Technology Collaboration Programme
by iea

ANNUAL REPORT 2022

HEAT PUMPING TECHNOLOGIES

Technology Collaboration Programme on
Heat Pumping Technologies - HPT TCP

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Technology Collaboration Programme
on Heat Pumping Technologies

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HPT TCP Annual Report 2022
www.heatpumpingtechnologies.org
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Content

Message from the Chairman

2022 was yet another challenging year for economic growth and the global supply of raw materials, merchandise and products. At the same time, the challenges of climate change were increasingly felt. The defossilization of the energy system must be accelerated, and the most efficient use of energy is a high priority.

Heat pumps are considered the most important technology for defossilizing the heat demand of buildings and industrial processes. The IEA has already stated this in the Roadmap to NetZero in 2021 (tenfold increase in heat pump sales by 2050) and confirmed it with the special report "The Futur of Heat Pumps" in the fall of 2022. It is interesting to note that despite the increased electricity prices and supply chain delays, for example, heat pump sales last year have increased by 38% in Europe. Compared to 2019, sales have even doubled. We could now say, " it's on, job done"; even in a complex environment, the heat pump is prevailing.

I think it is just the opposite. When thousands of heat pumps are installed, their efficiency and best integration and interaction with the energy system has a multiplied importance. Now more than ever, the efficiency of heat pumps must be improved. The importance of refrigerants with a low global warming potential increases, and the interaction of heat pumps with other energy systems, up to the flexibility is important. In addition, we must think about the mass production of heat pumps, the knowledge of planners and the skills of installers.

The environment analysis and the identification of opportunities and threats were the basis for our Strategic Work Plan, which was part of the Request for Extension (RfE) of our program for the period 2023 - 2028. We have broadened our focus by selecting our projects not only by application areas but also by challenges. These include system integration, value chains, extending operation range and applications, and new technologies and refrigerants. This is an important development, and it is gratifying that we have already been able to launch new projects (Annexes) that address these challenges. In this context, it is important that we coordinate our activities with other IEA Technology Collaboration Programmes and collaborate with them where possible. In addition to the heating sector, we must not forget the major challenges of building cooling. The IEA already declared this in 2018 in its Special Report "The Future of Cooling": The electricity demand for cooling will triple by 2050. Since 2018, we have only worked on one cooling project. This is where we need to step up. Maybe with a Comfort and Climate Box for hot and humid climates and in collaboration with new member countries from these geographic regions. I would be pleased.

Regarding the activities of our programme, I look back with pleasure on the past year. In May, in Oslo finally again an ExCo meeting onsite with interesting discussions until late at night. Highlights were also the development of the RfE (Request for Extension) and its approval, various webinars with Member Country Reports, in November in London another exciting ExCo meeting where we welcomed the Czech Republic as a new member, as well as the numerous ideas and proposals for new projects that contribute to the fulfillment of our strategy. The "crowning glory" was the IEA Report "The Future of Heat Pumps".

All the successes I am proud to tell you about are only possible with a team of highly motivated and experienced people. Therefore, I thank the ExCo delegates, the operating agents and their experts in the Annexes, the Heat Pump Centre staff, 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

Highlights 2022

New member country of HPT TCP

In October Czech Republic formally joined the HPT TCP, and thereby the TCP has 18 member countries. The Czech delegates attended the spring ExCo meeting as invited guests and attended the fall meeting as formal delegates.

Revision and approval of the strategic work plan for HPT TCP 2023-2028

The HPT TCP worked very hard during the year to assess the outcomes and impacts of their work over the previous five years while also keeping track of changes in their environment in order to develop a new strategic work plan for the following five years, from 2023 to 2028. The output of this work was compiled in a request for an extension of the HPT TCP, which was submitted to IEA in early fall and presented to the End-Use Working Party (EUWP).

The documentation included many successes and best practices. The work performed by the HPT TCP received an excellent review from the EUWP, and the request for an extension was approved by IEA's Committee for Energy Research and Technology (CERT) later in the fall. The revised strategic work plan for HPT TCP can be found on page 51.

Release of IEA's special report "The Future of Heat Pumps"

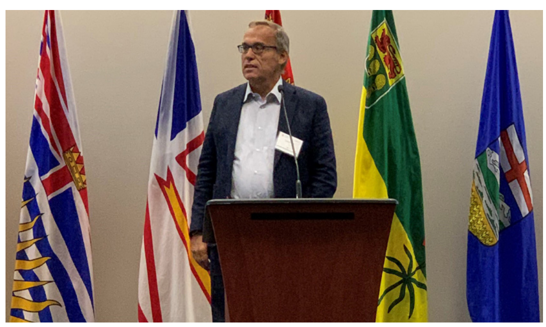
On November 30, IEA released their World Energy Outlook special report "The Future of Heat Pumps" (see page 9). One of the key messages of this report is that heat pumps are the key solution to reduce natural gas use for heating, support energy security, cut emissions and keep energy bills affordable. The community of HPT TCP were involved in providing input to and reviewing this report. When released, its messages were communicated in all the communication channels of HPT TCP.

Generation of the cross-TCP report ***"Technology and Innovation Pathways for Zero-carbon-ready Buildings by 2030."*** A strategic vision by IEA Technology Collaboration Programmes.

At the beginning of the year, HPT TCP authored one of the subchapters titled ***"Installation of about 600 million heat pumps covering 20% of buildings heating needs required by 2030"*** in this report (see page 10), which was developed collaboratively between the IEA and several experts from the IEA TCPs and published in September. The representatives from the different TCPs reviewed and provided input to each other's contributions.

Participation in IEA's Future Buildings Forum Think Tank Workshop

In October representatives from HPT TCP participated in the Future Buildings Forum Think Tank Workshop, which took place in Gatineau, Canada. The theme for this workshop was "Existing buildings: Pathways to Net Zero carbon to 2035" and representatives from all the TCPs related to buildings participated in this workshop, hosted by EBC TCP.



HPT chairman Stephan Renz at Future Buildings Forum Think Tank Workshop, Gatineau, Canada 2022.

Innovation and policy measures to solve the heat challenge – an inspiring side-event at the CEM113/MI7 meeting in Pittsburgh

In September, a side event for inspiration and learning from each other was organized at the Global Clean Energy Action Forum, a joint convening of the ***13th Clean Energy Ministerial*** and ***7th Mission Innovation*** ministerial meeting (CEM-13MI7) in Pittsburgh. HPT TCP, ***Global Alliance for Building and Construction's*** (ABC's) **Clean Heat Forum**, and ***Mission Innovation's Innovation Community on Affordable Heating and Cooling of Buildings*** (MI#IC7) hosted the session.

This *session presented innovative technology and policy solutions* that aim to *reduce emissions from* the *heating sector* worldwide. The audience could learn how technologies like the breakthrough ***Comfort and Climate Box*** (CCB) can meet heating and cooling needs and be deployed at scale and how national and subnational governments are developing technology, financial, and energy policies supporting the rapid deployment of clean heating.

Panel discussion during GCEAF in Pittsburg, USA, September 2022.

Member Country Reports

Three Member Country Report workshops were organized within the HPT TCP during the year. ExCo delegates, Operating Agents and Annex participants were invited to the workshops. On each occasion, three to four countries presented the national status for (i) Market statistics, (ii) Policy, and (iii) R&D activities. Norway, South Korea, UK, Finland, Sweden, Austria, China, Denmark and Switzerland gave their presentations during the workshops. After the events, the presentations, as well as summarizing text, were uploaded to the HPT TCP ***website***, and news were spread on Social Media. These events were well attended and appreciated by the audience, and facts and data from them have been included as input to IEA publications.

Several finalized annexes

During 2022 the final reports from the work performed within the following Annexes were published on the HPT website

- Heat Pumps in Multi-Family Buildings for space heating and domestic hot water (***Annex 50***)
- Long-term performance measurement of GSHP Systems serving commercial, institutional and multi-family buildings (***Annex 52***)
- Comfort and Climate Box – Speeding up market development for integrating heat pumps and storage packages (***Annex 55***)

The results from Annex 50 showed that the use of heat pump systems in apartment buildings is possible and already practiced, as shown by many good examples from several countries. Nevertheless, there is still no evidence of wider use of this solution for heat supply, the reasons being both of administrative and technical nature. More standardized solutions are needed.

ANNEX
50
START DATE:
1 January 2017
END DATE:
30 June 2021
Heat Pumps in Multi-Family Buildings for space heating and DHW

ANNEX
52
START DATE:
1 January 2018
END DATE:
31 December 2021
Long term performance measurement of GSHP Systems serving commercial, institutional and multi-family buildings

ANNEX
55
START DATE:
1 April 2019
END DATE:
30 September 2021
Comfort and Climate Box

Ground-source heat pump (GSHP) systems for larger buildings provide renewable heating and cooling for a wide range of system applications. The conclusions from Annex 52 reveal that long-term performance measurements from such systems are valuable tools for commissioning, fault detection, system optimization and component development.

The final outcomes from Annex 55 show that a Comfort and Climate Box (CCB) solution, which means an integrated combination of a heat pump, energy storage and control, is a key solution for decarbonizing heating and cooling of buildings. It can satisfy consumer demands for comfort, reliability, and affordability while simultaneously fulfilling the needs of policy makers, utilities and grid operators concerning climate goals, energy security and grid stability.

Several New Annexes

During 2022, work actively began in two new annexes, ***Annex 59*** Heat Pumps for Drying and ***Annex 60*** Retrofitting Heat Pump Systems in Large Non-domestic Buildings. ***Annex 61*** Heat Pumps in Positive Energy Districts officially started at the end of the year, while the active work is planned to begin in early 2023. At the end of the year, three countries each had joined Annex 59 and Annex 60, and five countries had joined Annex 61.

ANNEX 59
START DATE: 1 January 2022
END DATE: 31 December 2024
Heat Pumps for Drying

ANNEX 60
START DATE: 1 January 2022
END DATE: 31 December 2024
Retrofitting Heat Pump Systems in Large Non-domestic Buildings

ANNEX 61
START DATE: 1 September 2022
END DATE: 31 December 2025
Heat Pumps in Positive Energy Districts

14th IEA Heat Pump Conference

During 2022 much preparation work for the 14th IEA Heat Pump Conference on the theme "Heat Pumps – Resilient and Efficient", which will take place on May 15 -18, 2023, in Chicago took place. The call for abstracts was closed in June, and the submission of full papers were due in November. Thereafter the review process of the close to 200 submitted papers was initiated. Moreover, the call for Nominations for the Peter Ritter von Rittinger International Heat Pump Award 2023, the highest international award in the heat pump, air conditioning and refrigeration field, was launched and closed during the year. The winners of the awards will be announced during the conference.

14th IEA HEAT PUMP CONFERENCE

Publication of three Issues of the Heat Pumping Technologies Magazine

HPT published three issues of the Heat Pumping Technologies Magazine in 2022 on the topics:

- *Refrigerants*
- *Control and monitoring of heat pump systems*
- *Smart integration of heat pumps with electric storage and solar photovoltaics*

International Energy Agency

About the International Energy Agency (IEA)

The IEA is at the heart of global dialogue on energy, providing authoritative analysis, data, policy recommendations, and real-world solutions to help countries provide secure and sustainable energy for all. The IEA was created in 1974 to help coordinate a collective response to major oil supply disruptions. While oil security remains a key aspect of our work, the IEA has evolved and expanded significantly since its foundation.

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

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

About the IEA Technology Collaboration Programme

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. Under this framework, over 6000 experts from governments, academia and industry from 55 countries are collaborating to enforce research, development and commercialisation of energy technologies.

The scope and strategy of each collaboration are in keeping with the IEA's Shared Goals of energy security, environmental protection and economic growth, as well as engagement worldwide. Individual technology collaborations working across several technology or sector categories involve: energy efficiency end-use technologies (in buildings, transport, industry and electricity), renewable energy and hydrogen, fossil energies, fusion power, and cross-cutting issues (equality in energy transition, energy system analyses).

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.

About the IEA's work on heat pumps in 2022

In the ***IEA's Net Zero by 2050 Roadmap***, released in May 2021, heat pumps have been identified as a central technology in the global transition to secure and sustainable heat in industry and buildings. In 2022, several IEA reports further strengthened this message.

The Future of Heat Pumps

This World Energy Outlook Special Report provides an outlook for heat pumps to 2030, identifying key opportunities and policy solutions to accelerate their deployments, overcoming major barriers and fully exploiting the benefits this technology can provide in terms of energy security, emission reductions, lower energy bills and employment.

Some of the key outcomes of the report highlight that the pace of heat pumps installations is growing rapidly and, if governments' announced energy and climate-related commitments are to be met in full and on time [Announced Pledges Scenario, APS], the share of heat pumps in total heating needs in buildings could jump from one-tenth today to nearly one-fifth in 2030. As a result, natural gas demand falls by 80 billion cubic metres (bcm), heating oil drops by 1 million barrels per day, and coal declines by 55 million tonnes of coal equivalent. In aggregate, this means heat pumps account for nearly half of the global reductions in fossil fuel use for heating in buildings by 2030. The potential for heat pumps to cut dependence on natural gas for heating is particularly large in the European Union, where natural gas use could be reduced by 21 bcm in 2030, an amount equivalent to almost 15% of EU pipeline import from Russia in 2021.

The accelerated deployment of heat pumps brings a range of benefits by creating jobs [heat pumps workers nearly triple to 2030, APS], lowering energy bills and shielding consumers from price shocks [savings in low-income households range between 2% and 6% of their household income in 2021], cutting emissions of greenhouse gases [global CO_2 emissions decline by half a gigatonne by 2030, APS] and improving air quality.

Accelerating the take-up of heat pumps to take advantage from all the benefits listed above requires overcoming a number of barriers. Chief among them are: the higher upfront cost of buying and installing the devices relative to other heating options; other non-cost deterrents to consumer adoption; manufacturing constraints; and potential shortages of qualified installers. Concerted action by governments, in partnership with the heat pump industry, and supported by international collaboration and research, is needed to address these hurdles and achieve higher deployment rates.

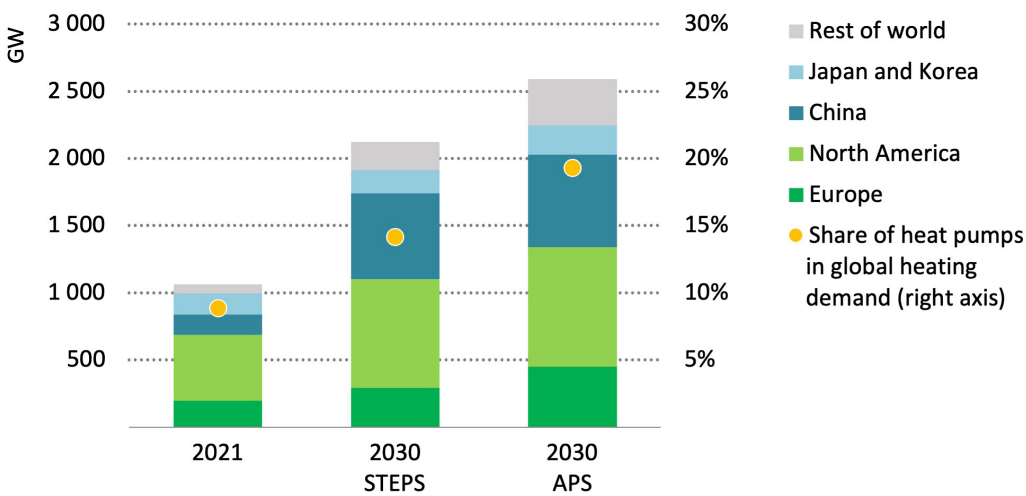


Figure 1. Heat pump capacity in buildings by country/region and scenario, 2021 and 2030.

***Heat Pumps* section of the 2022 edition of IEA's *Tracking Clean Energy Progress* report**

Tracking Clean Energy Progress assesses recent developments for 55 components of the energy system that are critical for clean energy transitions. Progress is assessed against short-term milestones of the Net Zero by 2050 Scenario (NZE), a scenario consistent with the global climate target of 1.5°C. Recommendations are provided on how the analysed components can get 'on track' with the NZE pathway by 2030. ***Heat pumps currently need "More effort" to be on track with this trajectory.*** Heat pumps currently available on the market are three-to-five times more energy efficient than natural gas boilers, and installing heat pumps instead of a fossil-fuel based boiler significantly reduces greenhouse gas emissions in all major heating markets, even with the current electricity generation mix, an advantage that will increase further as electricity systems decarbonise. However, in 2021, heat pumps still met only around 10% of the global heating need in buildings.

Technology and Innovation Pathways for Zero-carbon-ready Buildings by 2030. A strategic vision by IEA Technology Collaboration Programmes.

