Technology Collaboration Programme
by iea

ANNUAL REPORT 2023

HEAT PUMPING TECHNOLOGIES

Technology Collaboration Programme on Heat Pumping Technologies - HPT TCP

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IEA HPT

Technology Collaboration Programme on Heat Pumping Technologies

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Message from the Chairman

The most important part, and a supporting pillar, of the collaboration program HPT TCP are the projects (formerly called Annexes). They are platforms for international knowledge sharing around research and development and their results are published on our website and communicated via public webinars. During 2023, 11 ongoing annexes involved 70 teams from our member countries. The research teams are often recruited by the delegates of our member countries and when possible, their projects are financed. This promotes research that correspond to our strategic fields of action and have a direct impact in the respective countries.

The second pillar, which is essential for the impact-oriented functioning of the program, is the Heat Pump Center (HPC). It manages, coordinates and edits the communication via numerous activities, channels and target groups. The HPC also develops a five year strategy in coordination with the input from delegates, project teams, the findings from environmental analyses, and the IEA's objectives and reports. This strategy is the basis on which the HPC, together with the national experts, initiate new projects and support them until the results are published.

These activities are only possible because the member countries, as the third pillar, co-finance the program as well as the numerous projects which the delegates initiate. The delegates are also an important source of information regarding drivers, policies, market developments or successes in research and industry from their countries and regions. They report on this in the Member Country Reports.

However, the three pillars are only stable if participants work together in all areas and make a substantial contribution to achieving the goal of improving and disseminating the technology. Only then can we fulfill our vision of heat pumps becoming the cornerstone of sustainable energy systems worldwide with us as a key independent actor driving this change.

As you can see from the highlights in this report, we were very successful in this respect in 2023. One important event was our 14th International Heat Pump Conference, held in Chicago in May. During the opening ceremony, the IEA Director Fathi Birol, the US Secretary of Energy Jennifer Granholm and the Deputy Director-General of Energy at the European Commission Mechthild Wörsdörfer emphasized the importance of heat pump technologies for the development of a secure and environmentally friendly energy system. They called on us to intensify our work, further increase the spread of this technology and improve it for use in a wider range of applications. We are prepared to take on the challenge. This motivates other countries to work with us. In 2023 we welcomed Spain and Ireland as new members, raising our numbers to 20 constituents.

For the future, we need to accelerate the identification of relevant topics leading to new projects and closely integrate them into our communication work. The findings, knowledge generation and results from our projects should be deployed and disseminated at a faster pace. We need to follow IEA's "Net Zero Roadmap" now, because every installed, and efficiently operated heat pump immediately reduces greenhouse gas emissions.

We can only achieve our goals with a team of highly motivated and experienced people. I therefore thank the delegates of the executive committe, the experts in the projects, the staff of the Heat Pump Center and of the IEA for their commitment. I would also like to express my gratitude to our member countries – without their financial support, our activities would not be possible.

Stephan Renz, Chairman of the Executive Committee

Highlights 2023

The 14th IEA Heat Pump Conference – “Heat Pumps – Resilient and Efficient”

On May 15–18, the 14th IEA Heat Pump Conference on the theme “Heat Pumps – Resilient and Efficient” took place in Chicago. The conference, which spanned over four days, including a day dedicated for workshops on May 15, brought together about 400 attendees from 25 countries, served as a crucial platform for discussing the latest advancements in heat pumping technologies and fostering collaboration among policymakers, innovators, investors, industry, academia, and researchers. The conference started off with three high-level plenary opening speakers setting the scene for the coming days.

- **Fatih Birol,** Executive Director of the International Energy Agency
- **Jennifer Granholm,** the US Secretary of Energy
- **Mechthild Wörsdörfer**, the Deputy Director-General DG Energy at the European Commission

In total, 168 papers were presented during the conference and on May 15 nine different workshops were organized by the operating agents of the different international collaboration projects (annexes) and by Heat Pump Centre.

In a ceremony held at the banquet of the conference, four awardees were given the prestigious **Peter Ritter von Rittinger International Heat Pump Award,** the highest international award in the air conditioning, heat pump and refrigeration field.

For further info, see pages 16–18.

Two new member countries – Spain and Ireland

In May, Spain officially joined the HPT TCP, and in October, Ireland's membership process was completed. Thereby, HPT TCP has 20 member countries.

