:
October 2016 – May 2020

Operating Agent:
Carsten Wemhoener, OST – Eastern Switzerland University of Applied Sciences
carsten.wemhoener@ost.ch

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

Further information:
www.heatpumpingtechnologies.org/annex49

ANNEX
50

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

INTRODUCTION

The building sector is a major energy consumer in every country and one of the top three contributors to greenhouse gase emissions. Therefore, the massive reduction of CO_2 emissions from buildings and the long-term achievement of a climate-neutral building sector go hand in hand.

Applying heat pump technologies and renewable energy is more complex for multi-family buildings (MFB) than for newly built apartments because multi-family homes involve a range of heat demand characteristics. First, the share of domestic hot water demand on the overall heat demand varies due to varying building standards and different climates. Second, the temperature level of the heating system is influenced by these aspects as well as by the installed heating transfer system. Therefore, dealing with the variety of heat demand characteristics poses a challenge to the broader adoption of heat pumps in multi-family buildings.

Annex 50 thus focuses on solutions for multi-family homes, and it attempts to identify barriers for heat pumps on these markets and propose how to overcome them. With regard to the demand of participating countries, new buildings and retrofits will be considered as well as buildings with higher specific heating demand.

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

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 MFBs with diverse energy standards for the building envelope
- Collecting and visualizing the realized projects

RESULTS

One of the main outcomes from 2020 was finalizing the overview of heat pumps solutions in multi-family buildings.

The matrix was further developed during the last year. The "solution matrix" consists of a number of "solution families" representing the general types

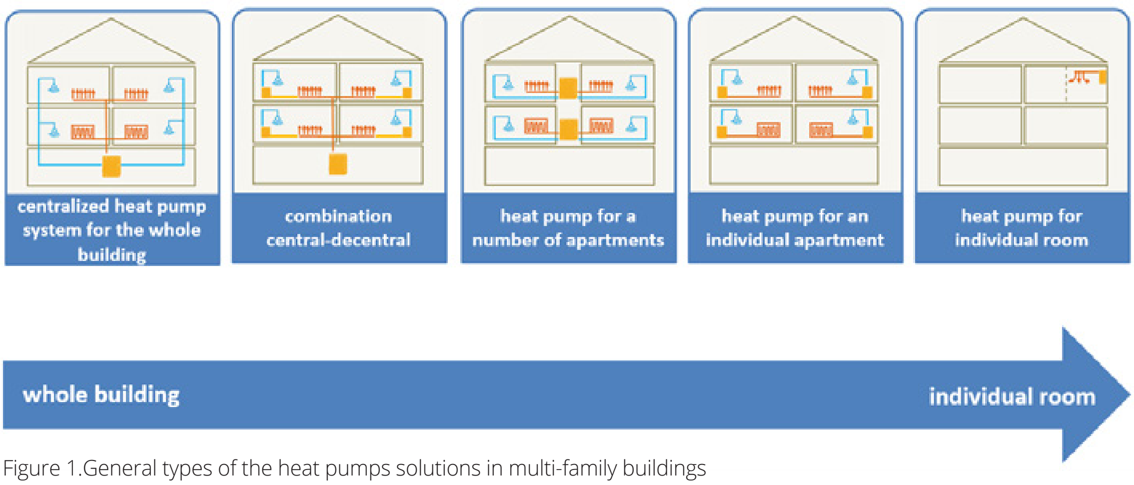


Figure 1.General types of the heat pumps solutions in multi-family buildings

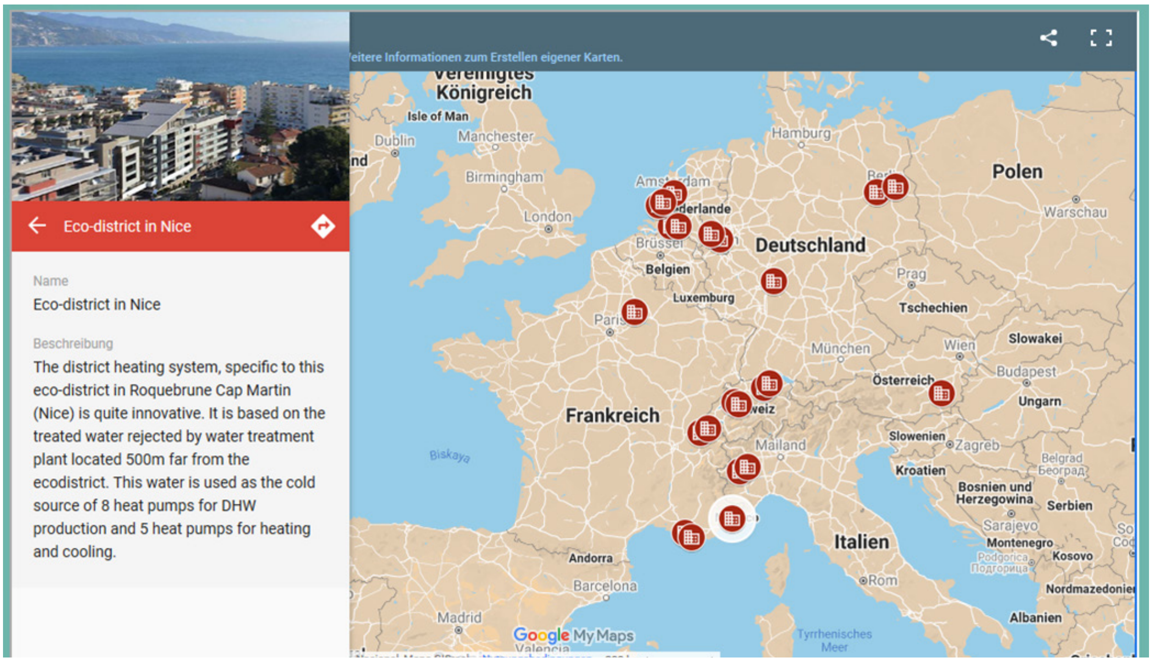


Figure 2. An interactive map with a brief description of the case studies

of solutions for heat pumps in MFBs. The single solutions are aligned starting with a heat pump for the whole building, up to a heat pump for an individual room.