This report has been developed collaboratively between the IEA and several experts from the IEA TCPs. In the report, IEA TCPs present their vision on how their activities could help achieve some of the most impactful short-term milestones for the buildings sector outlined in the IEA's Net Zero by 2050 Roadmap. The IEA HPT TCP published an article within this report entitled "***Installation of about 600 million heat pumps covering 20% of buildings heating needs required by 2030***". The article highlights the role played by research and international collaboration for accelerating heat pumps deployment and overcoming some of the main barriers, as well as identifying short-term priorities in this direction.

Energy Technology Perspective 2023

The scale-up of heat pumps deployment in the years ahead requires a scale-up on heat pumps manufacturing capacity and has implications for the entire heat pumps supply chain and electricity infrastructure. This report presents the risks and opportunities surrounding the development and scale-up of heat pumps, as well as other selected clean energy and technology supply chains in the years ahead, viewed through the lenses of energy security, resilience, and sustainability.

Heat pumps have shown to have a supply chain which is less concentrated and more robust compared to the one of other analysed mass-manufactured clean energy technologies. This links to the fact that they share components with other industries and appliances, and the demand for criticals materials is lower compared to other key technology areas such as wind, electrolyzers and solar PV.

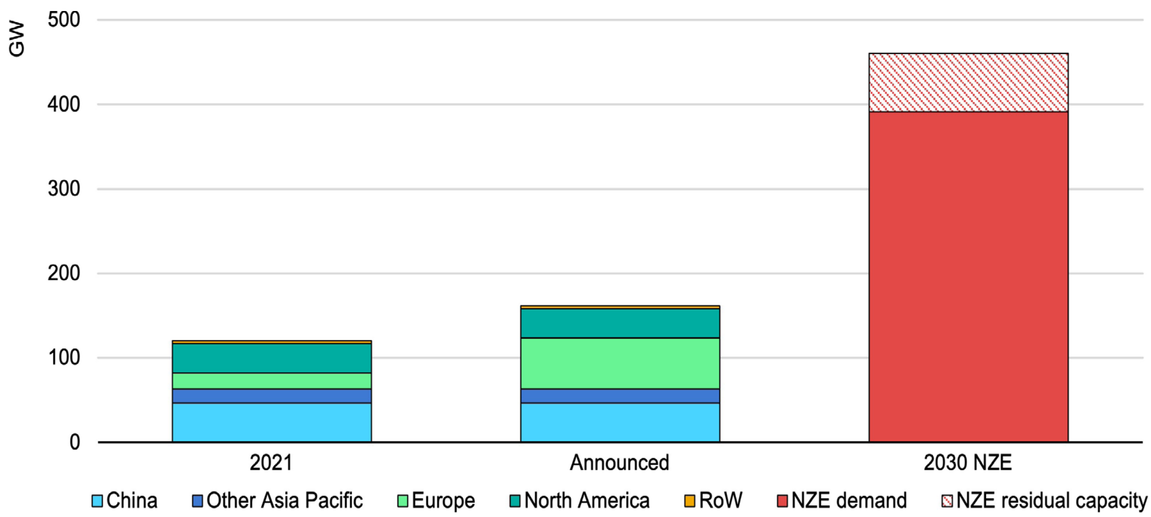
Heat pumps analysed in this report are those primarily used for (space and/or water) heating in buildings and those for which the heating function is just as important as the cooling capability, aiming to exclude as much as possible air-air reversible heat pump units used primarily for space cooling. Following such a definition, the report highlights that global heat pumps sales doubled over the last decade, and heat pumps manufacturing capacity reached around 120 GWth in 2021. China holds 40% of global manufacturing capacity, followed by North America (30%) and Europe (15%). Looking at manufacturers, many of the largest manufacturers of heat pumps are headquartered in Japan, and Japan and China hold the majority of patents issued for heat pumps.

Nonetheless, the global heat pump industry is facing some bottlenecks amid rapid growth, in part due to limited supplies of semiconductors. However, some manufacturers in the heat pump industry are confident that current shortages can be overcome within the next 12-18 months. The scope for raising production at short notice varies among manufacturers, and some, particularly in Europe, are already operating at rates close to maximum capacity. The location and type of new manufacturing expansions might be impacted by the current location of existing production sites, and by environmental regulation – particularly on F-gases. In addition, transportation costs and region-specific regulations also impact where heat pumps are manufactured, and today, most heat pumps are manufactured where they are sold.

While announcements of new heat pump factories are not frequent, in 2022, some of the major manufacturers, notably in Europe, have announced expansion plans. If realised in full, announced projects would grow global manufacturing capacity by around one-third. However, to meet the sales needed in the NZE Scenario, global manufacturing capacity would need to almost quadruple to around 460 GWth by 2030. See Figure. 2.

Lead times for new factories or expansions range from 1 to 3 years, and most of the heat pump industry appears confident that it will be able to ramp up output quickly if bottlenecks in component supplies (notably semiconductors and compressors) are avoided. ***USD 15 billion in cumulative investment together would be required by 2030 to remain on- track with the NZE Scenario, with a 5-fold increase in heat pumps installers (around 800 000 additional workers).***

Governments and industry have vital roles to play in addressing persistent market barriers and enabling heat pumps to play their full part in tackling today's most pressing issues – energy security, energy affordability, and rapid reductions in emissions.



Notes: RoW = rest of world; NZE = Net Zero Emissions by 2050 Scenario. Announced capacity includes existing capacity.The manufacturing capacity needed to meet projected demand in the NZE Scenario (NZE demand) is estimated assuming a utilisation rate of 85%. NZE residual capacity, thus, represents the manufacturing capacity that would remain unused, on average, which provides some flexibility to accommodate demand fluctuations. Heat pump capacity (in GW) is expressed as thermal output capacity. By and large, Europe is the main region to have concrete public expansion plans from manufacturers in place. terms of use: https://www.iea.org/terms

Figure 2. Heat pump manufacturing capacity by country/region according to announced projects and in the NZE Scenario.

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 fulfill the IEA's mission

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

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

Strategy

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

2. Perform RDD&D activities within the areas of heating, cooling and refrigeration for the building, community, transport and industrial sectors while widening the scope to include to a larger extent:
   - Affordable and competitive technologies for heating
   - More efficient cooling and air-conditioning, especially in warm and humid climates
   - Flexible, sustainable and clean system solutions (e.g. in urban areas) using combinations of heat pumping technologies with energy storage, smart grid, solar and wind energy, thermal networks, energy prosumers, etc.
   - Possibilities offered by the developments in the area of digitalization and Internet of Things.
   - New or special markets and applications, including automotive, industry and consumer products (e.g. white goods)
   - New, alternative or natural refrigerants with lower global warming potential, high thermo dynamic potential and low toxicity for both new and existing applications

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

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

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

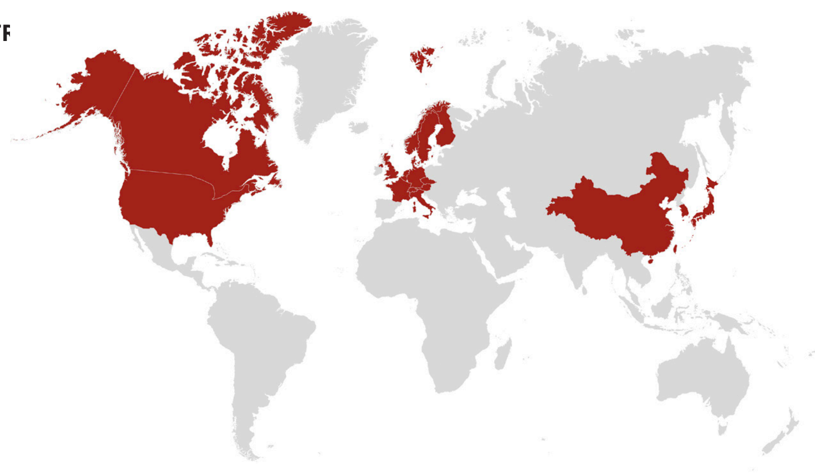
6. Increase activities to attract new members, including IEA key partner and association countries

Activities

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

HPT TCP MEMBER COUNTR

- Austria
- Belgium
- Canada
- Czech Republic
- China
- Denmark
- Finland
- France
- Germany
- Italy
- Japan
- The Netherlands
- Norway
- South Korea
- Sweden



* 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-shaing 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).

The Heat Pump Centre also involves programme support to ExCo, NTs and Annex coordinators (called Operating Agents, OAs), as well as stimulating and supporting the generation of new activities, arranging National Experts' meetings, representing the TCP at IEA meetings, supporting IEA publications, and conducting outreach activities.

This is the HPC Staff :

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

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

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

Metkel Yebiyo, Technical Expert and Editor
Metkel Yebiyo is a Researcher at RISE, working at the forefront of energy & sustainable built environment. At HPC, he is the editor of our prestigious Heat Pumping Technology Magazine and deals with annual reports, organising national expert meetings, and member country reports.
metkel.yebiyo@ri.se

Anneli Rosenkvist, Communication
Anneli is an experienced marketing and communication professional with knowledge in planning, coordinating, and executing communication strategies. At HPC, she is responsible for and can offer support within graphical design, newsletter, website and social media.
anneli.rosenkvist@ri.se

Activities and Achievements

ExCo meeting in Oslo, Norway, May 2022.

Executive meetings

After two years of holding Executive Committee (ExCo) meetings online, the HPT TCP community could finally meet up again – at hybrid online/onsite meetings, since some people were still prevented from travelling. The spring ExCo meeting took place in Oslo on 11-12 May. The day before the ExCo meeting on 10 May, the Norwegian ExCo delegate organized a ***national workshop*** where the international audience was informed about the policy and market situation for heat pumping technologies in Norway, alongside with information about research activities within the country. At present, Norway is the country with the highest penetration of heat pumps per capita in Europe. The national audience was informed about the activities performed within HPT TCP.

ExCo meeting in Oslo, Norway, May 2022.

The fall ExCo meeting took place in London on 9-10 November as a hybrid meeting. However, this time most of the delegates attended in person. The day prior to the meeting, the ExCo delegate from the UK organized a ***national seminar***. The ambitious plans to accelerate the roll-out of heat pumps in the UK in order to decarbonize the heating sector were presented together with information about national research, demonstration, development and deployment projects.

Czech Republic joined the HPT TCP in October. Representatives from the country attended the spring ExCo meeting as invited guests and as formal delegates at the fall ExCo meeting. During the meeting, they held a presentation about the *present status* of the energy transition and heat pumping technologies in their country.

[Strategy point 2]

ExCo Chairman Stephan Renz presenting at the UK National Seminar in London, November 2022.

Digital workshops and webinars

During the year, the HPT TCP organised several digital workshops and webinars, for example, three workshops when Member Country Reports were presented and discussed on ***16 June***, ***7 September*** and ***21 November***. On 13 June, the team of Annex 52, "Long-term performance monitoring of GSHP systems for commercial, institutional, and multi-family buildings", together with HPC, organized a very well-attended webinar to present the final results from the work within the Annex, which had recently been finalized. Later during the year, on 24 October, the Operating Agent of the joint HPT Annex 55 / ES Task 34 "Comfort and Climate Box" and HPC organzed a well-attended ***webinar***, where the final results from this Annex were described. On 4 October, HPC invited openly to an online ***national experts meeting***. During this meeting, ideas and proposals for new Annexes to be performed within HPT TCP were presented and discussed (see page 50 Outlook into the future).

[Strategy point 3]

Request for Extension

During 2022 a lot of effort was put into preparing for the Request for Extension for the next five years, 2023-2028, which was due to be submitted to IEA during the summer. The request involved compiling an End-of-Term report and revising the TCP's strategic work plan. Since the ExCo had performed a mid-term evaluation, led by HPC, of the present strategic work plan (2018-2023) during 2020 and at the beginning of 2021, the HPT TCP community was well prepared for a revision of the strategic work plan. On March 17, HPC organized an online strategy workshop with the ExCo delegates, and the output from this workshop formed the basis for the development of the revised strategic work plan. The draft strategic work plan, as well as the End-of-Term report, was discussed at the spring ExCo meeting in Oslo, and the final version of the documents were approved by ExCo before submission to IEA.

For many decades, the HPT TCP, as well as industry and business associations, have been fighting for ***recognition*** of the technology within the IEA and among policy makers around the world. Now, in 2022, we can conclude that we have succeeded in many ways. The technology is well recognized by IEA as the ***future norm for heating*** of a decarbonized building sector and for contributing to the decarbonization of the industry sector. In addition, the legal framework in many regions of the world is ***well prepared*** for a ***large-scale roll-out of heat pumps***; many countries have announced support schemes for end consumers investing in heat pumps and other measures are taken to support the value chain. Besides being an efficient and clean energy technology, in 2022, the role of heat pumps to decrease the reliance on Russian natural gas and strengthen energy security emerged as very important. Although the technology is available and works well and markets are growing, ***barriers for accelerated deployment*** of this clean, energy-efficient secure technology should be reduced and removed by different measures. At the same time, further research and innovation is needed to utilize the full potential of system integration, to ensure robust, sustainable and affordable value chains, and to expand the operating range of heat pumping technologies. In addition, further research is needed to develop new technologies and adopt the technology for low or ultra-low GWP technologies. All these aspects were taken into account when developing the revised strategic work plan for 2023-2028, which is described on page 50.

The request for extension, including the End-of-Term report for 2018-2023 as well as the Strategic Work plan for 2023-2028, was presented for IEA's End-Use Working Party (EUWP) in September by the HPT TCP ExCo Chair. In October, the ExCo Chair received a very positive assessment of the submitted documents by EUWP as well as an approval of the request from IEA's CERT (Committee on Energy Research and Technology).

Ongoing, new and completed annexes

The international collaboration projects within the HPT TCP, the annexes, form the core of TCP activities. During 2022, the following eight annexes were ongoing:

- Advanced Cooling/Refrigeration Technologies Development (Annex 53)
- Heat pump systems with low GWP refrigerants (Annex 54)
- Internet of Things for Heat Pumps (Annex 56)
- Flexibility by implementation of heat pumps in multi-vector energy systems and thermal grids (Annex 57)
- High-Temperature Heat Pumps (Annex 58)
- Heat Pumps for Drying (Annex 59)
- Retrofitting Heat Pump Systems in Large Non-domestic Buildings (Annex 60)

See further pages 23.

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

- Heat Pumps in Multi-Family Buildings for Space Heating and DHW (Annex 50)
- Long-term performance measurement of GSHP systems serving commercial, institutional and multi-family buildings (Annex 52)
- Comfort and Climate Box (Annex 55)

During the two ExCo meetings and the online National Experts meetings arranged during the year, several ideas and proposals for potential new annexes were presented, discussed and further developed. More information about these ideas and proposals can be found on page 50, Outlook into future.

[Strategy point 2]

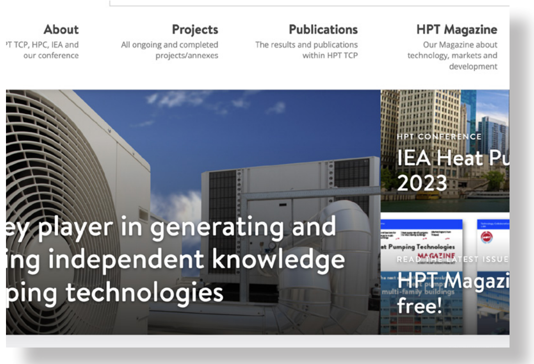
The IEA Heat Pump Conference

During 2022 the preparations for the next coming IEA Heat Pump Conference, which will take place on 15-18 May 2023 in Chicago, (see page 20), increased in activity. The call for abstracts was open during the spring and closed in June. A large number of abstracts, spread over several topics and areas of applications for heat-pumping technologies, were received. During the second half of the year, reviewers to review the submitted papers were recruited by the regional coordinators. The deadline for submitting full papers was in November, and thereafter the review process of the close to 200 submitted papers started. In parallel, during the summer, the call for nominations for the Peter Ritter von Ritteringer heat pump award was opened, and nominations were due at the end of November.

[Strategy point 1]

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

One of the Heat Pump Centre's (HPC) main activities is publishing the prestigious 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 2022 on the topics "***Refrigerants***", "***Control and Monitoring of Heat Pump Systems***", and "***Smart Integration of Heat Pumps with Electric Storage and Solar Photovoltaics***". They were published together with an electronic newsletter with short versions of selected articles. The prestigious Heat Pumping Technologies Magazine has played a significant role in expanding our research outreach, attracting new audiences, and sparking important discussions on the current energy challenges and the robust policy backing for heat pumping technologies.



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, Twitter and on the Chinese social media platform WeChat. It continuously follows the web traffic and number of readers on our communication channels and has noted a considerable increase in both from year to year.

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 2022 presentations and summaries from Member Country Report workshops have been published on the website. This offers website visitors a good source for information regarding market development and the present status and conditions for the deployment of heat pumps in different parts of the world.

Linkedin

Heat Pump Centre (HPC) continued to send out the "HPC 60 seconds" e-mail, a monthly overview in bulleted format of HPC activities for people actively involved in the TCP.