Heat pumps highlighted in IEA flagship reports

In January, IEA released the 2023 edition of their flagship report, Energy Technology Perspectives. Heat pumps were one of six highlighted and analysed clean energy technologies. Also, in IEA’s updated Net Zero Roadmap, published during the fall, heat pumps were highlighted as one of the most important clean energy technologies. In October, IEA published their World Energy Outlook. One of the messages was that sales of heat pumps and electric heaters will surpass sales of fossil fuel heaters before 2030 with stated policies as of today.

For further info, see pages 6–8.

HPT National Experts Meeting

In October, the Heat Pump Centre organised the HPT TCP National Experts meeting in Nuremberg. About 30 experts worldwide were brought together during a dynamic workshop to ideate groundbreaking collaborations on heat pumping technologies in line with the Strategic Work Plan for HPT TCP.

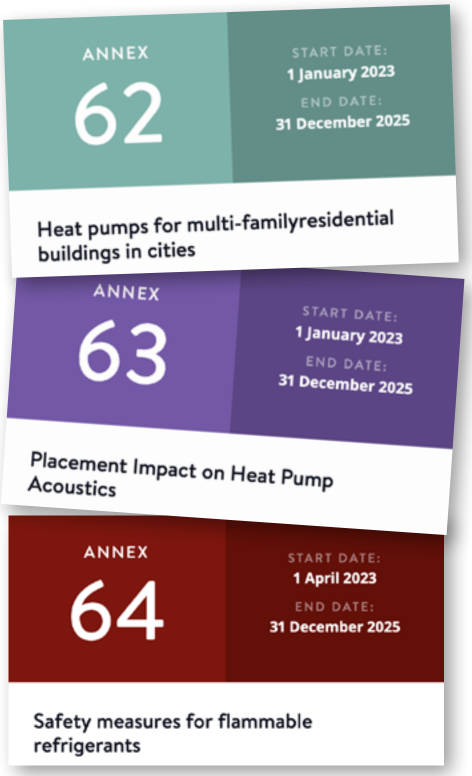
For further info, see page 13.

National experts together in Nuremberg.

New Annexes

During the year, the active work started in three new international collaboration projects – Annex *62 Heat Pumps for multi-family residential buildings in Cities, Annex 63 Placement Impact on Heat Pump Acoustics and Annex 64 Safety Measures for Flammable refrigerants.* Also, Annex 65 Heat Pumps in a Circular Economy was approved to be started, and active work was planned to start at the beginning of 2024.

For further info, see pages 35–40 and 42.



Finalized Annexes

During 2023, the work was finalised in two of the international collaboration projects, Annex 53 Advanced Cooling/Refrigeration Technologies Development and Annex 56 Internet of Things for Heat Pumps. The work performed within Annex 53 was presented during a workshop organized during the 14th IEA Heat Pumps Conference in Chicago. Annex 56 organized a webinar presenting the final results in October. The final reports were published at the beginning of 2024.

For further info, see pages 21 and 24.

Participation in the Universal TCP meeting – discussing the establishment of a Heat Pump Coordination Group

In October, the HPT TCP was represented at the TCP Universal meeting organised by the IEA. Topics discussed during that meeting were, among other things, how to strengthen the communication from the TCPs to improve the outreach and a possible formal establishment of Coordination Groups on different topics, in which several of the TCPs and the IEA secretariat engage. The topic of one such Coordination Group proposed and discussed was Heat Pumps. Several of the TCPs and the IEA secretariat showed a lot of interest in this proposal.

Publication of three issues of the Heat Pumping Technologies Magazine

During 2023, HPT TCP published three issues of the Heat Pumping Technologies Magazine

- ***Industrial Heat Pumps – Opportunities to Unlock Their Full Potential***
- ***Heat Pumps – Resilient and Efficient – Report from the 14th IEA Heat Pump Conference in Chicago***
- ***Heat Pumps in District Heating and Cooling Energy Grids***

International Energy Agency

About the International Energy Agency (IEA)

The IEA is at the heart of global dialogue on energy, providing authoritative analysis, data, policy recommendations, and real-world solutions to help countries provide secure and sustainable energy for all. The IEA was created in 1974 to help coordinate a collective response to major disruptions in the supply of oil. 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 the reliability, affordability and sustainability of energy. It examines the full spectrum of issues, including renewables, oil, gas and coal supply and demand, energy efficiency, clean energy technologies, electricity systems and markets, access to energy, demand-side management, and much more.

Since 2015, the IEA has opened its doors to major emerging countries to expand its global impact, and deepen 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 is 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 IEA's work on heat pumps in 2023

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 2023, several IEA reports further strengthened this message.

Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach

Since IEA's Net Zero by 2050 Roadmap was released in 2021, many changes have taken place, notably amid the global energy crisis triggered by Russia's invasion of Ukraine in February 2022. The energy sector's carbon dioxide emissions have continued to rise, reaching a new record in 2022. Yet there are also increasing grounds for optimism: the last two years have also seen remarkable progress in developing and deploying some key clean energy technologies. This 2023 update to the Net Zero Roadmap surveys this complex and dynamic landscape and sets out an updated pathway to net zero by 2050, taking account of the key developments that have occurred since 2021.

In this updated Net Zero by 2050 Roadmap, heat pumps are again identified as a key technology to contribute to the decarbonisation of heat in buildings and industry. Although significant progress has been made over the last decade, this roadmap highlights the need to increase the deployment of heat pumps in buildings over the next decade, with an annual growth rate of around 20% from 2022 to 2030, see Figure 1 left. Electrification, including via heat pumps, is also identified as a key lever for decarbonising heat in industry, and in the Net Zero Roadmap, electrification of heating applications accounts for 45% of the increase in electricity consumption in light industry by 2030, see Figure 1 right.

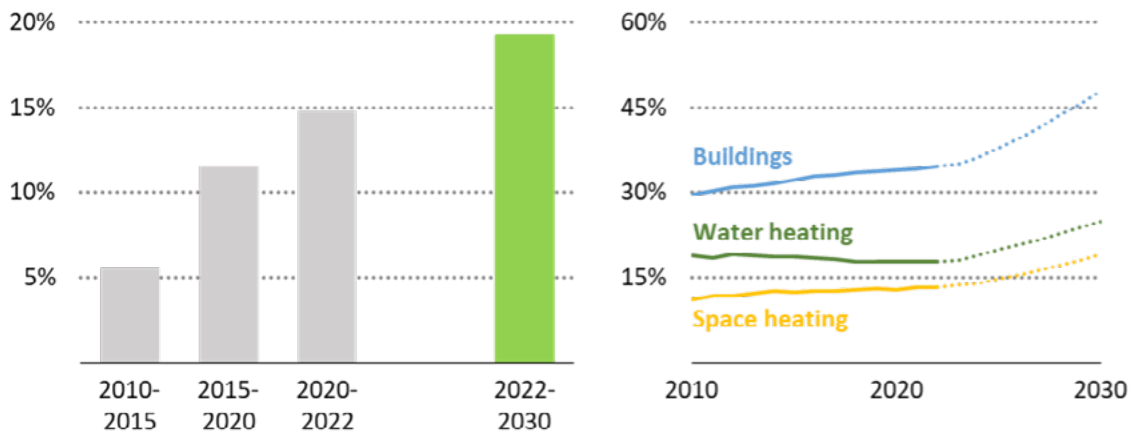


Figure 1: Global Heat Pump Sales growth rate (left) and share of electricity in buildings end-uses (right) in the NZE scenario 2010 – 2030 (Sources: IEA analysis based on data by EHPA, AHRI, CHPA, ChinaIOL, JRAIA; IEA, Annual growth in sales of heat pumps in buildings worldwide and in selected markets, 2021 and 2022, IEA, Paris ***https://www.iea.org/data-and-statistics/charts/annual-growth-in-sales-of-heat-pumps-in-buildings-worldwide-and-in-selected-markets-2021-and-2022*** , IEA. Licence: CC BY 4.0)

Heat Pumps **section of the 2023 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 2022, heat pumps still met only around 10% of the global heating need in buildings.

Global heat pump sales continue double-digit growth in 2022

IEA analyses showed that global sales of heat pumps grew by 11% in 2022, marking a second year of double-digit growth for the central technology in the world's transition to secure and sustainable heating. Increased policy support and incentives for heat pumps in light of high natural gas prices and efforts to reduce greenhouse gas emissions were key drivers behind the strong uptake. In Europe, heat pumps enjoyed a record year, with sales growing by nearly 40%. There were more heat pump units sold in China in 2022 than in any other country despite a slowdown in sales growth. In Northern China, district heating remains the most common heating solution in cities, but many of these households also have heat pumps installed for space cooling and providing additional heating from time to time. In Southern China, where winters are milder, air-to-air reversible units are a widespread solution for space heating, though sales were largely stagnant in recent years. In the United States, heat pumps overtook gas furnace sales in 2022 after years of almost equal growth. Most residential units in the country are air-to-air models in ducted air systems. These are larger than those typically used in Asia, where there is often one unit for each room.

Globally, heat pumps, when used as a main heating device, cover around 10% of heating needs in buildings today see Figure 2 below. This corresponds to over 100 million households, meaning that one in ten homes that require substantial heating are served by heat pumps today. However, many more households use heat pumps only for part of the winter or as a supplementary source of heating in regions where they are mainly used for cooling buildings.