Each "solution family" consists of several "family members". The members are various solutions in one logical group. Each of these single solutions will be described in detail in the further process of the annex (main advantages and disadvantages of the system, products available on the market, examples of realization, etc.). The current "solutions families" are presented in Figure 1, left.

This annex aims not only to classify and describe possible heat pump solutions in multi-family buildings, but to clearly show that heat pumps are already working in a significant number of multi-family buildings across participating countries. Therefore, a database has been created. An interactive map contains images and a brief description of the objects equipped with heat pumps, and detailed fact sheets can be downloaded. The map is regularly expanded to contain new buildings. It is also possible for anyone to submit a multi-family object with a heat pump so that it can appear on the map after an analysis using the system matrix.

The database is available at: *https://heatpumpingtechnologies.org/annex50/best-practices/*.

MEETINGS

Due to the pandemic, no face-to-face meetings took place in 2020. Instead, a series of online meetings were held which focused on all components of the "matrix tool" – from the completion of the classification of solutions, through the description of each solution, to the identification and preparation of actual case studies.

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January 2017 – June 2021

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ANNEX 51

ACOUSTIC SIGNATURES OF HEAT PUMPS

INTRODUCTION

To further increase the adoption of heat pumps, acoustic emissions must be reduced. To minimize noise annoyance, more focus must be placed on acoustics emissions at steady state and on the transient behaviour of acoustic signatures during different operating conditions. Heat pump placement is also critical, since sound emissions exhibit a pronounced directivity. Air-to-water heat pumps in particular provide a convenient and effective way to exploit potential energy savings and are often used in retrofit installations, making acoustic improvements crucial because of their noise-producing components like compressors and fans.

Psychoacoustic tests, which will provide input to the test design used in Annex 51, were carried out by RISE in Sweden and the Acoustic Research Institute of the Austrian Academy of Sciences. A joint acoustic data set is currently being analyzed using psychoacoustic hearing tests. The interesting results will be summarized in a document which will also be available for free download.
A concluding webinar guiding participants through the results of Annex 51 took place on November 30, 2020 (see Figure 1).

OBJECTIVES

- 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 meetings have been held physically (Austria Vienna, June 2017; France Lyon, January 2018; Sweden Borås, June 2018; Denmark Aarhus, January 2019; Germany Freiburg, October 2019),
  and two online (March 2020 and September 2020).
- Workshop on 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 (image below)
- 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

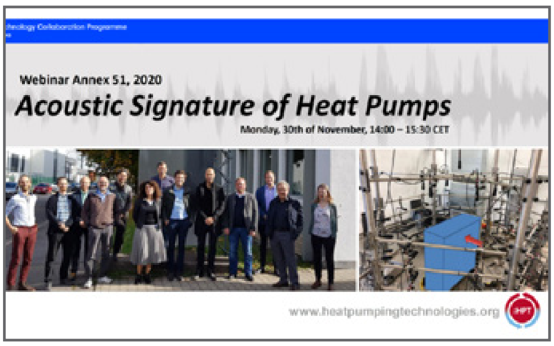
> ***Please visit the Annex 51 website to view the webinar and to download the presentations and eleven task documents.***

RESULTS

Simultaneous assessment of heat pump energy and acoustic performance

Heat pumps are a key technology in the energy system's transformation efforts to decarbonize the heat supply of the building stock. Besides energy and environmental measures, acoustics measures are gaining in importance since acoustics is a crucial measure of comfort. Operating air-to-water heat pumps require a compressor and a fan. Due to their rotation, both emit sounds that can be disturbing with regard to human psychoacoustics. It is thus necessary to develop energy-efficient, quiet heat pumps.

The operation of heat pumps can be optimized with respect to energy performance and acoustic emission reduction. Hence, we developed a simu-



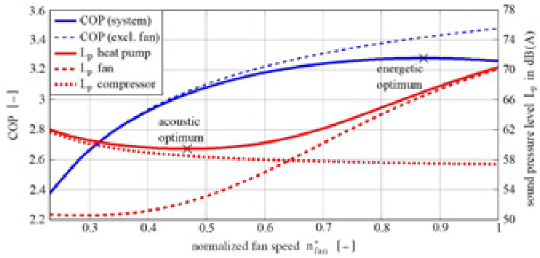


Figure 2. Variation of evaporator fan speed while providing constant condenser heating capacity (A7W50). [Source: RWTH Aachen]

lation model that determines the two thermodynamic properties of the refrigerant circuit and acoustic emissions. The interface between the energy and the acoustic model is the rotational speed of the compressor and of the evaporator fan. Figure 2 shows this relationship for a normalized fan speed. At constant condenser heating capacity, the evaporator fan speed is varied. The study concluded that the COP-optimal operating point does not correspond to the acoustically optimal operating point. This leads to a conflict of objectives between acoustically optimal and energy-optimal evaporator fan speeds. The following objectives have already been reached: The development of a dynamic simulation model for the acoustic evaluation of heat pumps, the coupling acoustic and energetic model, the parameterization of an acoustic model to measurement data and the reduction of acoustic emissions of heat pumps by optimizing their operation.