[Strategy point 4]

Collaboration with IEA

Representatives from the HPT TCP and Heat Pump Centre have had a continuous dialogue with the IEA secretariat and participated in meetings, most of them online. During the first half of the year, a cross-TCP project was elaborated, which resulted in an online article published on the website of IEA and promoted in their various communication channels at the beginning of September. In this article, a deep-dive was made for the building-related milestones of the IEA Net-Zero by 2050 Roadmap, published by IEA in May 2021 (see page 5 Highlights).

In June, Caroline Haglund Stignor, one of the co-leads of the Heat Pump Centre, was invited by IEA to be part of a fascinating panel discussion about heat pumps and what can be done to deploy the most efficient equipment quickly enough at a session titled "Super-efficient appliances pave the way to Net Zero" during the 7th IEA Energy Efficiency conference, which took place in Sønderborg in Denmark in June. During the discussion, the audience could learn about the Electric Ireland Superhomes, a one-stop-shop for a home energy retrofit, challenges related to supply chains and the lack of components that manufacturers experience right now and that there is no lack of installers in Europe, maybe of heat pump installers, but installers could be retrained. It was also discussed how finance could be unlocked to enhance the energy efficiency, how to create incentives and that emissions should be controlled beyond reporting.

Heat pump panel at the 7th IEA Energy Efficiency Conference, Sønderborg, Denmark, June 2022.

A month later, Caroline Haglund Stignor was invited by IEA to give a presentation about heat pumping technologies during a closed online workshop on the topic "Rollout of rooftop solar and heat pumps". This workshop was part of a project funded by the Technical Support Instrument of the European Union and implemented by the International Energy Agency in collaboration with the Directorate-General for Structural Reform Support (DG REFORM) to provide multi-country advice on concrete measures to reduce dependency on Russian fossil fuels.

During the fall, the HPT TCP network, coordinated by Heat Pump Centre, provided input of facts and figures and a review of the Special report Heat Pumps for the Future within the World Energy Outlook series, which was published by IEA on 30 November (see page 9). In conjunction with the publication of the report, Heat Pump Centre communicated ***summaries and key messages of the report*** in all their communication channels.

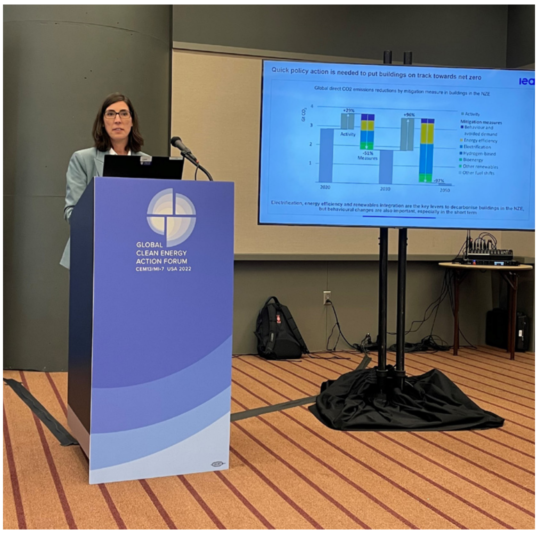
In parallel with the work to provide input to the report mentioned above, Heat Pump Centre collected input from the HPT TCP network to IEA's Energy Technology Perspectives 2023, which was published in early January 2023 (see page 11). Several meetings were organized with the IEA secretariat, and the report was reviewed by Heat Pump Centre as well as by the ExCo Chair.

[Strategy point 5]

Collaboration with other international organizations and other TCPs

In September, a side event on the theme "Innovation and policy measures to solve the heat challenge" was organized by HPT TCP (through Heat Pump Centre), the Global Alliance for Building and Construction's (ABC's) Clean Heat Forum, and **Mission Innovation's Innovation Community (Challenge)** on Affordable Heating and Cooling of Buildings (MI#IC7). The purpose of the side event was to inspire and learn from each other. The audience could learn how technologies like the breakthrough Comfort and Climate Box (CCB) can meet heating and cooling needs and be deployed at scale and how national and subnational governments are developing technology, financial, and energy policies supporting the rapid deployment of clean heating.

In October the Chair of HPT TCP, Stephan Renz, and Caroline Haglund Stignor, from Heat Pump Centre, participated in IEA's Future Buildings Forum Think Tank Workshop, which took place in Gatineau, Canada. The theme for this workshop was "Existing buildings: Pathways to Net Zero Carbon to 2035" and it used the Cross-TCP article (see page 5), which had been co-authored by several TCPs earlier during the year, as a starting point. The objective of the workshop was to identify international collaborative RDD&D activities, needed to unluck deployment of low and



Araceli P Fernandez, IEA, presenting at the side event at the Global Clean Energy Action Forum, a joint convening of the 13th Clean Energy Ministerial and 7th Mission Innovation ministerial meeting (CEM-13MI7) in Pittsburgh (see page 6).

zero carbon technologies in existing housing and buildings and to identify areas and project where joint activities between the TCPs should be carried out. Representatives from all the TCPs related to buildings participated in this workshop, which was hosted by EBC TCP. The HPT TCP Chair as well as Heat Pump Centre contributed actively to the preparation of this workshop and one of the sessions, "Technological Systems as Catalysts for Future Proofing Buildings" was led by HPT TCP Chair, Stephan Renz.

Meli Stylianou, EBC TCP, opening IEA's Future Buildings Forum Think Tank Workshop, which took place in Gatineau, Candada.

On December 15, Caroline Haglund Stignor from Heat Pump Centre was invited by IEA to moderate a webinar, “Pump up the volume: Heat pumps for a decarbonised future”, organized by CLASP, where the RAP heat pump policy toolkit was presented, followed by a presentation by IEA of their special report “The Future of Heat Pumps”.

The Annex 55 Comfort and Climate Box was finalized during 2022 and further information about important outcomes from the project is described on page 35. This project is built on valuable interlinked collaboration between HPT TCP, Energy Storage TCP and Mission Innovation’s Innovation Community on Affordable Heating and Cooling of Buildings (MI#IC7).

[Strategy point 3]

Main room IEA’s Future Buildings Forum Think Tank Workshop, which took place in Gatineau, Canada.

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

Every three years, the IEA Technology Collaboration Programme on Heat Pumping Technologies (IEA HPT TCP) convenes the IEA Heat Pump Conference. The United States is proud to announce that it will be hosting the 14th IEA Heat Pump Conference, which will be held in Chicago on 15-18 May 2023. The theme for the Conference is "Heat Pumps – Resilient and Efficient".

CONFERENCE GOALS

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

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

CONFERENCE PROGRAM HIGHLIGHTS

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

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

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

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

CONFERENCE INFORMATION

Those wishing to attend the Conference should visit the conference website: *www.hpc2023.org*. Detailed information, including registration and hotel accommodation forms, is available.

WHO SHOULD ATTEND?

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

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

CONFERENCE VENUE

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

The Renaissance Chicago Downtown Hotel, USA.

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), Czech Republic (CZ), China (CN), Denmark (DK), Finland (FI), France (FR), Germany (DE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), South Korea (KR), Sweden (SE), Switzerland (CH), the United Kingdom (UK), and the United States (US).

Bold, red text indicates Operating Agent (Project Leader).

Finalized 2022

NEW

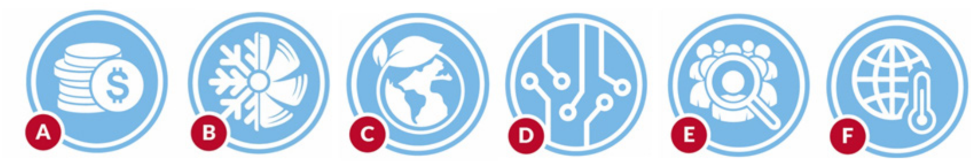
Letters A-F in right column, indicates which of the selected RDD&D areas in the strategy of HPT TCP the Annex is linked to, see below.

HEAT PUMPS IN MULTI-FAMILY BUILDINGS FOR SPACE HEATING AND DHW	50	AT, CH, **DE**, DK, FR, IT, NL	A
LONG TERM PERFORMANCE MEASUREMENT OF GSHP SYSTEMS SERVING COMMERCIAL, INSTITUTIONAL AND MULTI-FAMILY BUILDINGS	52	DE, FI, NL, NO, **SE**, US, UK	A, B
ADVANCED COOLING/REFRIGERATION TECHNOLOGIES DEVELOPMENT	53	CN, DE, IT, KR, **US**	B
HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS	54	AT, DE, FR, IT, JP, KR, SE, **US**	F
COMFORT AND CLIMATE BOX	55	AT, BE, CA*, CH*, CN, DE, IT, **NL**, SE, TR*, UK, US	A, B
INTERNET OF THINGS FOR HEAT PUMPS	56	**AT**, CH, DE, DK, FR, NO, SE	D
FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI-VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS	57	AT, DE, **DK**, FR, NL, SE	C
HIGH-TEMPERATURE HEAT PUMPS	58	AT, BE, CA, CH, CN, DE, **DK**, FI, FR, NL, NO, JP,	E
HEAT PUMPS FOR DRYING	59	**AT**, CH, DK	E
RETROFITTING HEAT PUMP SYSTEMS IN LARGE NON-DOMESTIC BUILDINGS	60	**UK**, AT, IT, NL	A, B
HEAT PUMPS IN POSITIVE ENERGY DISTRICTS	61	AT, DE, JP, **CH**, US	A, B,C

*) Participates from Energy Storage TCP

Selected areas for RDD&D activities in HPT TCP (2023-2018)

RDD&D-Research, Development, Demonstration and Deployment



ANNEX

50

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

INTRODUCTION

The perception of heat pumps by the policy- and lawmakers has changed significantly in favour of heat pumps as a solution for the decarbonization of heating in the housing sector. New strategies to reach climate neutrality point to heat pumps as the key solution.

Most heat pumps installed in Europe are dedicated for single-family houses. Heat pumps must also be installed in multi-family buildings (MFB) to reach the goals mentioned in the previous paragraph. The analyses completed within Annex 50 show that a lack of knowledge is one of the major barriers of a broader application of heat pumps in multi-family buildings. Both on the side of owners of the buildings or apartments, as well as investors.

The diversity of the multi-family buildings is significantly higher than in the case of single-family buildings. This results in more numerous and complex solutions which can be implemented for covering the heating demand and domestic hot water needs. Consequently, the choice of the most appropriate solution is a much more difficult task.

MAIN OBJECTIVES

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

PROGRESS AND KEY RESULTS

The approach of the Annex 50 was to find the way to create a holistic (integrated) method of presenting its results, as well as to work on all Tasks simultaneously. The result of this approach is a "solutions matrix" (see Figure 1).

> ***"The use of heat pump systems in apartment buildings is possible and already practiced. Nevertheless, there is still no evidence of a wider use of this solution. More standardized solutions are needed."***

Each part of the matrix can be used or presented as a stand ing-alone component and is connected to a specific Task of the Annex.

A general classification of heat pump solutions for multifamily residential buildings was elaborated. The solutions are described in a standardized way according to eight representative categories. Overall, 13 solutions were identified, ranging from a fully centralized system to a completely decentralized system. The solutions were grouped into five "families", each grouping specific sub-solutions. The purpose of the solution matrix is to give guidance to designers, planners and installers.

The aim of the Annex was not only to classify and describe possible solutions of heat pumps in multi-family buildings but also to clearly show that heat pumps are already working in a significant number of multi-family buildings across participating countries. Parallel to the theoretical classification of the solutions, numerous case studies representing implementation of heat pumps in multifamily buildings were collected. The cases show a wide variety of possibilities for the use of heat pumps. To reflect the holistic approach and to illustrate the practice, each case study is connected to a corresponding solution in the solution matrix.

OUTLOOK

The description of the proposed "solution matrix" should rather be seen as a framework prepared for further elaboration than as an accomplished task. Each description is a compromise between various views of the involved Annex partners. In some cases, a specific national perspective results in a different view on the topic. It is recommended to open the discussion about the characteristic of each concept to the broader audience.

The case studies database should be regarded as a well-established tool with a large expanding potential. The collected cases explicitly show the applicability of heat pumps in multi-family buildings. The database should be further developed with more case studies in order to reach its full potential.

The work of the Annex 50 will continue and build upon the results already achieved in the frame of the new Annex 62, "Heat pumps for multi-family residential buildings in cities".

FINAL REPORTS ANNEX 50

The following documents are available for free download on the IEA HPT Annex 50 website:

Miara, M. et al. 2022, ***Final Report Annex 50: Heat Pumps in Multi-Family Buildings for Space Heating and Domestic Hot Water, Technology Collaboration Programme on Heat Pumping Technologies*** (HPT TCP), Report no. HPTAN50- 1, 2022

Executive Summary Annex 50: Heat Pumps in Multi-Family Buildings for Space Heating and Domestic Hot Water (DHW)

2-page summary Annex 50: Heat Pumps in Multi-Family Buildings for Space Heating and Domestic Hot Water (DHW)

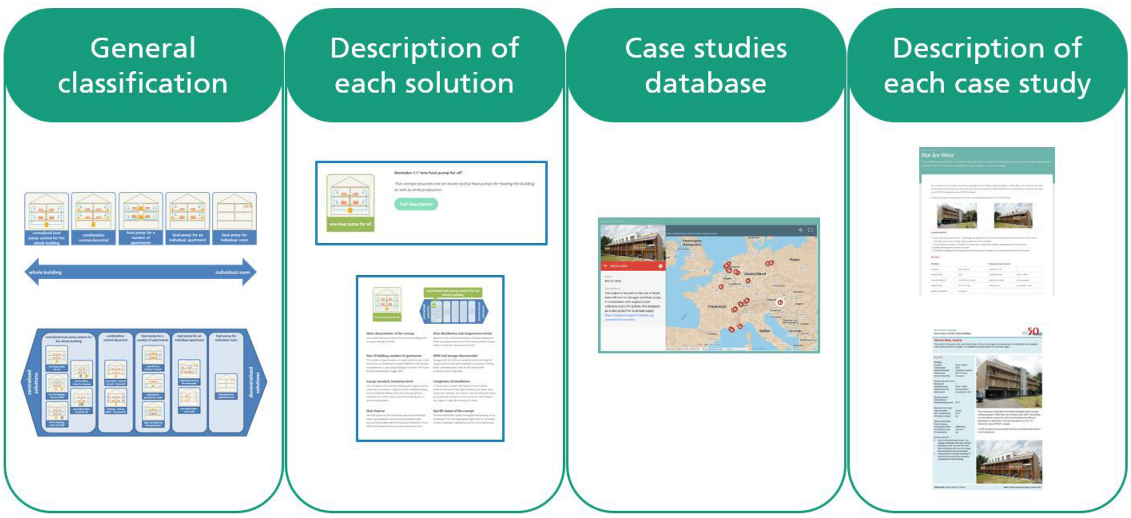


Figure 1. Main elements of the "solutions matrix", the holistic result of the Annex 50, Source: Annex 50.

Project duration:
January 2017 – June 2021

Operating Agent:
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marek.miara@ise.fraunhofer.de

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

Further information:
www.heatpumpingtechnologies.org/annex50

ANNEX
52

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

INTRODUCTION

Carefully instrumented and analyzed long-term performance measurements from large 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 has revised 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 provided 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.

> ***All in all Annex 52 has resulted in 33 case study reports and other reports, seven journal papers and 14 conference papers.***

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.

RESULTS

Annex 52 finished in December 2021. 24 case study reports are completed and published on the Annex 52 website. An additional 6 reports, including the Final Report, have been uploaded in 2022. See Figure 1

Annex 52 finished in December 2021. 24 case study reports are completed and published on the Annex 52 website. An additional 6-10 reports have been uploaded in 2022.

Results for 26 projects with 119 years of data in total have been collated. Not all projects can measure at the same boundaries, but 12 projects with 59 years of data have measurements for boundary 2, which includes the ground heat exchanger and heat pump(s). Seasonal performance factors within this boundary for heating and cooling together (SPFHC2) are in the range 1.4-12.6, with an average of 4.6. 80% of the project years have SPFHC2 of 3 or higher, and 34% of the project years have SPFHC2 of 5 or higher. One German building with 14 years of data that makes significant use of direct cooling from the ground has an average SPFHC2 of 8.2, and it has increased over time from an SPFHC2 of about 6 to 12.8 for the last two years of measurements.

Two guideline documents, for instrumentation and data and for calculation of uncertainties, are published on the website. A third guideline for key performance indicators other than SPF and COP was completed at the beginning of 2022. The annotated bibliography that has been compiled within the Annex contains 82 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.

The final results from Annex 52 were presented at the IEA HPT Exco Meeting in Oslo in May 2022. A webinar presenting the overall results from Annex 52 was conducted in the spring of 2022, and the presentations and recording are available from the website.