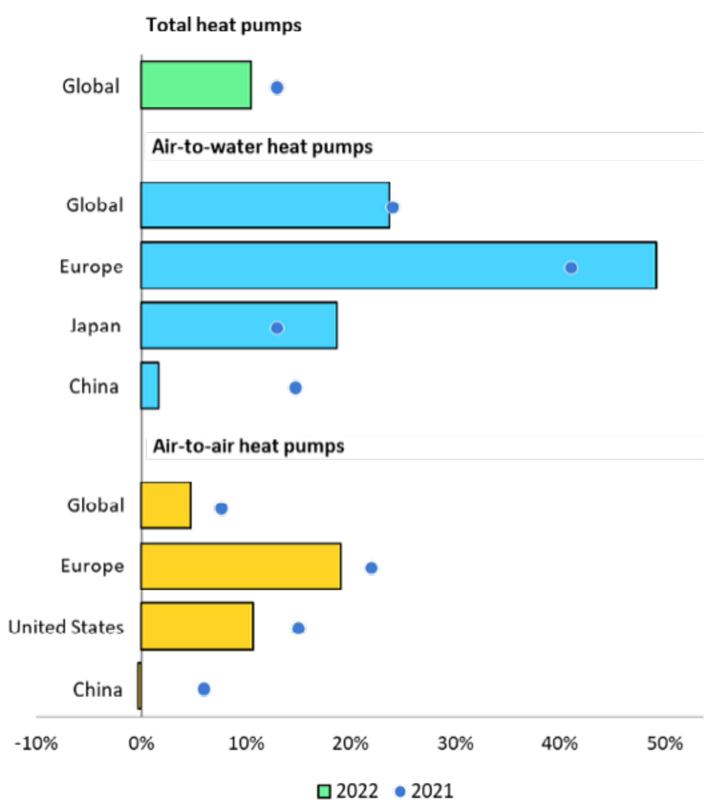


Figure 2: Annual growth in sales of heat pumps in buildings worldwide and in selected markets, 2021 and 2022 (Sources: IEA analysis based on data by EHPA, AHRI, CHPA, ChinaIOL, JRAIA; IEA, Annual growth in sales of heat pumps in buildings worldwide and in selected markets, 2021 and 2022, IEA, Paris ***https://www.iea.org/data-and-statistics/charts/annual-growth-in-sales-of-heat-pumps-in-buildings-worldwide-and-in-selected-markets-2021-and-2022*** , IEA. Licence: CC BY 4.0).

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 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

» *Accelerated deployment*
- 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.
- Innovations related to heat pumping technologies are brought to the market, contributing to fulfilling the net zero emission targets.

» *Energy security*
- 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 security of supply.

» *Economic growth of secure and sustainable solutions*
- The HPT TCP contributes to removing gaps and overcoming barriers in the sustainable value chain of heat pumping technologies.

» *Environmental protection*
- 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*
- HPT TCP has more member countries representing the largest economies, different parts of the world facing different contexts, IEA key partner and association countries.
- 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.

* of the IEA's Technology Collaboration Programme on Heat Pumping Technologies

Strategic initiatives

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 etc.)
• 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 commissioning • 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

HPT TCP MEMBER COUNTRIES

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

* Research, Development, Demonstration and Deployment

Organization of the HPT TCP

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

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

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

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

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

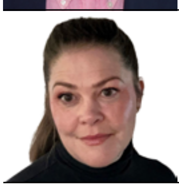
This is the HPC Staff :

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

Caroline Haglund Stignor, Assistant Manager/Annex Manager/Outreach activites
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



Lotten Wiklund, Communications Officer
Communications specialist with over 20 years of experience in journalism, editorial work, digital media production, web, content and media strategy with a focus on research, science, technology and digital medialandscapes.
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Activities and Achievements

Dr. Fatih Birol, Executive Director of the International Energy opend the 4th IEA Heat Pump Conference.

14th IEA Heat Pump Conference

Many of the committees, such as the National Organising Committee (NOC), the International Organizing Committee (IOC) and the Scientific Committee (SC), as well as the Heat Pump Centre, were highly engaged in the preparation and performance of the 14th triennial conference organized by this TCP on May 16–18 in Chicago. The conference was a success, with about 400 attendees from 25 countries and 168 papers were presented. See pages 16–18 for more information about the conference.