A simulation study was conducted, and it concluded that customer requirements for operation that is simultaneously energy-efficient and quiet contradict each other. Therefore, the evaporator fan speed is varied while heat capacity at the condenser and ambient temperature (A7W50) is kept constant. For this operating point, the acoustic optimum is at significantly lower rotational speeds compared to energy-optimal operation. At the acoustic optimum, the COP is reduced by 7.6% compared to the energy optimum. The emitted sound level, however, decreases by 7.74 dB(A). Furthermore, Figure 2 shows a pareto effect between energetic efficiency and acoustic emissions: By comparatively small deviations from the energetic optimum, the sound emissions can be reduced disproportionately.

Report on heat pump installation with special focus on acoustic impact

The version 1 report for task 5.1 has been compiled by AIT, TU Graz, DTI and IBP Fraunhofer and is available for download on the Annex 51 website. It presents tools for calculating sound pressure levels ranging from simple calculation tools to two-dimensional visualization, advanced sound propagation calculation tools and full three-dimensional calculation of sound propagation.

The virtual placement of heat pumps includes acoustic measurements of noise sources, aurealization and methods for calculating sound propagation as well as a chapter on modelling and mapping and hardware and software for visualization and acoustics. The analysis of acoustic interaction of multiple heat pumps is discussed in detail using a terraced housing estate as an example. Several scenarios have been investigated including one heat pump per household, one heat pump per house and a local heating supply. For these cases, the maximum sound pressure level at a number of sound emmision points of interest (e.g. windows and borders) has been calculated and presented using a penalty point system. This delivery also included the analysis of unit placement, indoor and outdoor sound propagation, a discussion of the potential of sound absorption at nearby surfaces and a compilation of common “unclever” decisions in heat pump placement, such as incorrect locations, installation on roofs, development of neighboring property, improper sound-absorbing measures and installation of further units in the neighborhood.

MEETINGS

Members of the Annex 51 team first convened at CETIAT (France), RISE (Sweden), DTI (Denmark) and ISE (Germany) and then had two online meetings on March 18-19 and September 9, 2020. The final meeting focused primarily on the publication of the promised deliverables.

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April 2017 – December 2020

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www.heatpumpingtechnologies.org/annex51
www.researchgate.net/project/IEA-HPT-Annex-51-Acoustic-Signatures-of-Heat-Pumps

ANNEX
52

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

INTRODUCTION

Carefully instrumented and analyzed long-term performance measurements from large GSHP systems are 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 are measuring performance of a wide range of 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 can be considerably more complex than single-family residential GSHP systems. The case studies will provide a set of benchmarks for comparisons of such GSHP systems around the world, using an extended system boundary schema for calculation of system performance factors. This schema is a revised and extended version 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.

"The outcomes from this annex will help building owners, designers and technicians evaluate, compare and optimize GSHP systems"

Figure 1: The Frölunda Club house in Sweden, part of the Annex 52 measurements. Photo: J.D. Spitler

OBJECTIVES

- Survey and create a library of quality long-term measurements of GSHP system performance for commercial, institutional and multi-family buildings. All types of ground sources (rock, soil, groundwater, surface water) are included in the scope.
- Refine and extend current methodology to better characterize GSHP system performance serving commercial, institutional and multi-family buildings with the full range of features shown on the market, and to provide a set of benchmarks for comparisons of such GSHP systems around the world.
- The guidelines provided by the *SEPEMO* project will be refined and extended to cover as many GSHP system features as possible and will be formalized in a guidelines document.

RESULTS

With one year left of Annex 52, most of the seven participating countries are now in the middle of writing their case study reports. Two guideline documents are nearing completion.
The pandemic in 2020 caused problems regarding annex meeting arrangements and affected the collection of measurement data and site visits. The pandemic has delayed publication of conference

papers and presentations related to the annex. The system boundary schema developed in Annex 52, revised from the SEPEMO schema for more complex GSHP systems, has now been implemented on all the Annex 52 case studies.

The annotated bibliography that has been compiled within the annex now 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.
Substantially revised and expanded drafts of the instrumentation and measurement guidelines have been written in 2020. Also, the uncertainty analysis guide compiled within the annex has been substantially revised, expanded and thoroughly discussed at this year's meetings. Both documents will be a help for the case studies and for future studies. Compilation and systematization of key performance indicators other than SPF and COP were initiated during 2020 and are ongoing.

In 2020, two new open-access journal papers were published about case studies within Annex 52 (see page 23) in addition to three previously published journal papers. One of the two publications covers the long-term performance of a club house in Gothenburg, Sweden (Figure 1 and 2), where both the SEPEMO and Annex 52 boundary schemes for evaluating and benchmarking the performance of the ground source heat pump system were used and compared. The study confirms previous findings within the annex – that auxiliary system components, in particular legionella protection systems, may have a large impact on the overall performance of the system. The second publication addresses the ground source heat pump system serving the Hugh Aston Building in the UK and provides high-quality and high-frequency open access measurement data as a reference data set.

An overview of the Annex 52 work was presented at the ASHRAE digital annual meeting at the end of June.

Figure 2: The Frölunda Club house ground source heat pump system. Photo: J.D. Spitler

MEETINGS
Because of the pandemic in 2020, the international expert meetings were held online:

- 5th Expert meeting - March 21, 2020. Revised Instrumentation guidelines draft, revised uncertainty analysis guideline draft, outline of performance analysis guideline draft were discussed.
- 6th Expert meeting - 9 thematic weekly meetings held on Fridays between October 9 – December 11 2020. Participating countries presented progress and case studies. New drafts of guidelines for instrumentation and uncertainty analysis were discussed along with the outline and scope of a guideline on key performance indicators.