A conference paper with results from five years of measurements from the Studenthuset building in Stockholm was presented at the Clima 2022 conference in May, a paper concluding the entire Annex 52 work was presented at the European Geothermal Congress 2022 in October, and a paper comparing the results from a centrialized and a distributed GSHP system was presented at the IGSHPA Conference Research Track 2022. A summarizing paper about the Annex 52 work was submitted to HPC 2023 in 2022. Two technical articles about Annex 52 results have been published in Rehva Journal and Energi & Miljö in 2022 and a follow-up article in Energi & Miljö will be published in early 2023.

All in all Annex 52 has resulted in 33 case study reports and other reports, seven journal papers and 14 conference papers.

FINAL REPORTS FROM ANNEX 52

Gehlin, S., Spitler, J.D. (2022). ***Final report***. IEA HPT Annex 52 – Long-term performance monitoring of GSHP systems serving commercial, institutional and multi-family buildings.

Gehlin, S., Spitler, J.D. (2022). Case Study Summary Report. IEA HPT Annex 52 – Long-term performance monitoring of GSHP systems serving commercial, institutional and multi-family buildings.

Gehlin, S., Spitler, J.D. Witte, H., Andersson, O., Berglöf, K., Davis,M., Javed, S., Bockelmann, F., Turner, J., Clauss, J. (2022). ***Subtask 3 Report – Guide for analysis and reporting of GSHP system performance – system boundaries and key performance indicators (KPI) – Final Document.*** IEA HPT Annex 52 – Long-term performance monitoring of GSHP systems serving commercial, institutional and multi-family buildings.

Gehlin, S., Spitler, J.D. (2022). ***Subtask 1 Report – Annotated Bibliography – Final Document.*** IEA HPT Annex 52 – Long-term performance monitoring of GSHP systems serving commercial, institutional and multi-family buildings.

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

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

A number of case study reports from Annex 52 can be found at the Annex website: ***https://heatpumpingtechnologies.org/annex52/documents/***

2-pages summary of Annex 52 – Long-term performance monitoring of GSHP systems for commercial, institutional, and multi-family buildings

Project duration:
January 2018 – December 2021

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Participating countries:
Finland, Germany, the Netherlands, Norway, Sweden, UK and USA

Further information:
www.heatpumpingtechnologies.org/annex52

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 the development of higher efficiency and reduced greenhouse gas (GHG) emission AC/refrigeration focused HP technologies. Specific areas of investigation include but are not limited to the following:

- » Advance the technology readiness level (TRL) of non-traditional cooling technologies and alternative compression technologies;
- » Independent control of latent and sensible cooling and tailoring systems for different climates (e.g. hot dry or hot humid);
- » Advances to VC-based technologies, both conventional and non-traditional.

MEETINGS

- » 23-24 February 2022, virtual meeting – Progress to-date on Task 2 activities summarized.
- » 1 December 2022, virtual meeting – Progress to-date on Task 2 and Task 3 activities summarized.

PROGRESS HIGHLIGHTS

Korea's Annex 53 team has been developing a membrane heat pump system which includes two major processes, dehumidification and refrigeration. The dehumidification system consists of two parallel chambers separated by the membrane and a vacuum pump that assists in removing the moisture. The water vapor of wet air in the feed chamber is transported to the permeate chamber through the membrane, driven by the vapor concentration gradient due to the vacuum pump connected with the permeate chamber.

The membrane used in this experiment is a hydrophobic polyurethane (PU)-based dense membrane which has a non-ionic water vapor channel composed of silica particle clusters. Silica particle with 150 nm in size is surface-modified with a Silane coupling agent to control dispersion in the PU membrane. The membrane contains 4.8 wt% of silica particles, and its thickness was about 10 micron. The water vapor transport rate according to the ASTM-E96 method (Desiccant method, 38°, 90%) is measured to about 150 g/m2h.

The Korean team has measured the outlet humidity and the water vapor transport rate, the mass of vapor permeated through the membrane, under various experimental conditions of different feed flow rates and feed chamber heights. In addition, a theoretical analysis, combining mass transport theory and volume conservation of an infinitesimal control volume, has been established to estimate the outlet humidity and the water vapor transport rate. The experimental data are entirely consistent with the behaviour predicted by theory.

China's Annex 53 team at Tsinghua University developed an ultra-efficient air conditioner using multi-stage compression, smart evaporative cooling ventilation, and a photovoltaic panel.. A rotary compressor with triple suction ports was used to achieve the three-stage compression. For the condensers, water is pumped and sprayed on the fin-and-tube condenser, and outdoor air flows through the fin-and-tube heat exchanger and the microchannel heat exchanger. For the evaporators, the high-temperature evaporator handles part of sensible heat, while the low-temperature evaporator absorbs the remaining sensible and latent heat. A mechanical ventilation fan with a wet-membrane humidifier was used to provide fresh and cool air to the indoor environment. In addition, a photovoltaic (PV) panel is integrated into the system to provide auxiliary energy to the compressor.

The air conditioner prototype was designed to meet the Indian energy standard. Through a typical 10-day lab-simulated year-round performance test, the calculated annual power consumption of the prototype air conditioner was 746.2 kWh, which was 82.8% lower than that of the baseline prototype.

The US Annex 53 team at the University of Maryland has been advancing elastocaloric (EC) cooling technology. On-going research aims to develop a device that can achieve 50-100 K total temperature gradient and provide up to 100 W of cooling capacity for every 200 g of elastocaloric material. To date the research team has made significant efforts on two EC systems. The first is a nearly 1 kg setup that is under development (Figure 1). Model estimates suggest that it can provide both significant useful cooling and cooling capacity.

The other EC system boasts a modular multi-stage design with a 50 x 50 mm footprint (Figure 2). Simulation suggests temperature lifts of up to 37 K for a four-stage device, and currently 27.2 K has been achieved experimentally for a three-stage prototype.

The US Annex 53 team at Ames Laboratory has been developing magnetocaloric (MC) cooling technology, which has the potential to be as much as 30% more energy efficient than vapor compression (VC) systems. By focusing on using magnetic fields that are easily produced with simple permanent magnet arrays and operating at frequencies exceeding the typical 1-4 Hz to boost cooling power density, the system developed by the Ames Laboratory research group demonstrated the potential to meet or exceed design and cost targets. In the demonstration cooling system, a spinning magnet produces alternating magnetic fields on the AMR beds and fluid flow is coordinated with the magnetic field profile so that the regenerator absorbs heat from a load at the cold heat exchanger and expels heat to the hot side heat exchanger.

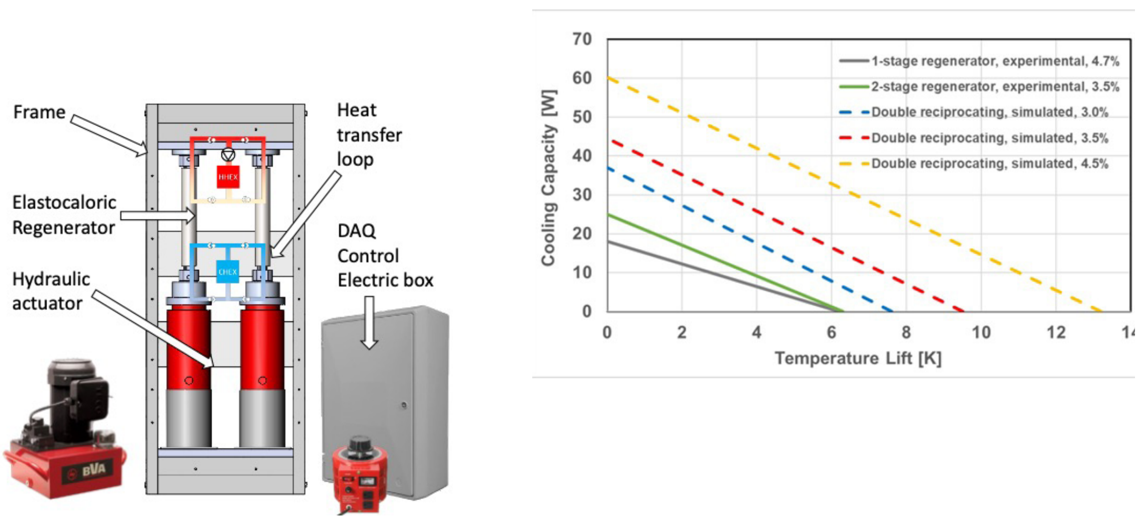

Figure 1: (Left) Elastocaloric single and double reciprocating schematic; (Right) Simulation results of cooling capacity and useful temperature lift generated by different EC configurations

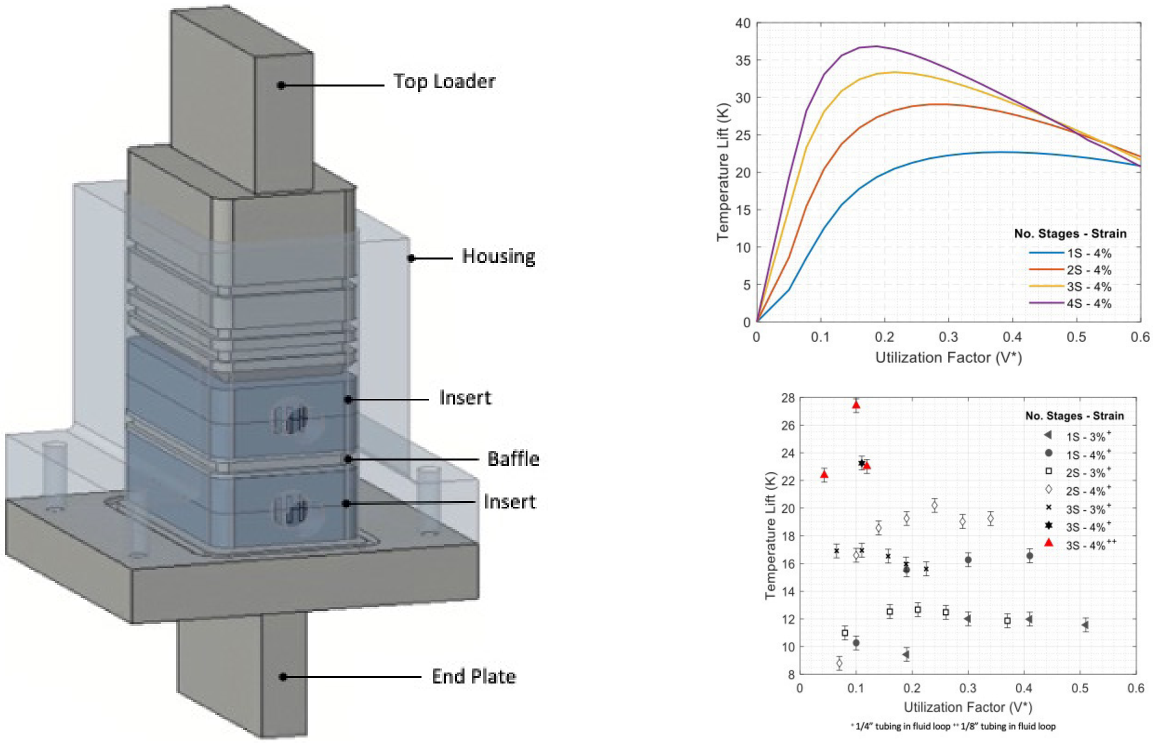

Figure 2: (Left) Model of a two-stage active elastocaloric regenerator; (Top Right) Simulated results for single and multi-stage EC devices; (Bottom Right) Experimental results for one-stage, two-stage, and three-stage prototypes at 3% and 4% applied strain

The full system hardware has been assembled and measurements of the magnetic field have been made. Next steps in characterizing the system are to fill with heat transfer fluid and measure no-load temperature spans. These initial tests will be used to verify that the valves and fluid flow timing are operating as expected. Full characterization of the system with different loads and ambient temperatures will be performed to validate model results and demonstrate the technical feasibility of a high-power density system and, therefore, economic feasibility of magnetocaloric cooling technology.

The progress from the chinese team at the Tsinghua university can be summarised as follows: An integrated construction method of vapor compression cycle and heat exchanger network, named GraPHsep, was developed to automatically realize selecting the refrigerant, constructing the refrigeration cycle, and constructing the medium heat exchanger network. It could be an AI tool for the optimization design of thermal systems with multiple heat sources and heat sinks. The perfect-temperature-matching vapor compression systems based on zeotropic refrigerants, concentration adjustment, and evaporating pressure improvement were proposed, simulated, and experimentally tested. The results showed a performance increase but not as predicted. The additional investigation will be conducted continuously.

The US team at the AMES national laboratory used models team used models and hardware to demonstrate system-level performance of high–power density MC devices using gadolinium-based MC materials. Models and limited experiments show MC cooling achieves more than 500 W/kg power density based on MCM material mass at a 10 K temperature span. Most recently, we compared system-level cooling power density of our device and scaled-up MC devices to off-the-shelf compressors. MC devices showed equivalent or higher power density up to ~500 W and, with future advances in MC materials and active regenerators, are projected to meet the power density of compressors up to nearly 10kW.

The progress from the team at CITY HONG KONG University can be summarised as follows:Various absorption thermal energy storage cycles were comprehensively compared. The compression-assisted cycle achieved a maximum energy storage efficiency of 1.53, the double-effect cycle obtained a maximum energy storage density of 365.4 kWh/m3, the basic cycle yielded a maximum exergy storage efficiency of 0.61. Novel CO_2/ionic liquids were investigated in transcritical absorption heat pumps, with CO2/[OMIM][Tf2N] identified to maximize the cycle performance after pressure optimization. Equipping an expander further improved the COP by 11.9%. A microchannel membrane-based desorber using H2O/LiBr was experimentally studied. Heat transfer, mass transfer, and pressure drop were correlated with prediction accuracies improved by 39%, 63%, and 78%.

> ***Global action, both short-term and long-term, is urgently needed to encourage the development of high-efficiency and low-GWP AC and refrigeration heat pump (HP) technologies.***

The progress from the team at FRAUBHOFER Institute Germany can be summarised as follows: A previously published model for first-order magnetocaloric materials was adapted to elastocaloric materials. Based on this material model, the maximum attainable efficiency of a caloric cooling system can be estimated, assuming a carnot-like thermodynamic cycle and neglecting heat losses. This model was then incorporated in system simulations of the active elastocaloric heat pipe, enabling the quantification of thermal losses in a cooling system and thus giving the chance for further optimization. Besides this, the concept of latent heat transfer for caloric cooling was successfully also demonstrated for an electrocaloric system (publication in preparation).

The progress from the Chinese team at Xian Jiatong University can be summarised as follows: In 2022, we have demonstrated an electrocaloric tubing refrigerator. The EC material were made into a shape of tube, with metalized inner and outer wall. Heat exchange fluid can running inside the tube in one direction. The heated and cooled fluid during the heating and cooli processes of the EC tube was accumulated in separated pools as heat sink and heat source, respectively. The EC capillary tube exhibited a maximum DT of 3.53 K under the applied electric field of 108.7 MV/m. The cooling capillary tube continuously flowing silicone oil achieved a maximum Tspan of 1.5 K.

The mechanical driven elastocaloric refrigerator prototype has been upgraded to two-stage architecture using NiTi plates instead of NiTi wire assembly. The system was expected to achieve up to 24 K temperature span and maximum 3 W cooling at zero span. 2. A single-stage tubular elastocaloric regenerator was assembled and tested using 3 mm NiTi tubes. The regenerator featured 25.4 K maximum temperature span and 9 W cooling at zero span. Two-stage and three-stage regenerators have been assembled. 3. The heat driven elastocaloric cooling prototype was finalized after eight versions of trials over the past two years. The actuator consisted of three independent NiTi actuator wires and a single superelastic NiTi wire was used as refrigerant. At 100°C driving temperature, the refrigerant wire achieved 5 K temperature change. The temperature span between the heat sink and low-temperature heat source will be tested soon.

The progress from the US team at University of Maryland can be summarised as follows: Elastocaloric solid-state refrigerants have a lower environmental impact compared to conventional vapor compression refrigerants, but they require significant advancements to gain widespread implementation. We conducted experimental tests with a single-stage device and identified fluid-solid ratio, cycle time, and applied strain as key factors affecting thermal response. Test results for the regenerator yielded a maximum steady-state temperature span of 16.6 K at 4% strain and under zero load conditions, over two times larger than the baseline value. The tubes also withstood over 30,000 cycles without failure.

Reinhard Radermacher

Project duration:
October 2018 – December 2022

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ANNEX
54

HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS

INTRODUCTION

Low-GWP refrigerants are considered long-term solutions for environmentally friendly heat pump systems. Considerable studies have shown that design modifications are necessary to optimize low-GWP refrigerants. In particular, system-level design, analysis, and optimizations are much needed. Annex54 aims to address the challenge via 1) a comprehensive review of recent R&D progress on component- and system-level design, analysis, and optimization using low GWP refrigerants, 2) in-depth case studies of system-level optimization, which can provide design guidelines and real-world experiences, 3) review of design optimization and advancement impacts on LCCP reduction, and 4) outlook for 2030. All the efforts are accomplished by academic and industrial participating countries. The work can be a valuable reference for researchers, engineers, and policymakers across the HVAC industry. It is of particular interest to those to dive deep into the R&D of heat pump systems.