The day prior to the official start of the conference, on 15 May, nine very well-attended workshops on different topics were organized by the Operating Agents of the Annexes and by the Heat Pump Centre. In many of the workshops, the results from the ongoing or recently finalized international collaboration projects, so-called Annexes, were presented. Two of the workshops, organized by the Heat Pump Centre, were dedicated to discussing different types of investors' roles in accelerating the deployment of efficient heat pumping technologies. Heat Pump Centre coordinated the planning of the workshops and promoted them prior to the conference.

A report from the conference as a whole, including the workshops, can be found in the ***Heat Pumping Technologies Magazine, issue 2, 2023.***

The months after the conference, the conference proceedings, including all papers and presentations, were published openly on the ***HPT website.***

During the closing ceremony of the conference, the place and date for the next triennial Heat Pump Conference were launched – the 15th IEA Heat Pump Conference will be held in Vienna, Austria, further highlighting Europe's commitment to advancing sustainable heating and cooling solutions. The conference will take place in Hofburg Vienna, historical building in the center of Vienna, 26-29 May, 2026. During the end of the year, the planning and preparations for this event began.

Executive Committee meetings

The spring ExCo meeting took place in Chicago on 19 May, the day after the 14th IEA Heat Pump Conference. The meeting was well attended by delegates, Operating Agents and invited guests who had all attended the conference. In addition, online attendance was also possible. Spain joined the TCP right before the spring ExCo meeting and attended online during the spring meeting. Representatives from Ireland and Poland were invited to this meeting to give presentations about the status of heat pumping technologies in their countries since they had shown interest in joining HPT TCP. Before the fall meeting, Ireland had joined, and the representatives could participate as a full member.

The fall ExCo meeting was hosted by one of the newest member country in HPT TCP, the Czech Republic, and took place in Prague on 28-29 November. Also, at this meeting, online attendance was possible even though most attended on-site. In the afternoon, the second meeting day, the Czech ExCo delegates, Mr. Caha and Mr. Vorisek, organized a very interesting round table discussion where high-level policy makers from several ministries and industry representatives discussed the potential and barriers for large-scale heat pumps in district heating and industries. Among them was the Czech CERT delegate, Mr. Muller. The ExCo delegates, the Operating Agents and the invited guests to the ExCo meeting attended the event. The background of this event was that in the Czech Republic, 40% of the population is connected to district heat-

HPT TCP Executive Committee meeting in Prague.

ing systems, and 54% of this heat is produced from coal. This needs to be phased out by 2030. The first step will be done by biomass, municipal waste, and gaseous fuels. However, this is not enough to reach the climate and energy security targets. Therefore, in the next step, large heat pumps need to be implemented to a large extent in the district heating systems, following examples in Sweden, Norway, Finland etc.

After the ExCo meeting, a two-day international conference on industrial heat pumps followed in the same venue. Many of the delegates stayed to attend this interesting conference, and the HPT TCP as a whole as well as some of the Annexes were highlighted during the conference.

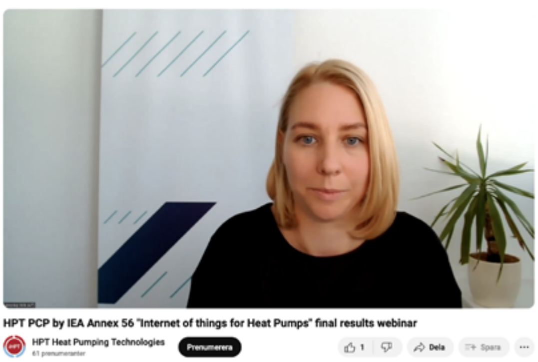
[Strategic Objective E, Strategic Initiative 2]

Digital workshops and webinars

During the year, the HPT TCP organised several digital workshops and webinars, for example, four workshops where, all togehther 12 Member Country Reports were presented and discussed on 14 March, 20 June, 12 September and 12 December. This year, we increased the invitations to the open audience and not only to the HPT TCP community. Thereby, we had a number of participants from countries beyond the member countries. On 18 October, a webinar to present the final results from Annex 56, Internet of Things for Heat Pumps, was organized by the Operating Agent in collaboration with the Heat Pump Centre.

On 15 December Heat Pumps Centre presented the results from a special study performed on the theme "How to attract investors to increase investment in the supply/value chain for heat pumps" for the ExCo delegates during a digital workshop.