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January 2018 – December 2021

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ANNEX 53

ADVANCED COOLING/REFRIGERATION TECHNOLOGIES DEVELOPMENT

INTRODUCTION

It is widely acknowledged that air conditioning (AC) and refrigeration systems are responsible for a large share of worldwide energy consumption today, and this demand is expected to increase sharply over the next 50 years absent action to ameliorate the increase. IEA projects that AC energy use by 2050 will increase 4.5 times over 2013 levels for non-Organization of Economic Coordination and Development (OECD) countries and 1.3 times for OECD countries. Worldwide action, both near-term (e.g., increase deployment of current "best" technologies) and longer-term (RD&D to develop advanced, higher efficiency technology solutions), is urgently needed to address this challenge. HPT Annex 53 was initiated in late 2018 and focuses on the longer-term RD&D need. Technologies under investigation include the vapor compression (VC) based systems 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 state of development of cooling systems based on the magneto caloric (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.

OBJECTIVES

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

> ***"Research results from several participants show promise to improve cost-effectiveness (reduced size and weight) of EC-based cooling systems."***

- Advance the technology readiness level (TRL) of non-traditional cooling technologies and alternative compresson technologies to the point that forward-thinking manufacturers could be encouraged to engage in subsequent partnerships in bringing them to market.
- Independent control of latent and sensible cooling and tailoring systems for different climates (e.g. hot dry or hot humid). Advances to VC-based technologies, both conventional and non-traditional.
- Advances to VC-based technologies, both conventional and non-traditional.

PROGRESS

At Xi'an Jiao Tong University, progress is underway toward development of a low-grade heat-driven elastocaloric (EC) cooling cycle concept. The key feature is use of a heat-activated high-temperature shape memory alloy (SMA) actuator driving a low-temperature super elastic (SE) alloy refrigerant. This approach could reduce actuator size and weight by more than 10 times compared to a mechanical actuator (Figure 1).

Ames Laboratory's team is making progress toward cost-effective mechanical actuator selection for EC systems. Magnetic SMAs are a good match for en-

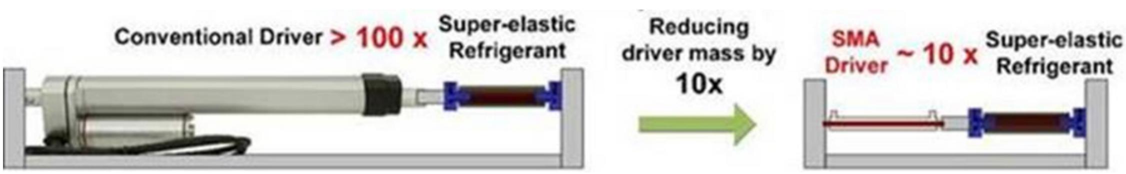

Figure 1. Heat-driven EC system (courtesy of Xi'an Jiao Tong University, S. Qian)

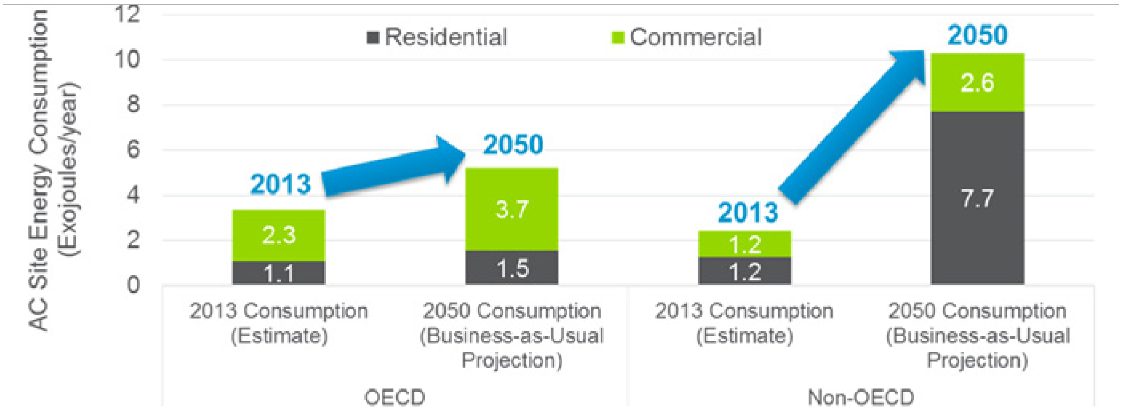

Figure 2. Current and projected space cooling site energy consumption for OECD and Non-OECD countries. Courtesy W. Goetzler, Guidehouse, Inc.; Source: IEA ETP 2016.

ergy density but have limited availability. Electric motors are widely available and can provide the necessary power density with gearboxes. A rotary-to-linear converter with a bending-type regenerator provides a compact EC heat pump concept.

The University of Maryland team is investigating the potential of stacked SE layers for an EC system. A single-stage EC system test station is operational. Promising tests are being performed on SE Nitinol®. Results indicate that direct strain measurement is required to provide accurate data. The station could become a rapid test facility for EC materials.

At the City University of Hong Kong, the team is progressing toward development of a hybrid compression-assisted absorption thermal energy storage (CATES) cycle, see Figure 3. When charging, the compressor helps move refrigerant to the condenser tank until the desired sorbent/refrigerant concentration is reached. Then the valves V1/V4 close, V2/V3 open and the compressor assists in moving refrigerant from the evaporator tank. The two tanks have different roles in the two processes. With a heat input charging temperature to the system generator of 80°C, the energy storage efficiency and density reach 0.67 and 282.8 kW/m3 for the CATES cycle, compared to 0.58 and 104.8 kW/m3 for the basic absorption cycle.