OBJECTIVES

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

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

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

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

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

» Making an outlook for heat pumps with low-GWP refrigerant for 2030 (partially fulfilled)

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

MEETINGS

Workshop

Annex 54 hosted two workshops on 1) June 13 during the 15th IIR-Gustave Lorentzen Conference, 2) October 10 during the Chillventa Conference. During the workshops, experts from Annex 54 participating member countries presented low-GWP refrigerants utilizing technologies for residential heat pumps (air-to-air, water-to-water, and ground source heat pumps), and heat pump water heaters. Details of workshops presentation materials are available from the ***Annex 54*** website.

Business meeting

Annex 54 hosted one onsite meeting and one online business meeting through email communications. In the communications, we discussed the overall Annex schedule, 2022 and 2023 tasks, and future workshops.

RESULTS

In 2022, we achieved considerable progress in the following two areas: 1) Task 2: case studies and design guidelines for optimizing heat pump systems using low GWP refrigerants. 2) Task 3: a review of design optimization and advancement impacts on life cycle climate performance (LCCP) reduction. The work can be a valuable reference for researchers, engineers, and policymakers across the HVAC industry. The progress accomplished by participating countries is described below.

The research groups in the U.S.A. reported the activities related to flammable refrigerants and heat exchanger optimization. Wang (AHRI, 2022) reported leakage and ignition testing from PTAC and mini-split systems with R-290 and R-452B in a whole room scale, which was conducted under the AHRTI's Flammable Refrigerant Research Project 9007. Nawaz (ORNL,2022) experimentally investigated the performance of the R-290 in a heat pump water heating application and concluded that R-290 is a feasible alternative for residential HPWHs. Aute (University of Maryland, 2022) provided the next-generation heat exchanger design framework and summarized 5.3 kW condenser optimization works for R-32 and R-454B and concluded that shape-optimized flow channels have the potential to reduce the size/weight of heat exchangers by 25%, and refrigerant charge by 30%.

Several research groups in German collaboratively summarized the heat pump market survey; integrated fluid screening and evaluated the SCOP of HCs, HFOs, and mixtures. Oltersdorf (2022, Franhofer ISE) reported the most recent findings on the heat pump (HP) market development in Germany, technical trends, and characteristics of the market-available HPs. Hoges (2022, RWTH Aachen Univ.) investigated HCs and HC mixtures in residential heat pumps and concluded that the HC mixture was only beneficial in the internal heat exchanger cycle. Vering (2022, RWTH Aachen Univ.) provided an overview of suitable heat pumps depending on the refrigerant (from the bottom), and SCOP evaluation.

Azzolin (2022, University of Padova, Italy) reported a 5 kW capacity solar-assisted heat pump water heater working with CO2. The heat pump was experimentally evaluated with a finned coil evaporator and with three PV-T evaporators. Using a finned coil evaporator was beneficial for the high compressor speed, and three PV-T evaporators were beneficial for the low compressor speed.

Codella (2022, Chemours, Italy) compared energy efficiency, emission, and cost aspects of R410A alternatives: R32, R454B, and R454C for residential heat pump applications. HFO refrigerants (R-454B and R-454C) showed higher energy efficiency, lower electrical energy consumption, lower annual cost and lower direct emission (-92,9%) and indirect emission (-15,3%) than R-410A.

Palm (2022, KTH, Sweden) provided the details of the Swedish heat pump market, from smaller residential units to larger residential and commercial units. He also shared case studies and design guidelines for the optimization of components and systems, including a geothermal R290 heat pump for multifamily buildings (EBOX), a CO2 system for heating and cooling the commercial building, and an R290 heat pump and chiller for the process cooling and heating. He also shared his experiences using automotive compressors

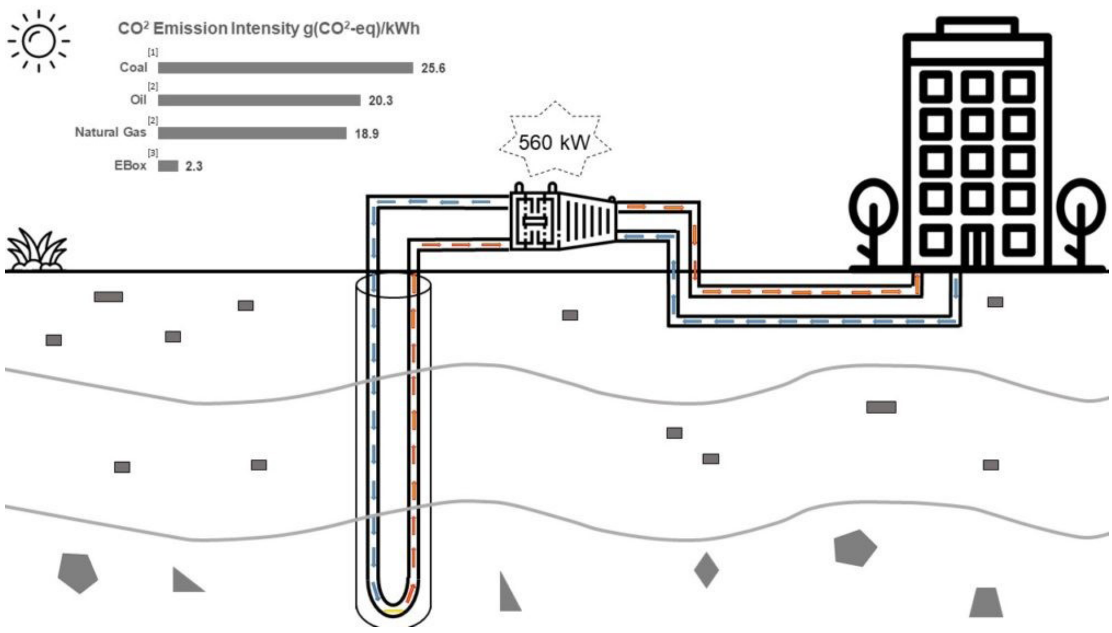

Figure 1: Principle of EBox-Geothermal R290 Heat Pump.
(Source: https://megawattsolutions.se)

for stationary applications with hydrocarbon refrigerants. The research was focused on charge distribution and charge minimization.

Zach et al. (2022, Austria) identified low GWP refrigerants and provided an overview of the Austrian heat pump market and examples of low GWP refrigerants in applications other than domestic heat pumps. Verdnik et al. (2022, Austria) provided design guidelines for optimization of components and systems of R-290 heat pumps. Zach F. et al. (2022, Austria) made an estimation for the developments of the Austrian heat pump market until 2030 with a focus on residential and commercial heat pumps. It can be seen that the heat pump market will increase from about 31,000 systems in the heating sector in 2021 to about 80,000 to 100,000 systems in 2030.

Project duration:
January 2019 – December 2023

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www.heatpumpingtechnologies.org/annex54/

ANNEX 55

COMFORT AND CLIMATE BOX

INTRODUCTION

The pace and scale of the global clean energy transition is not in line with climate targets. Energy-related carbon dioxide (CO2) emissions rose again in 2018 by 1.7%. The buildings sector represented 28% of those emissions. The growing global need for thermal comfort is a large contributor to emissions of greenhouse gases worldwide, and the transition to renewable energy is too slow.

Technology can reduce buildings emissions while improving comfort and energy services. Multiple cost-effective technologies unleash average energy savings of 500 Mtoe per year in the buildings sector worldwide between 2020 and 2050. To meet the needs of the future, new innovative thermal comfort solutions need to be developed. Heat pumps cut typical energy use for heating by four or more. Integrated systems consisting of heat pumps and storage are an important technological option in order to accelerate the use of renewable energy for heating and cooling. By combining heat pumps and storage, several issues are addressed, such as:

- Balancing and controlling electricity grid loads.
- Capturing a large (or larger) share of renewable (local/regional) power input (e.g., solar thermal, solar PV).
- Optimizing economics, CO2 emissions, total fuel use over time.
- Providing optimal supply security to buildings

This was the first Annex to integrate the work from the TCPs Heat Pumps (HPT) and Energy Storage (ES), building upon the earlier work in the fields of Heat Pumps and Storage systems.

COMFORT & CLIMATE BOX (CCB)

The central concept in Annex 55 was the Comfort and Climate Box (Figure 1), a concept that denoted the combined package, consisting of a Heat Pump, an Energy Storage Module and Controls. This package formed an actual physical unit but also consisted of separate modules that formed an integrated 'virtual package', where all components of the CCB had been designed to work together in a modular fashion and should be operated under a dedicated and optimal integrated control strategy.

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

OBJECTIVES

The objectives of Annex 55 were to accelerate the market development of Climate and Comfort box solutions. The technical challenge was the smart combination of different technologies in one system. Specialists from various fields of technology are required and needed to cooperate in order to accelerate product development and market introduction of combined heat pump/storage packages: The Comfort and Climate Box (CCB). The goal was to develop nearly market-ready systems, including, as a minimum, a heat pump and a storage system.

KEY FINDINGS

- Comfort & Climate Box (CCB) developments has shown the differences in market status, technical boundary conditions and priorities in quality criteria in the participating countries. From this, we can conclude that a one size fits all approach for CCB's will not work.
- In research projects and field trials, there seems to be a shift away from efficiency toward other quality criteria that are indicators for the game changers for the local re-

quirements like compactness, affordability and flexibility. The latter making an integrated-box-type solution, its integration in the grid a promising type of technology.

» The gaps in current standardization and testing procedures that could benefit the up-scaling of integration of CCB's are identified, and solutions are proposed. A road map for policy makers and other stakeholders has been presented.

» The development of energy modules by more than ten different companies in the Netherlands shows that it is technically and commercially viable to bring integrated solutions to the market that offer other benefits than purely efficiency. In the near future, we hope to see more local developments like these that answer the local demand for integrated comfort and climate box solutions.

FINAL REPORTS FOR HPT ANNEX (ES TCP TASK 34)

IEA HPT Annex 55 ***Final Report – Comfort & Climate Box – towards better integration of heat pumps and storage***

IEA HPT Annex 55 ***Executive Summary – Comfort & Climate Box – towards better integration of heat pumps and storage***

IEA HPT Annex 55 ***2-page Summary – Comfort & Climate Box – towards better integration of heat pumps and storage***

Final Report Part 2 IEA HPT Annex 55 – ***Market Status in Participating Countries***

Final Report Part 3 IEA HPT Annex 55 – ***Field Trial Results***

Final Report Part 4 IEA HPT Annex 55 – ***Technical Boundary Conditions in Participating Countries***

Final Report Part 5 IEA HPT Annex 55 – ***Research Projects***

Final Report Part 6 IEA HPT Annex 55 – ***Standards***

Final Report Part 7 IEA HPT Annex 55 – ***Roadmap***

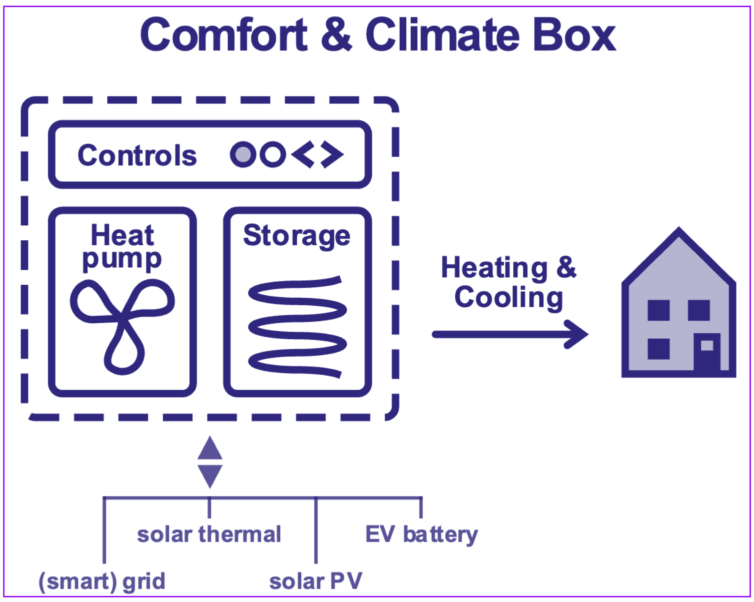

Figure 1. The possible components of a CCB

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

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

ANNEX

56

INTERNET OF THINGS FOR HEAT PUMPS

INTRODUCTION

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

> ***In the energy transition, digital technologies are intended to enable flexible energy generation and consumption.***

The IoT Annex explores the opportunities and challenges of connected heat pumps in household applications and industrial environment. There are a variety of new use cases and services for IoT-enabled heat pumps. Data can be used for preventive analytics, such as what-if analysis for operation decisions, predictive maintenance, fine-tuning of the operation parameters and benchmarking. Connected heat pumps allow for demand response to reduce peak load and to optimize electricity consumption, e.g. as a function of the electricity price. Digitalization in industry can range from automated equipment, advanced process control systems to connected supply value chains. IoT-enabled heat pumps allow for integration into the process control system and a higher-level energy management system, which can be used for the overall optimization of the process.

Each level of participation of a heat pump in a connected world (Figure 1) is also associated to different important risks and requirements to connectivity, data analysis, privacy and security for a variety of stakeholders. Therefore, this Annex has a broad scope looking at different aspects of digitalization and will create a knowledge base on connected heat pumps. The Annex will provide information for heat pump manufacturers, component manufacturers, system integrators and other actors involved in IoT.

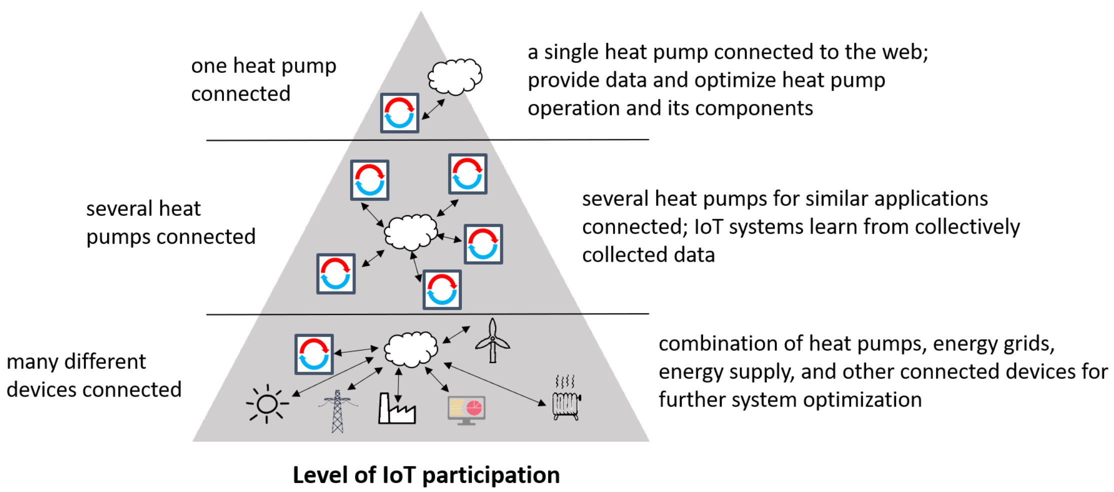

Figure 1. Heat pumps as a part of the Internet of Things (source: AIT Austrian Institute of Technology GmbH)

OBJECTIVES

- » Provide guidance, data and knowledge about heat pump technologies with respect to IoT applications
- » Review the status of currently available IoT-enabled heat pumps, heat pump components and related services
- » Identify requirements for data acquisition from newly designed or already implemented heat pump systems considering types of signals, protocols and platforms for buildings and industrial applications and related privacy issues and ongoing standardization activities
- » Evaluate data analysis methods and applications (digital twins), including machine learning, semantic models, hybrid models, data-driven models and soft sensors
- » Analyse business models for IoT enables heat pumps (strengths, weaknesses, opportunities, threats)
- » Evaluate market opportunities created by IoT-enabled heat pumps and identify success factors and further demands to software and hardware infrastructure.

MEETINGS

- » 02.02.2022, online meeting with 6th Deep Dive Session on Hardware in the loop and digital twins, outlook on heat pumps of the future in France, interactive group work on SWOT analysis for business models
- » 28.04.2022, online meeting with 7th Deep Dive Session on Safety and security for connected heat pumps, work on task on State of the Art and on Interfaces and protocols
- » 21.06.2022, online meeting with 8th Deep Dive Session on Digital Twins, group discussion on all tasks to align activities
- » 4.10.2022, online meeting with 9th Deep Dive Session on digital operation analysis and digital building twin, another expert presentation on cyber security, interactive group work on SWOT analysis for business models, further work on all tasks
- » 29.11.2022 – 30.11.2022, meeting at Fraunhofer ISE in Freiburg, 10th Deep Dive Session on Intelligent Buildings, group work on communication protocols and interfaces, lab tour and further work on all tasks

RESULTS

State of the Art: More than 25 examples of IoT applications, projects and services have been collected and were described in dedicated fact sheets. The Danish team has submitted a large number of cases. A survey has been conducted among Austrian manufacturers to evaluate the general sentiment on the relevance of interconnected heat pumps, state-of-the-art use cases, market availability and selected technology trends. It indicates significant progress in technology implementation.