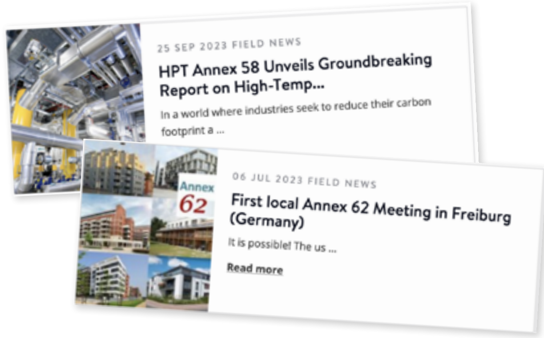
[Strategic Objective E, Strategic Initiative 2]



Veronika Wilk, operating agent of Annex 56 Internet of Things for Heat Pumps during final webinar.

Ongoing, new and completed annexes

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



During 2023, the following eleven 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)
- Retrofit Heat Pump Systems in Large Non-domestic Buildings (Annex 60)
- Heat Pumps in Positive Energy Districts (Annex 61)
- Heat Pumps for Multi-Family Residential Buildings in Cities (Annex 62)
- Placement Impact on Heat Pump Acoustics (Annex 63)
- Safety Measures for Flammable Refrigerants (Annex 64)

However, Annex 53 and Annex 56 were in the reporting phase.

See further pages 21 to 40.

HPT TCP National Experts Meeting

On 26 October, the Heat Pump Centre organized an ideation workshop where heat pumping technologies experts from the different member countries, representing academia and research institutes, industry, and policy, attended. 30 attendees from all over the world converged the day after the European Heat Pump Summit in Nuremberg, setting the stage for forward-thinking proposals. During the workshop, ideas and proposals for new international collaboration projects in line with the HPT TCP Strategic Work Plan 2023-2028 (see page 10) were discussed. These ideas and proposals are further presented on page 41, "Outlook into the Future".

[Strategic Objective D, Strategic Initiative 1]

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

One of the Heat Pump Centre's 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 2023 on the topics:

- ***Industrial Heat Pumps – Opportunities to Unlock Their Full Potential***
- ***Heat Pumps – Resilient and Efficient – Report from the 14th IEA Heat Pump Conference in Chicago***
- ***Heat Pumps in District Heating and Cooling Energy Grids***

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-pump 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 tweets on X (former Twitter), LinkedIn, and 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) in improving and updating annex pages on the website with new information, such as publications and links to webinars. This is important for increasing the reach out of the results from the work within the HPT TCP.

During 2023, presentations and summaries from Member Country Report workshops have been published on the website. This offers website visitors a good source for information regarding market development and the present status and conditions for the deployment of heat pumps in different parts of the world.

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

[Strategic Initative 3]

Collaboration with IEA and other TCPs

Fatih Birol, Executive Director of the International Energy Agency, was invited to give the first presentation during the plenary opening session of the conference. He finalized his speech by thanking the HPT TCP, which for more than 40 years has brought together academia, industry, market and policy – "even in those days when heat pumps were not a star in the energy movie...". For further info, see page 16.

The desk officer for HPT TCP from the IEA was invited to give a keynote presentation during the conference and to participate in the workshops organized by the Heat Pump Centre. In addition, he participated in both the spring and the fall ExCo meetings.

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 but also on-site. During the year, representatives from the HPT TCP contributed to the review and dissemination of several of the IEA reports publications with relation to heat-pumping technologies (see Page 6 IEA). Moreover, the Heat Pump Centre took an active part in the IEA review of TCP best practices on TCP communications initiated by CERT*, and later on, they discussed and commented on a review initiated by CERT on areas of improvement in CERT, its Working Parties and the TCPs together with ExCo Chair.

In October, the HPT TCP was represented at the TCP Universal meeting organised by the IEA. Topics discussed during that meeting were, among other things, the results from the CERT reviews mentioned above. Moreover, an outcome from one of the CERT reviews was to formalize so-called TCP Coordination Groups on different topics under CERT, in which several of the TCPs and the IEA secretariat engage together with external partners. The topic of one such Coordination Group proposed and discussed was Heat Pumps, and the IEA secretariat discussed this proposal with the ExCo Chair and Heat Pump Centre, who provided comments. Several of the TCPs and the IEA secretariat showed a lot of interest for this proposal during the TCP Universal meeting. It was also discussed during the fall ExCo meeting, where a decision to formally support this proposal from HPT TCP was taken. Moreover, other Coordination Groups of interest and relevance for HPT TCP were presented at the TCP Universal meeting, e.g. on Flexibility and Thermal Networks.