MEETINGS

June 24-25, online meeting -- Participants agreed to a one-year time extension. The Task 1 report was completed and submitted to the Heat Pump Centre.

December 16-17, hybrid meeting online and in-person (at Tsinghua University) -- Progress to-date on Task 2 projects summarized.

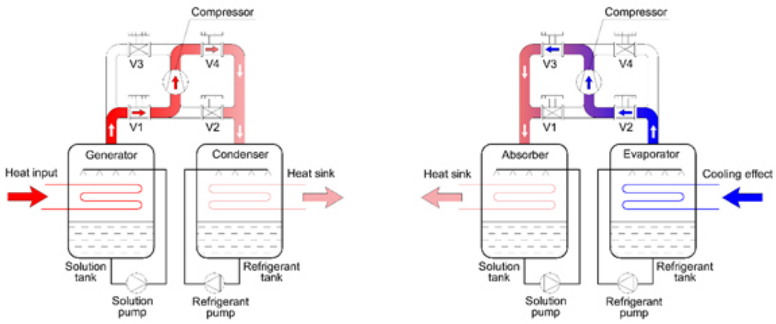

Figure 3. CATES system operating cycle schematic, charging and discharging process (courtesy of Wei Wu, City University of Hong Kong)

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January 2019 – December 2022

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ANNEX

54

HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS

> ***Significant progress has been made on optimizing and designing components using low-GWP refrigerants for heat pump applications.***

INTRODUCTION

Low-GWP refrigerants are considered to be a long-term solution for environmentally friendly heat pump systems. Many studies have shown that design modifications are necessary to be optimized for low-GWP refrigerants. In particular, component-level design and optimizations are much needed. There hasn't been a clear picture from recent R&D with respect to these needs. Furthermore, there is a lack of studies on optimizing components and providing guidelines for various heat pump systems.

Our annex aims to address the challenge via a comprehensive review of recent R&D progress on component optimization using low-GWP refrigerants and in-depth case studies of component optimization, which can provide design guidelines and real-world experiences. All the efforts are accomplished by academia and industrial organizations from participating countries.

OBJECTIVES

Annex 54 objectives are as follows:

- Objective 1 (in progress): Promote low GWP refrigerant application to accelerate phase down of high GWP HFCs
- Objective 2 (in progress): Develop design guidelines of optimized components and systems for low GWP refrigerants

RESULTS

The University of Maryland addresses the circuitry optimization of tube-fin heat exchangers for low-GWP refrigerants as shown in Figure 1. A novel integer permutation-based GA approach is presented to solve the tube-fin heat exchanger circuitry optimization problem. The case studies on an experimental validated evaporator show that the proposed optimization approach can generate circuitry designs with capacities superior to circuitries designed manually, while guarantee good manufacturability. Overall, a 2.4–14.6% capacity increase is observed with different constraints.

Other progress

In 2020, we made considerable progress on the following two tasks: 1) review of the state-of-the-art technologies in HVAC components using low-GWP refrigerants, and 2) case studies and design guidelines for optimizing components and systems. The chart below is a progress summary from each participating country.

Team	Summary
US	Conducted a comprehensive review of R&D progress on components using low-GWP refrigerants for residential air conditioning applications. The review mainly focused on heat exchangers and compressors.
Germany	Conducted several projects on heat pumps using low-GWP refrigerants. The projects cover novel components investigations, design guidelines and field testing.
Italy	Conducted various R&D projects from academic institutions and industrial organizations. The activities focused primarily on developing novel components and systems for low-GWP refrigerants.
France	Conducted extensive investigations of low-GWP refrigerants for residential heat pumps, air conditioners, and heat pump water heaters. A total of 10 alternative refrigerants with low-GWP were evaluated with no less than 130 performance tests. These experimental results will be useful for the HVAC community for facilitating the selection of the most promising candidates for the replacement of R-410A, R-134a, and R-407C in residential heat pumps.
Sweden	Initiated several efforts on case studies and design guidelines for component and system optimizations, particularly for climates in northern Europe.

MEETINGS

- Meeting 1: Workshop

Location: Virtual meeting
Date: June 24, 2020
Progress made: There were six progress reports from participating countries.
France (Pierre Pardo, CETIAT)
Germany (Thore Oltersdorf, Fraunhofer)
Germany (Christian Vering, Aachen)
Italy (Giulio Onorati, Daikin Applied Europe)
Sweden (Björn Palm, KTH)
US (Tao Cao, Univ. of MD)

- Meeting 2: Business meeting

Location: Virtual meeting
Date: June 24, 2020
Progress made: Discussed following main topics:
2020 country draft report deadline is November 30, 2020
ANNEX54 Update will be published in HPC Magazine based on contents from meetings, workshops and country report.
HPT ExCo encourages dissemination of annex results through webinars/workshops so that we will organize either workshops during relevant conferences or our own expert meetings.
Future meetings discussed.