Business Models: A SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis was carried out in an interactive group work with the participants of the IoT Annex project. Three IoT-based heat pump business models were compared to the traditional, non-connected business models:

- » Predictive maintenance vs Fixed Interval / on-demand maintenance
- » Heat as a service (outcome-based) vs traditional model
- » Providing flexibility with heat pump pooling vs using a heat pump as an autonomous component in a building

For each pair of business models, the analysis was carried out for the most important stakeholders, such as consumers, heat pump manufacturers, vendors, installers, aggregators, suppliers, etc. The analysis will be published in the Task 4 report, together with insights into IoT-based business models and services that are already implemented.

Networking: We reached out to related annexes in other technology collaboration programs, such as to IEA SHC Task 68 (Efficient Solar District Heating Systems) and IEA DHC Annex TS4: Digitalisation of District Heating and Cooling (Optimised Operation and Maintenance of District Heating and Cooling systems via Digital Process Management).

Project duration:
January 2020– December 2022

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https://heatpumpingtechnologies.org/annex56/

ANNEX 57

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

INTRODUCTION

Since the start of 2022, the need and interest regarding flexibility and smart control of heat pumps have been growing rapidly, as the implementation rate has increased very fast due to the accelerated phase-out of gas in Europe. The energy prices have grown in this period, but also the variation in the hourly spot market price for electricity is changing a lot. This means that the consumers are trying to move the electricity consumption away from the peak price hours very fast.

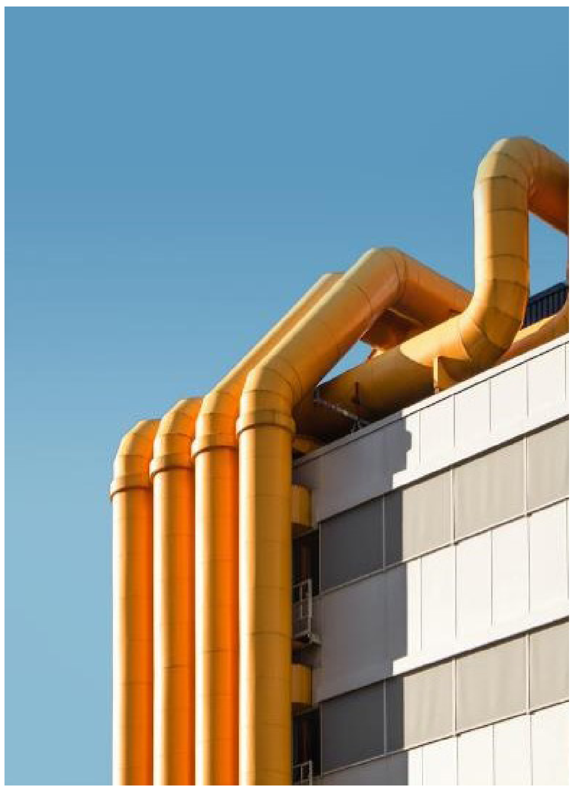
The high implementation rate regarding heat pumps in Europe means that the need for moving consumption has increased, both due to electricity price variation but also due to the need to minimize grid constraints

Annex 57 focuses on coming technologies, and the possibilities of heat pumps to increase the flexibility in energy systems with different sources such as PV, wind-power, and biomass and where end users can be consumer or prosumer or both (Multi-Vector). Individual heat pumps, as well as heat pumps in a district or local grid, can increase the flexibility.

The CO2 reduction goals mean the need for using excess heat from industries, the commercial sector and other sources are growing. Heat pumps, combined with District Heating, are a way to make these energy sources available in buildings. At the moment, the interest in heat pumps for district heating and processes is growing. District heating, in general, and heat pumps connected to the grids, in particular, are predicted to play a key role in the energy grid and supply for the future. With the implementation of district heating, it is possible to cover up to 50% of the heating demand in Europe, and heat pumps can deliver around 25 % of the energy to the district heating grid. The Heat Roadmap Europe 4 scenarios, with a larger share of district heating in the energy system, show that CO2 emissions can be reduced by more than 70 % compared to today's situation.

OBJECTIVES

- Task 1: Energy market analysis – Future developments and sector coupling.
- Task 2: Best practice examples – Description of existing projects with flexible solutions with heat pumps in thermal grids
- Task 3: Concepts – development of representative and promising solutions
- Task 4: Flexibility – Assessment and Analyses of different options
- Task 5: Business models – Development and evaluation of innovative concepts
- Task 6: Dissemination



MEETINGS

Meetings: We have had online meetings regularly: 4 times in 2022 and a physical in Aarhus on November 22-23.

Workshop: Preparation and coordination of a workshop at the IEA Heat Pump Conference in Chicago in May.

RESULTS AND RECENT PROGRESS

France joined in 2022, and the participating countries are, at the moment, Austria, Sweden, Germany, The Netherlands, France and Denmark. Flexibility from individual heat pumps has been integrated into the annex.

» Task 1 is still in progress. National reports from Austria and Sweden are finalized. We are expecting a report from Aalborg University this year; they are conducting simulation studies regarding flexibility for different countries.

» Task 2 is in full progress. 32 cases are in our case list, and 11 of these are regarding individual heat pumps; the templates are made with both a short description and a detailed description; we expect to finalize the descriptions within a month. 11 Cases are described

» Tasks 3: The frame and content of the report is made.

» Task 4 and 5: The frame and content is stated.

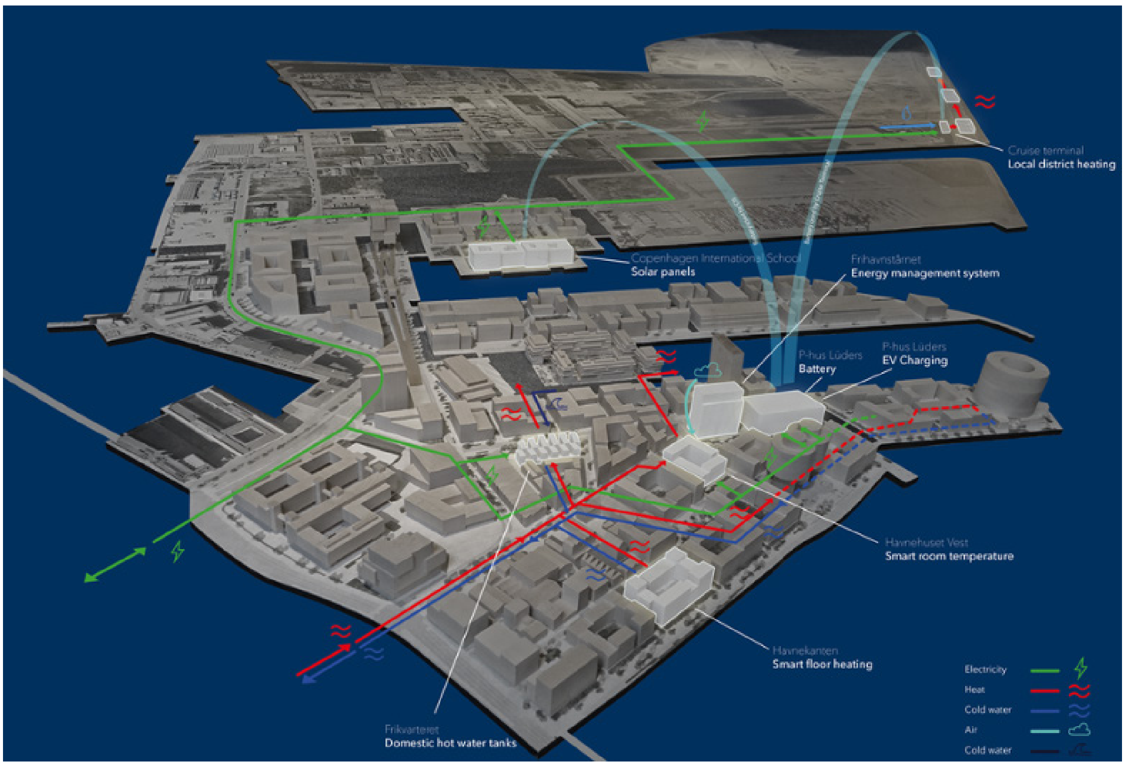


Figure 1. Integrated energy sytems in EnergyLabs Nordhavn

Project duration:
January 2021 – December 2022

Operating Agent:
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Participating countries:
Austria, Denmark, France, Germany, the Netherlands, Sweden

Further information:
www.heatpumpingtechnologies.org/annex57

ANNEX
58

HIGH-TEMPERATURE HEAT PUMPS

INTRODUCTION

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

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

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

This will be achieved by the following sub-objectives:

- » Provide an overview of the technology, including the most relevant systems and components that are commercially available and under development (Task 1 – Ongoing).
- » Identify technological bottlenecks and clarify the need for technical developments regarding components, working fluids and system design (Task 1 – Ongoing).
- » Present best practice system solutions for a range of applications to underline the potential of HTHPs (Task 2 – Ongoing).

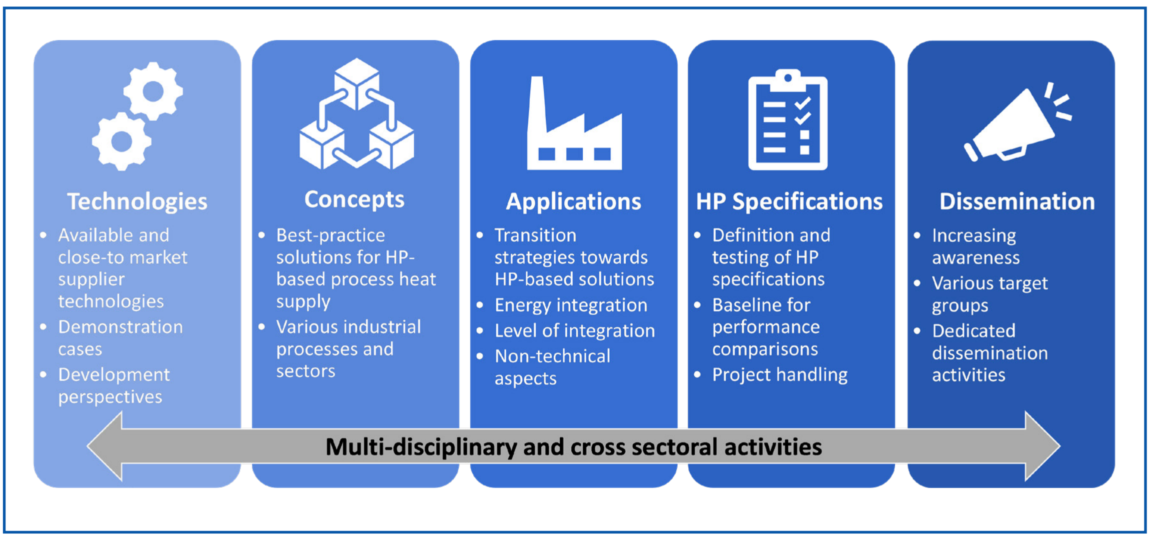

Figure 1. Overview of activities in Annex 58.

- Present strategies for the transition to heat-pump based process heat supply (Task 3 – Planned).
- Enhance the information basis about industrial heat pumps, potential applications and potential contribution to the decarbonization of the industry (Task 1, 2 & 3 – Ongoing).
- Develop guidelines for the handling of industrial heat pump projects with a focus on the HP specifications and the testing of these specifications (Task 4 – Planned).
- Disseminate the findings to various stakeholders and add to the knowledge base for energy planners and policy makers (Task 5 – Ongoing).

MEETINGS

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

- 6th Status Meeting, 18.01.2022, Online Teams Meeting
- The meeting was used to coordinate the work on Tasks 1 and 2.
- 7th Status Meeting, 28.02.2022, Online Teams Meeting
- The meeting was used to coordinate the work on Tasks 1 and 2 and to plan the Annex 58 session at the HTHP Symposium and the 8th status meeting, which will be physical in Copenhagen.
- 8th Status Meeting, 31.03.2022, Copenhagen, Denmark
- The meeting was used to finalize the report of Task 1, to proceed with Task 2 and kick off Task 3.
- 9th Status Meeting, 08.07.2022, Online Teams Meeting
- The meeting was used to coordinate the work on Tasks 1 and 2, and 3.
- 10th Status Meeting, 21.09.2022, Online Teams Meeting
- The meeting was used to coordinate the work on Tasks 1 and 2, and 3.
- 11th Status Meeting, 03.11.2022, Online Teams Meeting
- 12th Status Meeting, 15.12.2022, Online Teams Meeting

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

Deep Dive about heat-driven HTHP technologies, 03.11.2022, Online Teams Meeting

The Deep Dive included presentations from the University of Ghent, DLR, and ORNL on general principles and ongoing R&D activities, as well as a presentation from QPinch, focusing on their state-of-the-art equipment and the commercial perspective.

Deep Dive about the application potential of high-temperature heat pumps, 15.12.2022, Online Teams Meeting

The Deep Dive started with a presentation from the IEA with a focus on the results related to industrial heat pumps from the "Net Zero by 2050 – A Roadmap for a Global Energy Sector" and the report "The Future of Heat Pumps". Furthermore, there were presentations from TNO and OST about studies on the estimation of the application potential. Finally, we concluded the Deep Dive with a comment from Thomas Nowak, EHPA.

RESULTS

High-temperature heat pumps (HTHP) are attracting growing interest and are considered a key technology for decarbonizing industrial process heating. The recently published IEA report "Net Zero by 2050 – A Roadmap for the Global Energy Sector" outlined the importance of industrial heat pumps and concluded that heat pumps should cover 15 % of the process heat demand of light industries at temperatures up to 400 °C, while this share should increase to 30 % by 2050.

This corresponds to a required installation capacity of 500 MW per month over the next 30 years. The majority of these systems are expected to have supply temperatures above 100 °C and are accordingly considered high-temperature heat pumps.

The relevance of high-temperature heat pumps is confirmed by the large interest in the Annex

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

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

By now, 33 supplier technologies were described, while information could be gathered for 14 demonstration cases. These descriptions are published on the ***Annex 58 homepage*** and publicly accessible while the report is in preparation.

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

Project duration:
January 2021 – December 2023

Operating Agent:
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Participating countries:
Austria, Belgium, Canada, China, Denmark, France, Finland, Japan, Germany, Netherlands, Norway, South Korea, Switzerland, USA

Further information:
www.heatpumpingtechnologies.org/annex58/

ANNEX 59

HEAT PUMPS FOR DRYING

INTRODUCTION

Drying processes are widely used in industry, including the food, paper, chemicals, and ceramics industries, as well as in commercial laundries and in household applications, such as white goods. The Handbook of Industrial Drying describes at least 15 different dryer types and identifies more than 20 different industrial drying sectors, making it challenging to generalize about drying technologies.

Drying processes make a significant contribution to energy consumption, accounting for 10-25% of industrial energy consumption. To this day, drying continues to be the main process used in industrial preservation for a large number of products. Industrialization has helped to optimize drying processes, which are conducted under varying, but controlled conditions. However, the basic principle of drying remains the same as it was thousands of years ago, with convective dryers continuing to be the most commonly used type of dryer.

Industrial convective drying plants are mainly operated by burning fossil fuels and product waste. The moisture extracted from the material to be dried is, in most cases, released into the environment in pure gaseous form or with a drying medium (e.g. air, steam). This exhaust air contains high amounts of energy, which is often only partially utilised by heat recovery. Modern industrial drying processes are either an open loop system using heated ambient air, or closed loop systems that re-circulate the drying air.

Heat pumps offer an opportunity to utilize a heat source at low temperatures (at the evaporator) and supply a heat sink at a higher temperature (condenser). In the case of a closed loop drying system, the combined heating and cooling load is used for the recovery of drying energy, which is essentially the latent heat from the water evaporation, returning this energy back into the drying process in the form of dehumidified and re-heated drying air.