[Strategic Objective C, e, G, Strategic Initiative 2, 5]

Collaboration with other international organizations

On 26 May, Heat Pump Centre was one of the coorganizers, of an international conference in Stockholm which explored on the ***Decarbonization of the European Heating Sector with Sweden as a Role Model.*** The conference was organized together with NIBE AB, RISE Research Institutes of Sweden, the Royal Institute of Technology, Swedish National Museum of Science – the aim of fostering a constructive dialogue between stakeholders. The event was organized in conjunction with the Swedish Presidency of the European Council and brought together leading scientists, policymakers, and industry representatives from across Europe to discuss strategies for transitioning to a carbon-free future. Swedish Minister for Energy and Enterprise Ebba Busch opened the conference,

Swedish Minister for Energy and Enterprise Ebba Bush at conferece Decarbonization of the European Heating Sector - Sweden as a Role Model.

emphasizing the importance of collaborative efforts to overcome energy supply challenges and rising prices.

Representatives from different business associations were invited to and participated in the workshops on investors role in the energy transition, organzed by the Heat Pump Centre during the IEA Heat Pump Conference in Chicago in May. For further info, see pages 16–18.

In September, a representative from the Heat Pump Centre participated in and reported from the ***Heat Pump Forum*** in Brussels, organized by the European Heat Pump Association (EHPA). The key question for that event was – Are We Moving Fast Enough to Reach the Climate Ambitions?

In October, the Heat Pump Centre promoted and informed about the HPT TCP during the European Heat Pump Summit in Nuremberg. During the event, they had several interesting discussions with representatives from industry as well as academia and made many new contacts.

[Strategic Objective A, B, E, Strategic Initiative 4]

*CERT IEA's Committee for Energy Research and Technology

14th IEA Heat Pump Conference in Chicago - Heat Pumps Resilient and Efficient

The 14th International Energy Agency (IEA) Heat Pump Conference was organized in Chicago, Illinois, on May 15–18, 2023 by the HPT TCP. The conference was hosted by Oak Ridge National Laboratory (ORNL) and the US Department of Energy. The conference brought together about 400 attendees from 25 countries and served as a crucial platform for discussing the latest advancements in heat pumping technologies and fostering collaboration among policymakers, innovators, investors, academia, and researchers. The conference venue was the Renaissance Chicago Downtown Hotel, which is located centrally in Chicago.

Objectives of the conference

The 14th IEA Heat Pump Conference served 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. A report from the conference as a whole, including the workshops, can be found in the Heat Pumping Technologies Magazine, issue 2, 2023.

From left: Thomas Fleckl, Brian Fricke, Ramachandran Narayanamurthy, Stephan Renz and Monica Axell.

Workshops

The operating agents of IEA HPT TCP annexes and the Heat Pump Centre hosted workshops, which were held on Monday (May 15, 2023). The workshops provided an interactive venue for the various annexes to disseminate the results of their work and to solicit input from the audience regarding future focus and direction. In addition the Heat Pump Centre hosted two workshops about Investors' role for accelerating the deployment of energy efficient heat pumping technologies. Because of the number of workshops to be held, four parallel tracks were planned for both the morning and afternoon on Monday. The workshops hosted during the conference and their corresponding annexes are as follows:

» Advanced Cooling and Refrigeration Technology Development (HPT Annex 53)
» Progress in Heat Pumps with Low GWP Refrigerants (HPT Annex 54)
» Comfort and Climate Box (HPT Annex 55)
» Flexibility in Energy Grids Provided by Heat Pumps (HPT Annex 57)
» Decarbonizing Process Heating with High-Temperature Heat Pumps: How to Exploit the Potential (HPT Annex 58)
» Heat Pumps in Positive Energy Districts – Opportunities, Challenges and Perspectives (HPT Annex 61, EBC Annex 83 and SHC Task 66)
» Acoustic Signatures and Placement Impact of Heat Pumps, Interactive Augmented Reality and Psychoacoustics (HPT Annex 63)
» Comfort and Climate Box for Cooling and Dehumidification – new annex proposal
» Investors' Role in Different Parts of the Value Chain of Heat Pumps (Heat Pump Centre)
» The Role of Public and Private Funded Projects to Tenfold the Number of Heat Pumps (Heat Pump Centre)

Opening Ceremony

The IEA Heat Pump Conference officially started on Tuesday (May 16, 2023) with welcoming remarks and plenary lectures. Four hundred participants from 25 different countries joined the conference. IOC Chair Thomas Fleckl; a DOE representative, Ram Narayanamurthy; and NOC Chair Brian Fricke each provided welcoming remarks to the conference audience.

Workshop during conference.