- Meeting 3: Workshop during the 14th IIR-Gustav Lorentzen Conference on Natural Refrigerants

Location: Virtual meeting
Date: December 7, 2020
Progress made: There were six expert presentations from participating countries.
"Introduction of IEA HPT's Annex 54: Heat Pumps for Low GWP Refrigerants" by Dr. Yunho Hwang (US)
"NEDO's efforts in research and development of natural refrigerant utilization technology" by Mr. Masamichi Abe (Japan)
"Application of natural refrigerant R290 as the replacement of current refrigerants" by Dr. Thore Oltersdorf (Germany)
"Systematic application of the decision-making process for the fluid selection of natural refrigerants in heat pumps" by Mr. Christian Vering (Germany)
"Condensation and flow boiling heat transfer of hydrocarbons in minichannels" by Dr. Stefano Bortolin (Italy)
"Natural refrigerants for residential air-conditioning systems: component research review and novel system design" by Dr. Tao Cao (US)

- Meeting 4: Business meeting

Location: Virtual meeting
Date: December 7, 2020
Progress made: Discussed following main topics:
Overall annex schedule and 2020 annual report reporting deadlines were explained.
HPC Magazine updates: We are planning to collect from each country and provide two-page Annex 54 updates in January 2021.
HPC Annual Report progress update by each participating country is summarized below.
Future webinars/workshops/meetings (HPT ExCo encourages dissemination of annex results)

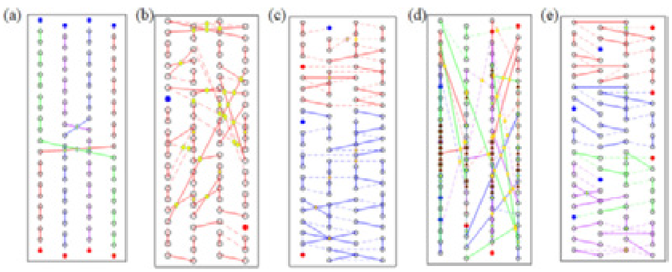

Figure 1: Optimal circuits under different constraints: (a) baseline, (b) unconstrained, (c) with manufacturing constraints; (d) with refrigerant DP constraint; (e) with manufacturing and refrigerant DP constraints.

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January 2019 – December 2021

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ANNEX

55

COMFORT AND CLIMATE BOX

INTRODUCTION

Integrated systems consisting of heat pumps, storage and controls are 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, system performance can be enhanced in several ways, including price, compactness, reliability, efficiency and serviceability. Meanwhile, better smart-grid integration and a larger share of direct renewable energy use become feasible.

Under the combined direction of the IEA Technology Collaboration Programs (TCPs) on energy storage (ECES) and heat pumps (HPT), HPT Annex 55 was initiated in early 2019 and will focus on improving combined systems of heat pumps, storage and controls.

Integrated systems consisting of heat pumps and storage are an essential technological option for accelerating the use of renewable energy for heating and cooling. By combining heat pumps and storage, several issues may be tackled a single process, such as: balancing & controlling electricity grid loads; capturing a larger share of renewable (local/regional) energy input; optimizing economics, CO_2 emissions, fuel use throughout time; and providing optimal supply security to buildings.

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

Commercial development of this type of solution is progressing very slowly, so the combined Annex 55 (ECES Annex 34) will accelerate market development of combined heat pump/storage packages (working title "Comfort and Climate Box" (CCB)). This will be the first annex to integrate the work from the TCP's HPT and ECES, building upon the earlier work in the fields of heat pumps and storage systems.

The central focus of Annex 55 is the Comfort and Climate Box (Figure 1), which denotes a combined

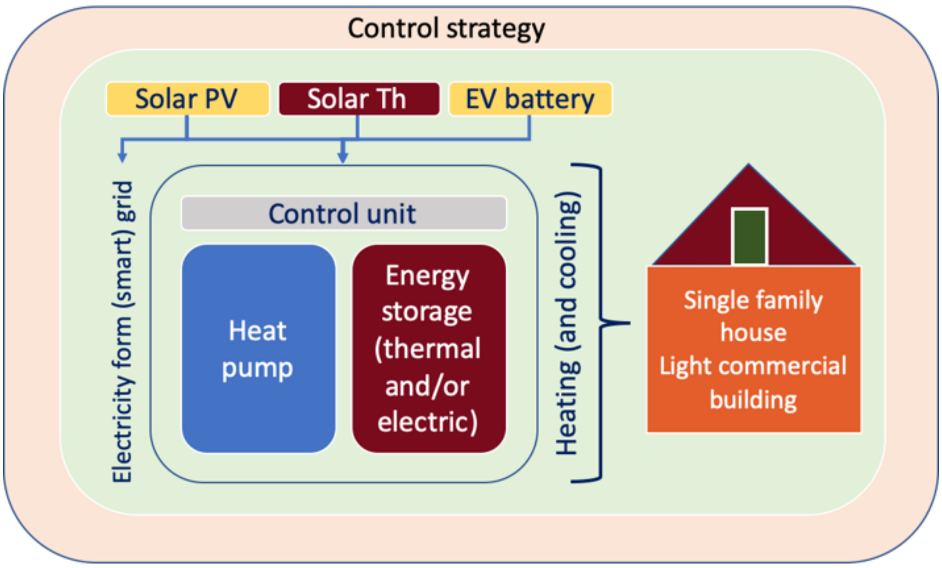


Figure 1. Outline of a Comfort and Climate Box.

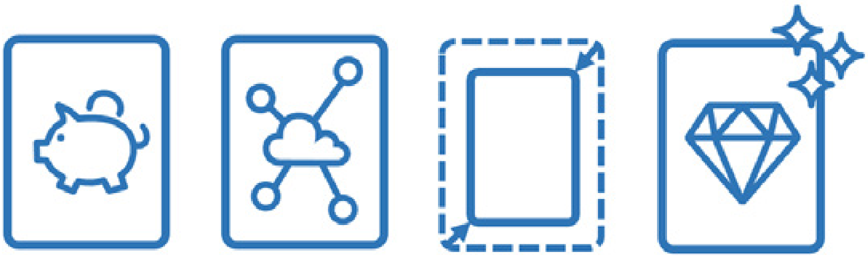


Figure 2: Four archetypes for CCBs: budget, flexility, compactness and top quality.

package, consisting of a heat pump, an energy storage module and controls. This package can form an actual physical unit but can also consist of separate modules that form an integrated 'virtual package', whereby all components of the CCB are designed to work together in a modular fashion and are 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 will focus on systems that will be close to market availability, i.e. technology readiness level (TRL ladder) 7 and upwards of high quality that are adapted to local market requirements.