> ***"With the help of the work in the Annex, we get insight into the the drying process and thus the data basis for process optimization."***

OBJECTIVES

The use of heat pumps in drying processes show great energy savings potential for the numerous industries reliant on drying processes. Annex 59 will thus explore and evaluate the potential that can be unlocked in a range of applications. Furthermore, the Annex shall seek to undertake the following:

- Collate relevant data of the state of the art of drying processes equipped with heat pumps
- Analyse drying processes at a theoretical level to find the optimal process design (e.g. lowering temperatures), in-process operation (drying time) as well as in heat pump design and integration.
- Gather experience from demonstration projects through monitoring and simulation of the entire drying system
- Make recommendations regarding the design of heat pump drying systems, taking into account performance compared with conventional dryers
- Highlight and review the most promising dryer concepts that can integrate heat pumps

MEETINGS

The Annex just finished its kick-off phase. In summer, the national kickoff in Austria has been held together with the Austrian partner institution AEE – INTEC. On November 7 in 2022, we had the international definition meeting/kickoff with the countries which already handed in a participation letter (Austria, Germany, China, USA) and also with Switzerland, Norway and Belgium which are interested and/or in preparation of getting national funding.

RESULTS

The Annex is reschedueld for 1 year deviation in order to have the full three years of "living" project time. However, activities so far were concentrated on national level (Austria). AIT was working together with the national partner AEE – INTEC on putting together templates for the overview of drying processes (Task1).

Further, modular and robust numerical models have been developed for the drying itself and also the dryer component (air flow, heat pump integration, etc.). These models will be validated and prepared for further exploitation within the Annex. In parallel, drying kinetics experiments of industrial product samples were performed at the Thermo-Physics-Laboratory of the AIT. The aim of these drying experiments was to gain a better understanding of the products drying behavior under lab conditions but also to provide the database for the implementation of the drying kinetics in the subsequent detailed system simulations of the dryer. One challenge was to translate the drying kinetics of the individual product – single kibble or crumb/single droplet - from the laboratory experiments to the situation in the dryer, which is ranging from packed bed situation to spray regimes.

Project duration:
January 2022 - December 2024

Operating Agent:
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Participating countries:
Austria, China, Germany, USA

Further information:
https://heatpumpingtechnologies.org/annex59/

ANNEX 60

RETROFITTING HEAT PUMP SYSTEMS IN LARGE NON-DOMESTIC BUILDINGS

INTRODUCTION

The objective of this Annex is to increase the take-up of heat pumps in existing large non-domestic buildings by demonstrating the success of retrofit projects to building owners and their technical advisors and by providing guidance on the selection of appropriate heat pump systems for their specific needs. This is important because the non-domestic sector contributes substantially to carbon emissions, but there is less experience of or guidance on retrofit heat pump systems than for dwellings.

Non-domestic buildings can vary widely in function, provision of energy services and built form. As the number of installed systems in each country is low, it can be difficult to locate local examples that demonstrate particular combinations of retrofit system and building. As a result, it is not always easy to identify which of the many types of heat pump system designs are most suitable for particular situations.

The Annex focuses on providing straightforward, high-level guidance for building owners and other decision-makers. It will provide guidance that helps building owners and their advisors with make decisions based on experience from working systems. It will compile an accessible database of working systems which will be complemented by an options support tool that provides links to summaries of the existing installations that most closely resemble users' circumstances. The tool will also provide generic advice that reflects the experience of designers and researchers.

The immediate target users are building owners and their advisors, with the aim of reassuring them that their system choices reflect previous relevant experience. This should encourage the take-up of appropriate heat pump systems and accelerate carbon savings.

The outcomes should also be of value to policy makers and to the heat pump industry by identifying areas where there is substantial evidence of successful application and also those where experience is limited.

The key stages are the identification and acquisition of information from installed systems, the construction of the database and options support tool and the delivery of useful information to the target users.

OBJECTIVES

- » Provide evidence of the practical feasibility and satisfactory operation of a range of installed retrofit systems in large non-domestic buildings in a number of countries, together with insights into the thinking that led to the choice of system.
- » Deliver simple-to-use, accessible advice to support the initial selection of system options for specific circumstances, signposted to evidence and summaries of the relative strengths of each option.

INTERMEDIATE TASKS

- » Review of existing relevant information.
- » Development and population of database of case studies.
- » Development, testing and application of options support tool.

MEETINGS

- » Kick-off meeting. 26th-27th September 2022 in London and online. Participants and potential participants described and discussed their anticipated activities within the Annex. Several potential participants still had to confirm financing.
- » In-person meeting - 26-27th April 2023, Belfast, UK.

PROGRESS

The Annex has begun and has started to map out its activities. Participants have already identified several case studies. Coordination with the EBC TCP has been established.

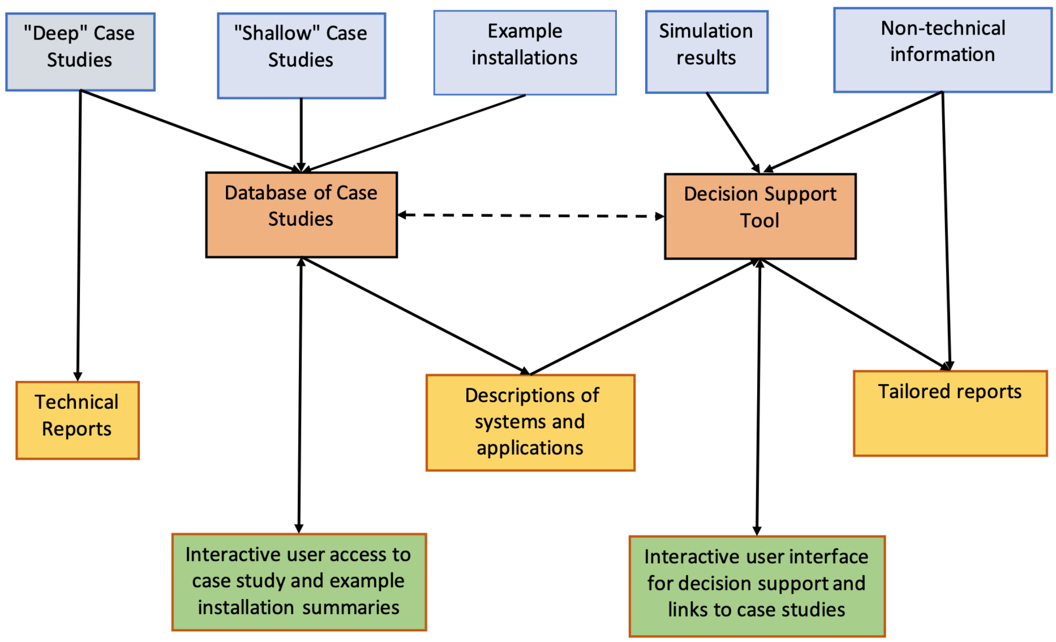

Figure 1. Schematic diagram of annex process.

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Project duration:
September 2022 - December 2024

Operating Agent:
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Participating countries:
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Further information: ***https://heatpumpingtechnologies.org/annex60/***

ANNEX 61

HEAT PUMPS IN POSITIVE ENERGY DISTRICTS

INTRODUCTION

Ambitious climate goals require transitioning to a renewable and high-performing energy system, with the built environment being a crucial sector for rapid emission reduction. For example, buildings account for 36% of the emissions in the EU, making the transformation of the building sector essential to achieving ambitious climate targets. Heat pumps are viewed as the future heating system in many scenarios and are expected to meet 50% of global heat demand by 2045.

The large-scale integration of heat pumps into the energy system is a future challenge and opportunity to create a highly performant and CO_2-free energy system. Positive energy districts are an ambitious objective to facilitate the urban energy transition, with heat pumps effectively coupling different thermal and electric loads in districts at high performance. The integration of electric and thermal loads also provides flexibility to the connected grids.

Annex 61 will investigate heat pump applications in building clusters and districts for both new and retrofit districts on a technical, economic, and ecological basis. The study will derive system concepts for the heat pump integration, which will be characterized regarding benefits and limitations based on a state-of-the-art analysis of heat pumps in clusters of buildings and positive energy districts.

Different integration options up to a centralized HP heating/cooling system will be documented as generic concepts based on decentralized HP on individual building level. Favourable system concepts will be analyzed in more detail using techno-economic analyses via simulation. The focus will be on integrating the heat pump with other technologies, such as on-site PV electricity generation and thermal/electric storage, as well as on design and control of the heat pump, also regarding energy flexibility potentials.

The simulations will be accompanied by real performance evaluations through monitoring heat pump operations in building clusters and districts. The monitoring results will show optimization potentials and will be used to verify the modeling and simulation results. The monitoring systems will be documented as best practice systems.

The results will be utilized by building system technology designers, urban planners, and building companies to achieve ambitious energy targets in districts. Utilities and ESCOs looking for new fossil-free business opportunities will also benefit. Based on the results, heat pump manufacturers can tailor and further develop their products for building clusters and district applications. Policy makers will also have access to evaluations to shape future ambitious energy targets.

OBJECTIVES

Characterisation and cross-comparison of heat pump application in positive energy districts in the participating countrie

- Development of generic system concepts for the integration of heat pumps in districts
- Techno-economic analyses of promising concepts by simulation
- Evaluation of the real performance of heat pumps in districts by monitoring projects
- Dissemination of interim and final results by workshops, articles, conference paper and the final report

MEETINGS

- Annex 61 online meeting on March 14, 2022. Half-day online preparation meeting to enquire about the interest and contributions of possible participants.
- Annex 61 meeting at the Univ. of Innsbruck on July 4/5, 2022. A face-to-face meeting to present contributions and prepare the state-of-the-art analysis and generic system concepts
- Annex 61 meeting at the Eurosun 2022 on September 29, 2022. Half-day meeting of conference attendees from AT, CH and DE to present an update on the state oft he art analysis and conduct further work planning.

PROGRESS

The Annex 61 is a new Annex officially started in September 2022 in order to investigate heat pump integration as well as design and control in positive energy building clusters and districts. In 2022 three meetings were organised where the first results of the state-of-the-art analysis were presented. Positive energy districts proved to be an ambitious energy target, and only a few districts in the participating countries are realised, yet, although further districts are in the planning phase. On the EU level, the joint programming initiative (JPI) Urban Europe supports the objective of 100 positive energy district demonstrators built by 2025. On the national level, however, different definitions, boundary conditions and criteria exist, e.g. the 2000-W-certification for districts in Switzerland also includes the embodied energy and the building-induced mobility in the balance, while in other countries and definitions, the focus is on operational energy. With respect to the methodology, it was discussed to evaluate what level of plus energy districts can be reached or what deficit has to be overcome if the plus energy balance is not reached. This also applies to strategies to move existing districts closer to a positive energy or net zero emission balance on the district level.

Another focus of the Annex is the derivation of generic system concepts for the heat pump integration in districts. A categorisation from a decentral integration on the individual building level in different steps to a centralised integration has been discussed. The easiest connection among buildings in a cluster is a purely electric connection enabling higher self-consumption and energy flexibility.

> ***"Heat pumps in districts can unlock higher system performance and energy flexibility by combining different buildings loads to reach the ambitious target of positive energy districts."***

A further option is a thermal integration on the source side by a collective heat source. Moreover, a decentralised and centralised integration can be combined, e.g. based on different building services as central heating and decentralised domestic hot water. A district heating station represents an entirely central integration of the heat pump for all building services. The different categories will be further detailed by system configurations of the respective integration. The evaluation of the different integration options is also accompanied by field monitoring projects, which deliver real data and can also be used to verify simulation models of the heat pump application in districts. Figure 1 depicts the integration options linked to field monitoring projects contributed by the Annex 61 participants.

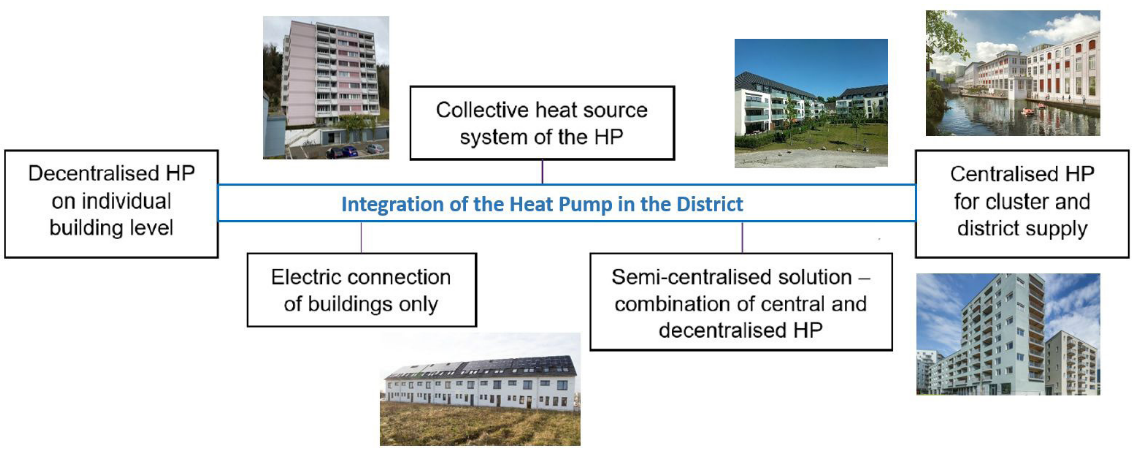

Figure 1. Integration options of heat pumps in clusters of building and districts and corresponding monitoring projects in Annex 61

Project duration:
September 2022 – December 2025

Operating Agent:
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Austria, Germany, Japan Switzerland and USA.

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Outlook into the Future

In 2023 HPT TCP will start to implement their newly revised and approved strategic work plan for 2023-2028 (see below). Some objectives and initiatives will be in focus during 2023. **Below these are marked in blue.**

STRATEGIC WORK PLAN FOR HPT TCP 2023-2028

VISION

Heat pumping technologies are the cornerstone for a secure, affordable, high-efficiency, clean and net-zero emission energy system for heating, cooling and refrigeration. We are the key worldwide independent actor to achieve this vision across multiple applications and contexts. We generate and communicate information, expertise and knowledge related to heat pumping technologies as well as enhance international collaboration.

MISSION

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 2023-2028 - **those prioritized during 2023 are marked in blue**

Accelerated deployment

- **A** The deployment rate is accelerated for efficient heat pumping technologies in different applications-buildings, industry, transport, electric and thermal energy systems – to keep pace with the milestones set out in the IEA Roadmap towards Net Zero Emissions by 2050.
- **B** Innovations related to heat pumping technologies are brought to the market, contributing to fulfilling the net zero emission targets.

Energy security

- **C** Integrated, affordable solutions for heating and cooling, where heat pumping technology is a key element, are explored, through collaboration with other TCPs, enabling energy savings, flexibility and responsiveness in the energy system and improving the security of supply.

Economic growth of secure and sustainable solutions

- **D** The HPT TCP contributes to removing gaps and overcoming barriers in the sustainable value chain of heat-pumping technologies.

Environmental protection

- **E** More decision-makers (policy, investors, utilities, real estate actors, industry, users etc.) acknowledge the multiple benefits of heat pumping technologies as a sustainable, clean, enabling, connecting, and affordable heating and cooling solution to reach the climatic ambitions and strengthen energy security. Decisions which promote heat pumping technologies are implemented.

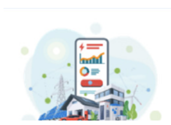
Engagement worldwide

- **F** HPT TCP has more member countries representing the largest economies, different parts of the world facing different contexts, IEA key partner and association countries.
- **G** HPT TCP is an active player in, or partner to, IEA, other TCPs, other international initiatives and organisations related to secure and sustainable heating and cooling and flexible energy solutions for everyone.

STRATEGIC INITIATIVES 2023-2028 - those prioritized during 2023 are marked in blue

1. Advance the RDD&D of heat pumping technologies through the creation of research opportunities, networking and meeting places for academia, industry, markets actors, investors and policy makers to collaborate under new Annexes (projects/tasks) and other activities (e.g. workshops) within the HPT TCP, see priority areas for RDD&D below.
2. Contribute to advanced and/or disruptive innovations through cross-cutting networking and collaboration with other TCPs, IEA, Mission Innovation and other relevant organisations, attracting new actors representing other relevant areas of knowledge.
3. Communicate the results and impact from the RDD&D work, tailor the messages and the dialogue using selected channels to reach relevant target groups, including policy makers, energy and environmental agencies, investors, utilities, manufacturers, city and building planners, system designers, architects, industry associations, installers, researchers and end-users. Arrange a high-quality conference about heat pumping technologies at least every third year, and establish this conference as the most important networking place.
4. Providing and enlarging a dialogue platform to share and report back experiences to those stakeholders and actors who could benefit from such knowledge.
5. Provide IEA, standardisation organisations and regional or national policy makers 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 partners and association countries.