The work will be oriented around the nine quality criteria that 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 sharing 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 interconnected with the global Mission Innovation program (MI), Innovation Challenge 7. MI7 functions as a non-hierarchical platform to enhance technology development within the building envelope.

RESULTS

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 local market conditions, it is crucial 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?

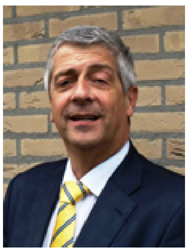
We have developed a set of four CCB 'archetypes' that should help policy makers to design appropriate support mechanisms to achieve their policy goals within the local market context (Figure 2).

MEETINGS

Februari 2020, Rome
General meeting focusing on discussions of quality criteria: What defines a successful integration of heat pump and storage components?

June 2020, online
Presentation of 4 'archetypes' for CCBs that share a specific focus on quality and require specific support to achieve better market penetration.

October 2020, online
Discussion of barriers and opportunities for CCBs in the participating countries.



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ANNEX
56

INTERNET OF THINGS FOR HEAT PUMPS

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

With heat pumps and its components becoming connected devices participating in the Internet of Things, a variety of new use cases and services can be enabled. Such services and applications can be related to any part of the lifecycle of the heat pump, to the connection or organization layer. Each level of participation of a heat pump in a connected world is also associated to different important risks and requirements to connectivity, data analysis, privacy and security for a variety of stakeholders. Therefore, this Annex will have a broad scope looking at different aspects of digitalization to analyse heat pump specific challenges and opportunities.

OBJECTIVES
The results of the annex will be disseminated to relevant target groups, such as OEMs, heat pump manufacturers, associations and regulatory authorities, by means of tailored messages. The annex will thereby do the following:

- Provide guidance, data and knowledge about heat pump technologies with respect to IoT applications
- Increase knowledge at different levels (OEMs, heat pump manufacturers, consultants, installers, legislators, etc.) and possibly contribute to the development of future standards.
- Review the status of currently available IoT enabled heat pumps, heat pump components and related services. A common glossary for the most important digitalization topics is currently being formulated.
- Identify requirements for data acquisition from newly designed or already implemented heat pump systems. Considering types of signals, protocols and platforms for buildings and industry applications and related privacy issues and ongoing standardization activities.
- Evaluate data analysis methods and applications (digital twins) for one or many heat pumps and sensors. Including machine learning, semantic models, BIM (Building Information Modelling) and soft sensors.
- Evaluate market opportunities created by IoT enabled heat pumps and identify success factors and further demands on software and hardware infrastructure.

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

RESULTS
Knowledge exchange: The annex is a lively platform for knowledge exchange among the participants about completed, ongoing and planned research in the field of IoT and heat pumps, which forms the basis for the collection of IoT use cases. We also reached out to related annexes in other technology collaboration programs, such as IETS (Annex 18 – Digitalization, Artificial Intelligence and Related Technologies for Energy Efficiency and GHG Emissions Reduction in Industry) and EBC (Annex 81 - Data-Driven Smart Buildings) to find synergies.
Structuring the fields of IoT, digitalization and heat pumps: A framework was established to organize and summarize IoT use cases from current, planned or recently finished projects or market services for heat pumps. With the framework, a consistent description of all important aspects should be achieved, ranging from stakeholders, participants,

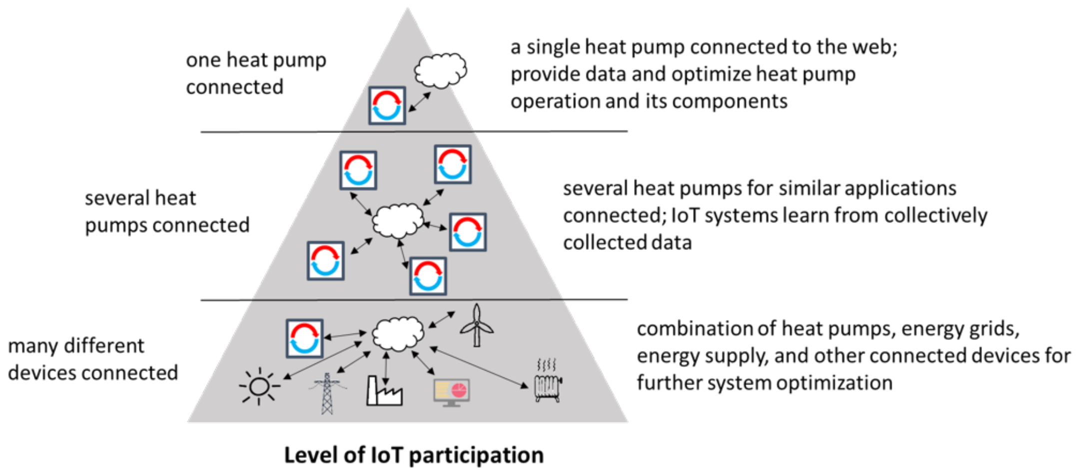

Figure 1. A heat pump can be part of the Internet of Things at different levels.

connection and data requirements, perceived benefits to technological readiness. Based on the specific use cases and application examples, common patterns as well as gaps can be detected that will contribute to the descriptions of the different tasks of the annex. Opportunities and challenges will be elaborated to define guidelines and best practice applications for IoT-enabled features for heat pumps.