RDD&D PRIORITY AREAS 2023-2028

System Integration	Robust, sustainable and affordable value chains	Extending operation range and applications	New technologies and refrigerants
			
Sector coupling, energy efficiency, flexibility, recilience, storage, digitalization, positive energy districts.	Improving affordability, securing value chains, circular economy, removing barriers from mass deployment.	To fulfill demands from all climate zones, new markets, new applications, and new demands. Refrigeration in emerging countries.	Non-traditional heat pumping technologies (for heating and cooling). Refrigerants (low GWP, safety ect).
• The role of heat pumps in integrated energy systems on building, district and city levels • Heat pumps as enabler for sector coupling • Methods for evaluating smart, flexible heat pumps	• Systems for circular economy for heat pumps • New business models • Easy to install products (plug and play and self commissoning • Standardization for scaling • Using bahaviour/ acceptance of HPT comfort and flexibility	• Heat pumps for industrial application • Heat pumps for district heating and cooling applications • Heat pumps for retrofitting of existing buildings with special requirements • Heat pumps/AC for cooling, dehumidification and drying • Cold climate heat pumps	• Non-vapour compression technologies • Other areas that need low TRL level research • Efficient operation, components ans systems for Low GWP refrigerants • Saftey meassurens for operating with low GWP refrigerants

SELECTED TARGETS FOR HPT TCP FOR 2023

During the first half of 2023, a considerable part of the HPT TCP's work, especially that of the Heat Pump Centre and the conference committees, will be aimed at preparing for the 14th IEA Heat Pump Conference, which will take place in Chicago, USA, on May 15-18.

The targets for HPT TCP for 2023 are:

- A successful 14th IEA Heat Pump Conference as a meeting place for a widened audience (representing market, research, industry, policy and investors), including representatives from other TCPs.
- Strategic relations/partnership with individuals and organisations within our prioritized target groups and new member countries (investors, broader network, policy, new member countries – also focus on Eastern Europe)
- New ideas and proposals for Annex according to the new HPT TCP SWP 2023-2028
- Investigation on how to improve the conditions for increased investment in RDD&D
- Investigation on how to renew the HPT TCP website (during 2024).

Based on the work to develop the revised strategic work plan for the next five-year period 2023-2028, the prioritized areas for ongoing and future research, development, demonstration and deployment (RDD&D) projects within the HPT TCP should be (i) system integration, (ii) robust and sustainable and affordable value chains, (iii) extending operating range and applications and (iv) new technologies and refrigerants. The schematics below show the ongoing and recently started projects (annexes) in blue text and the proposals and ideas for new annexes under different stages of development in red.

ONGOING AND PLANNED ANNEXES WITHIN THE PRIORITY AREAS FOR RDD&D 2023-2028

System Integration	Robust, sustainable and affordable value chains	Extending operation range and applications	New technologies and refrigerants
• Annex 62: IoT for Heat Pumps • Annex 57: Heat Pumps in Multi-Vector Energy Systems • Annex 61: Heat Pumps in Positive Energy Districts NEW • CCB for warm and humid climates • Sector coupling - survey of practical examples • Digital services for heat pumps • Using data to improve technology	• Annex 63: Placement Impact on Heat Pump Acoustics NEW • Heat pumps in circular economy • New or alternative business models for heat pumps	• Annex 60: Retrofit of Heat Pumps in Larger Non-Domestic Buildings • Annex 58: High Temperatur Heat Pumps • Annex 59: Heat Pumps for Drying • Annex 62: Heat Pumps in Residential Multi Family Buildings in Cities NEW	• Annex 54: Heat Pump Systems with Low GWP Refrigerants • Safety Measures for Flammable Refrigerants

Ongoing and recently started annexes (blue)
Ideas and proposals for new annexes (red)

In early 2023 two new annexes started. One of them is Annex 62, “Heat pumps for multi-family residential buildings in cities”, as a continuation of the previously performed Annex 50. This Annex will focus on heat pump solutions for multi-family houses in high-density cities. New buildings and retrofit will be considered, as well as buildings with higher specific heating demand. The case studies database and the tools developed in the previous Annex shall be further developed. Moreover, the work will focus on the following not yet sufficiently addressed topics – heat sources, standardized solutions, central vs decentral solutions, quarters solutions, cooling and urban heat and cold islands.

The other new one is Annex 63, “Placement Impact on Heat Pump Acoustics”. The work within this annex will build upon the achievements in the previously performed Annex 51. However, this project puts focus on the Placement Impact on Heat Pump Acoustics with some special topics of heat pump acoustics (selected applications and refined methods). The overall aim of this Annex is the same as for the previous one – to further remove acoustic barriers to establish heat pumps as the first choice as a renewable and efficient option for HVAC in buildings and industrial applications.

During 2023 some more new annexes will start. The first in line is Annex 64 “Safety measures for flammable refrigerants”. The ultimate goal of the Annex is to contribute to a broader safe use of flammable refrigerants. Another annex, which is close to start, has the title “Heat pumps in circular economy” and will provide analysis and share experiences with material efficiency and other circular economy aspects in domestic heat pumps. In addition the progress in the development on a new annex on the topic “Comfort and Climate Box solutions for warm and humid climates” is advanced and a start during the 2023 is likely to be realized. The primary objective is to explore the possibilities to develop integrated combination of air-conditioning, energy storage and control, possibly in combination with sanitary hot water heating and solar PV, dedicated for warm or warm and humid climates. The solutions should be efficient, affordable, applicable, and scalable. This annex is developed in collaboration with Energy Storage TCP. Moreover, several more ideas for new annexes are in the development phase, see Table above.

In 2023 we will continue the work performed in earlier years to explore the field of investors’ role in accelerating the energy transition. The most important types of investors for stimulating accelerated deployment of heat pumping technologies will be identified, alongside with information about what would create awareness among them, which type of facts they would need to take investment decisions and in which channels and networks we could reach them.

List of Publications for all Annexes 2022

ANNEX 52

Spitler, J. D., Gehlin, S., (2022). Long-term GSHP system performance measurements in the USA and Europe. Research Conference Proceedings of International Ground-Source Heat Pump Association Annual Conference , December 6-8th, 2022, Las Vegas, Nevada, USA. *https://doi.org/10.22488/okstate.22.000012*

Spitler, J. D., Gehlin, S., (2022). Final results from IEA HPT Annex 52 – Long-term performance of large GSHP systems. Proceedings of the European Geothermal Congress 2022, October 17-21 2022, Berlin, Germany.

Spitler, J.D. and Gehlin, S. (2022). Performance of a mixed-use ground source heat pump system in Stockholm. Proceedings of the 14th REHVA World Congress, Clima 2022. May 22-25, 2022. Rotterdam, The Netherlands. *https://doi.org/10.34641/clima.2022.126*

ANNEX 53

Zixu Yang, Youlin Zhang, Hansong Xiao, Rong Zhuang, Xiangfei Liang, Mengdi Cui, Xin Li, Jiaan Zhao, Qi Yuan, Ruiqi Yang, Baolong Wang, Wenxing Shi. Comprehensive test of ultra-efficient air conditioner with smart evaporative cooling ventilation and photovoltaic, Energy Conversion and Management, 254, 2022, 115267

Mengdi Cui, Baolong Wang, Falin Wei, Wenxing Shi. Novel zeotropic refrigeration cycles for air cooling with large temperature decrease, Energy and Buildings, 274, 2022, 112450

Qiulin Liu, Falin Wei, Guodong Li, Zongxiang Kan, Jiawei Yang, Hangtian Zhu, Baolong Wang, Huaizhou Zhao. Highly efficient thermoelectric air conditioner with kilowatt capacity realized by ground source heat-exchanging system, iScience, 25(5), 2022, 104296

Ding, Z., Wu, W., Huang, S. M., Huang, H., Bai, Y., & He, Z. (2023). A novel compression-assisted energy storage heat transformer for low-grade renewable energy utilization. Energy, 263, 125681.

Sui, Y., & Wu, W. (2023). Ionic liquid screening and performance optimization of transcritical carbon dioxide absorption heat pump enhanced by expander. Energy, 263, 125689.

Zhai, C., & Wu, W. (2022). Experimental evaluation on heat/mass transfer and pressure drop of a microchannel membrane-based desorber for compact and efficient H_2O/LiBr absorption refrigeration. International Journal of Heat and Mass Transfer, 195, 123198.

Ding, Z., Wu, W., & Leung, M. K. (2022). On the rational development of advanced thermochemical thermal batteries for short-term and long-term energy storage. Renewable and Sustainable Energy Reviews, 164, 112557.

N. Bachmann, A. Fitger, S. Unmüßig, D. Bach, O. Schäfer-Welsen, T. Koch, and K. Bartholomé, "Phenomenological model for first-order elastocaloric materials," Int. J. Refrig. 136, 245–253 (2022).

N. Bachmann, D. Schwarz, D. Bach, O. Schäfer-Welsen, T. Koch, and K. Bartholomé, "Modeling of an Elastocaloric Cooling System for Determining Efficiency," Energies 15, 5089 (2022), https://www.mdpi.com/1996-1073/15/14/5089.

Xiaoshi Qian, Pumping into a cool future: electrocaloric materials for zero-carbon refrigeration, Frontiers in Energy, 16, 19-22 (2022) Invited Paper

X. Chen, H. Qin, Xiaoshi Qian, et al. Science, 375 (6587), 1418-1422 (2022)

HengCui, Quan Zhang, Yiwen Bo, Peijia Bai, Mengyan Wang, Chunyang Zhang, Xiaoshi Qian, Rujun Ma, Flexible microfluidic electrocaloric cooling capillary tube with giant specific device cooling power density, Joule, 6, 258, (2022) Chen Y, Wang Y, Sun W, Qian S, Liu J. A compact elastocaloric refrigerator. Innov 2022;3:100205.

Qian S, Yao S, Wang Y, Yuan L, Yu J. Harvesting low-grade heat by coupling regenerative shape-memory actuator and piezoelectric generator. Appl Energy 2022;322:119462.

Emaikwu, N., D. Catalini, J. Muehlbauera, Y. Hwanga, I. Takeuchi, R. Radermacher, Experimental Investigation of A Staggered-Tube Active Elastocaloric Regenerator, Int. J. of Refrigeration, Available Online, September 16, 2022. DOI: https://doi.org/10.1016/j.ijrefrig.2022.09.006.

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

ANNEX 54

Azzolin M., Berto A., Bortolin S., Del Col D., 2022. Condensation heat transfer of R1234ze(E) and its A1 mixtures in small diameter channels, International Journal of Refrigeration, Vol. 137, pp. 153-165, https://doi:10.1016/j.ijrefrig.2022.02.002.

Guzzardi C., Azzolin M., Lazzarato S., Del Col D., 2022. Refrigerant mass distribution in an invertible air-to-water heat pump: effect of the airflow velocity, International Journal of Refrigeration, Vol. 138, pp. 180-196, https://doi.org/10.1016/j.ijrefrig.2022.03.006.

Menegazzo, D., Lombardo, G., Bobbo, S., De Carli, M-, Fedele, L., 2022. State of the Art, Perspective and Obstacles of Ground-Source Heat Pump Technology in the European Building Sector: A Review, Energies, 15(7), 2685, https://doi.org/10.3390/en15072685.

Molinaroli, L., Lucchini, A., Colombo, L.P.M., 2022. Drop-in analysis of R450A and R513A as low-GWP alternatives to R134a in a water-to-water heat pump, International Journal of Refrigeration, Vol. 135, pp. 139-147, https://doi.org/10.1016/j.ijrefrig.2021.12.007.

Zanetti E., Bonduà S., Bortolin S., Bortolotti V., Azzolin M., Tinti F., 2022. Sequential coupled numerical simulations of an air/ground-source heat pump: Validation of the model and results of yearly simulations, Energy and Buildings, Vol. 277, 112540, https://doi.org/10.1016/j.enbuild.2022.112540.

Zanetti E., Azzolin M., Bortolin S., Busato G., Del Col D., 2022. Experimental data and modelling of a dual source reversible heat pump equipped with a minichannels evaporator, Thermal Science and Engineering Progress, Vol. 35, 101471, https://doi.org/10.1016/j.tsep.2022.101471.

Zanetti E., Azzolin M., Girotto S., Del Col D., 2022. Performance and control of a CO2 dual source solar assisted heat pump with a photovoltaic-thermal evaporator, Applied Thermal Engineering, Vol. 218, 119286, https://doi.org/10.1016/j.applthermaleng.2022.119286.

Zanetti E., Azzolin M., Conte R., Girotto S., Del Col D., 2022. Experiments and dynamic modelling of dry expansion and flooded evaporators in a CO2 solar assisted heat pump, Applied Thermal Engineering, Vol. 217, 118964, *https://doi.org/10.1016/j.applthermaleng.2022.118964*.

Mei, Z., Y. Hwang*, J. Kim, Thermodynamic analysis and LCCP evaluation of kangaroo heat pump cycle for electric vehicles, Energy, Accepted on July 29, 2022.

Tancabel, J., V. Aute, E. Klein, C. Lee, Y. Hwang, J. Ling, J. Muehlbauer, R. Radermacher, Multi-Scale and Multi-Physics Analysis, Design Optimization, and Experimental Validation of Heat Exchangers utilizing High Performance, Non-Round Tubes, ATE, 216 (5), 118965, Available online July 5, 2022. https://doi.org/10.1016/j.applthermleng.2022.118965.

Lin, L., L. Gao, M. Kedzierski, Y. Hwang, A general model for flow boiling heat transfer in microfine tubes based on a new neural network architecture, Energy and AI, Accepted on March 10, 2022.

Recent findings and outcome of the market development and some projects for heat pumps in Germany OLTERSDORF T., Chillventa Congress 2022, Heat Pumping Technologies, 10.10.2022.

LC150 - Propan-Kältekreise mit deutlich reduzierten Füllmengen, SCHNABEL L., Kongress Energieforschung für Industrie und Gewerbe, Berlin, Germany, 17./18.05.2022.

EcoPack – High temperature low charge Isobutane heat pump, Ölén et al., 15th Gustav Lorentzen Conference on natural refrigerants. Trondheim, Norway, June 2022.

Ecopac – isobutane heat pump acting as economizer, Granryd, et al., 15th Gustav Lorentzen Conference on natural refrigerants. Trondheim, Norway, June 2022.

Experimental Analysis of Various Refrigerant Circuit Component Combinations for Low Charge Propane Heat Pumps, METHLER T., DANKWERTH C., JOOS L., FUGMANN F., MORAWIETZ K., SCHNABEL L., IIR GL 2022, Trondheim, Norway, DOI: 10.18462/iir.gl2022.0171.

Impact of Lubricant in the Evaporator as a function of Oil Circulation Rate in Variable Speed Heat Pumps working with R290, Ossorio, R., 26th International Compressor Engineering Conference at Purdue, Paper No. 2215, July 2022.

Planning, design and construction of a multi-purpose high-temperature heat pump test bench for hydrocarbons, TELES DE OLIVEIRA H., BRAUNGARDT S., FUGMANN H., SCHNABEL L., HENNINGER S. K., IIR GL 2022, Trondheim, Norway, DOI: 10.18462/iir.gl2022.0050.

Refrigerant charge estimation methods for brazed plate heat exchangers, WILL T., SCHNABEL L., KÖHLER J., IIR GL 2022, Trondheim, Norway, DOI: 10.18462/iir.gl2022.0161.

Detailed Brazed Plate Heat Exchanger Evaluation using Infrared Thermography, WILL T., SCHNABEL L., KÖHLER J., Annual Meeting on Reaction Engineering and ProcessNet, Subject Division, Heat and Mass Transfer, Würzburg, Germany, 20.07.2022

Entwicklung und Rolle von Propanwärmepumpen, SCHNABEL L., Berliner Energietage, Fachbereich 3.11 Wärmepumpen für Bestandsgebäude, Berlin, 03.05.2022.

Kältemittel Propan - Klimafreundlich und effizient, SCHNABEL L., Klimajournal, September 2022.

Einfluss einer Photovoltaikanlage auf die Ergebnisse einer LCCP Analyse einer Wärmepumpenanlage in einem Einfamilienhaus, Bachelorarbeit, Fachhochschule Technikum Wien, Gattermayer M., 2022 (Not public, no web adress available).

Wärmepumpen und die eingesetzten Kältemittel – Ausblick zur Marktentwicklung bis 2030. Zach F. et al., TGA magazine, *https://tga.at/*, 2022.

ANNEX 56

V. Wilk, R. Jentsch, T. Barz, C. Reichl, S. Hauer, B. Windholz, S. Knöttner, R. Hemm,

J. Spreitzhofer, G. Music, G. Steindl, W. Kastner, H. Plank, C. Heschl, R. Partl, D. Ziermann, R. Stelzer.

Digitalisation and IoT for heat pumps Tagung des BFE-Forschungsprogramms «Wärmepumpen und Kältetechnik» 22. Juni 2022, BFH Burgdorf

ANNEX 58

33 Descriptions of supplier technologies and 14 descriptions of realized demonstration cases, *https://heatpumpingtechnologies.org/annex58/task1/*

ANNEX 61

Ochs, F., Magni, M., Dermentzis, G. Integration of Heat Pumps in Buildings and District Heating Systems—Evaluation on a Building and Energy System Level Energies 15, 3889, 2022.

Wemhoener, C., Ochs, F., Bockelmann, F., Betzold, Ch., Heat pumps in positive energy districts. Eurosun 2022, Kassel (DE), 25 - 29 September 2022.

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