Building Information Modelling (BIM): It was developed in order to consolidate the large number of different information sources throughout the lifecycle of a building. BIM consists of one or more accurate digital models containing precise geometry and data needed to support the construction, fabrication and procurement activities needed to complete, operate and maintain a building.
BIM is a modeling technology characterized by:

- Building components that are represented by objects that carry computable graphic, identification data and parametric rules
- Components that include behavior descriptions
- Consistent and redundant data

Current research projects are working on the integration of HVAC components in BIM, such as heat pumps or air handling units, the combination of real-time construction information with BIM to create a digital twin for deviation detection and analytics, the use of BIM information to set up building performance simulations and the use of BIM for fault detection for facility management. It was concluded that standardization is key for efficient data exchange and interoperability and that integrated BIM is not fully realized yet. Further topics to be discussed in the annex relate to building energy management systems, control strategies for heat pumps and control hierarchy in buildings, as well as information modelling in facility management.

MEETINGS

Due to travel restrictions imposed by Covid-19, the bi-annual expert meetings were replaced by more frequent, shorter online meetings. January 14–15, 2020, Vienna, Austria. Impulse presentations and discussion on various topics defining the tasks of the Annex. Work on a glossary describing key IoT concepts and technical terms was started.
June 25–26, 2020, online meeting. French market overview on heat pumps with IoT features, insight in data protection and privacy law, several presentations on data acquisition and analysis of field data measurements.
October 21, 2020, online meeting with first Deep Dive Session on sematic modelling related to heat pumps with a special focus on building information modelling (BIM), introduction of a new framework to categorize IoT use cases.

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Further information:
https://heatpumpingtechnologies.org/annex56/

Outlook into the Future

In 2021, HPT TCP will continue implementing the strategic work plan for 2018-2023 for the TCP (see page 13).

For the first half of the strategy period, much focus was placed on the objectives related to Environmental Awareness and Engagement Worldwide, with a good outcome. For 2021, we will place a special focus on the HPT TCP objectives related to the other two areas:

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 increasing.
» Capacity building has improved.
» Cost-effective solutions are being identified, demonstrated and accepted by end users.

To make progress on the objectives above, the TCP has prioritized some milestones to be reached in 2021. These were selected based on the conclusions from the midterm evaluation of the strategic work plan from 2020. 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 and to increase collaboration with external partners.

Selected milestones for 2021 are:

» Successful conference organization and defined procedures for next conferences
» Outreach to new target groups or new individuals within our prioritized target groups
» Implementation of reengineering HPT and HPC procedures
» To be the go-to source for information about heat pumping technologies
» New ideas and proposals for annexes according to our strategy plan (including the mid-term evaluation)

Throughout 2021, much of the HPT TCP's work, especially that of the Heat Pump Centre and the conference committees, will be aimed at organizing and supporting the 13th IEA Heat Pump Conference. The conference will take place on Jeju, South Korea, in April as a hybrid online-physical conference, since it is one of the most important activities arranged by the TCP.

In addition to the priorities above, a central part of the strategic work plan is also the advancement of RDD&D for heat pumping technologies. This will be accomplished by creating research opportunities, networking possibilities and meeting places for academia, industry, private sector markets and policy makers. They will then be able to collaborate under the new annexes (projects) and activities within the HPT TCP. Based on the conclusions from the midterm evaluation of the strategic work plan, the TCP will continue initiating and performing RDD&D within all the prioritized areas (see page 13). 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 reach the tipping point for large-scale 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. At the same time, many of the innovations needed to reach the climate targets do not yet exist, according to IEA. Therefore, projects at low TRL levels are important to have in the portfolio as well.

In 2020, several countries confirmed participation the newly launched Annex 57, "Flexibility by implementation of heat pumps in multi-vector energy systems and thermal grids". The work started in the beginning of 2021. This annex is a continuation of Annex 47, "Heat Pumps in District Heating and Cooling Systems", which was finalized in 2019. In the new Annex 57, the interaction with the electrical grid and the flexibility heat pumps in such a system can offer will be taken into account. The annex will specifically describe how heat pumps in urban heating grids can be an actor on the electrical energy market. (Strategy area 2a,b,c)

A proposal for a new annex within "High Temperature Heat Pumps" was approved during the year. This annex will start in the beginning of 2021. It targets the process industry sector and aims to demonstrate the potential for electrifying, and thereby decarbonizing, the process heat supply for industry above 100°C and up to 200°C or higher in specific circumstances. (Strategy area 2e)

In 2020, proposals and ideas for other new annexes according to the strategic work plan were discussed and elaborated within the TCP on the following topics:

- Heat Pumps for Drying (Strategy area 2e)
- Heat Pumps in Positive Energy Districts (Strategy area 2a,b,c)
- Comfort and Climate Box Solutions for Warm and Humid Climates (Strategy area 2b)
- Retrofit Heat Pump Systems in Larger Buildings (Strategy area 2a)
- Large demonstration project for flexibility by heat pumps (Strategy area 2c,d)
- Health and energy-efficiency, win-win or not? (Strategy area 2a,b)

The ideas and proposals for new annexes will be further developed during designated workshops and the National Experts meeting of the HPT TCP scheduled for the fall of 2021. In 2021, we need to adapt our work to the new situation brought on by the Covid-19 crisis. Less travelling, face-to-face meetings and physical arrangements, and more online meetings, workshop and webinars will take place. However, the new situation does not only bring disadvantages, but offers us new possibilities to conduct more online events even after this crisis. In this way, we will be able reach out and stimulate capacity building within the field of heat pumping technologies even more effectively.

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