Plenary Speakers

Welcoming remarks were followed by two plenary lecture sessions: a policy-focused plenary lecture session and technical-focused plenary lecture session. Plenary session speakers included the following:

- Fatih Birol, Executive Director of the IEA
- Jennifer Granholm, US Secretary of Energy
- Mechthild Wörsdörfer, Deputy Director-General of the European Commission
- Min Soo Kim, President of the General Conference of IIR and Professor of Seoul National University
- Reinhard Radermacher, Professor from University of Maryland
- David Porter, Senior Vice President of the Electric Power Research Institute

Fatih Birol finalized his speech by thanking the Technology Collaboration Programme on Heat Pumping Technologies, which for more than 40 years has brought together academia, industry, market, and policy – "even in those days when heat pumps were not a star in the energy movie..." – for their stubborn and consistent efforts to make the heat pumps today an important part of the clean energy transition.

Jennifer Granholm said that innovation anywhere leads to progress everywhere and that experiences from the involvement with the IEA Technology Collaboration Programmes are that we innovate faster when we work together. She pointed out that two critical areas for research and innovation in the US are refrigerants and cold climate heat pumps.

Mechthild Wörsdörfer stated that heat pumps need to become the new boiler in Europe and that we need regulatory action, investment support, skilled workers, more research and innovation, and communication to achieve this.

Technical sessions

The opening session was followed by three days of technical presentations by the authors of the 168 conference papers. During the paper review process, the regional coordinators categorized the conference papers into the following tracks according to the papers' topics:

- **Track 1:** Residential and Building Applications. This track focused on topics such as net-zero buildings, renovation, hybrid systems, and domestic hot water for residential, commercial, and multifamily buildings.
- **Track 2:** Smart Energy Systems and Renewables. This track included markets and policy topics, smart grids and district heating and cooling, ground-source heat pumps, hybrid heat pumps, and combinations of technologies.
- **Track 3:** Industrial Applications. This track included topics such as waste heat recovery for a variety of uses in industrial processes.
- **Track 4:** Working Fluids and Advances. This track spanned a wide range of topics including systems and components development, sorption systems, working fluids and refrigerants, integration with thermal energy storage, and nontraditional technologies.

The technical presentations were then organized according to these tracks.

Given the number of oral presentations, three parallel oral presentation sessions were scheduled. Poster presentations were scheduled to occur during lunch and coffee breaks and one dediciated poster session. Each oral presentation session was moderated by a session chair. Preference for session chair assignments was given to the Executive Committee (ExCo) delegates of the IEA HPT TCP, and the Regional Coordinators coordinated the recruiting of the session chairs. Session chairs were responsible for introducing the speakers and moderating audience engagement with the speakers following their presentations.

Each oral technical session began with a keynote speaker. The Regional Coordinators and Scientific Committee selected one conference paper per session that was deemed to be of high quality and captured a key aspect of the session topic and designated that paper as the session keynote. In addition, two keynote speakers received special invitations from the IEA HPT TCP to present:

- Didier Coulomb (IIR), "Policies related to refrigerants and their impact on research needs within heat pumping technologies."
- Rafael Martinez-Gordon (IEA), "Global heat pump sales continue double-digit growth, IEA Global Energy Transition Stocktake."

All the papers and most presentations from the conference are openly available in the HPT TCP database: ***https://heatpumpingtechnologies.org/publications/***

Technical Tour of GTI Energy

An optional technical tour of GTI Energy was organized by the NOC. GTI Energy is a leading research organization focusing on developing, scaling, and deploying energy-transition solutions. Seventy-five conference attendees participated in the optional technical tour.

Peter Ritter von Rittinger Award

On Wednesday evening (May 17, 2023), a banquet was held for the conference attendees. As part of the banquet, there was a ceremony when the recipients of the Peter Ritter von Rittinger Award were recognized, and laudation speeches were given. This award is the highest international award in the air conditioning, heat pump and refrigeration field. The 2023 Peter Ritter von Rittinger awardees included the following:

Prof. Min Soo Kim
National University,
Seoul, Korea

Dr. Rainer M. Jakobs
Informationszentrum
Wärmepumpen und
Kältetechnik, Breuberg,
Germany

Prof. Jeffrey D. Spitler
Oklahoma State
University, Stillwater,
Oklahoma,
United States

Prof. Emirit.
Per Fahlén
Chalmers University
of Technology,
Gothenburg, Sweden

Min Soo Kim and Jeffrey Spitler were able to accept their awards in person at the banquet, whereas Rainer Jakobs and Per Fahlén received their awards virtually via live audio/video link during the banquet. The 2023 Ritter von Rittinger awardees are shown above.

Closing Ceremony

On Thursday afternoon (May 18, 2023), the 14th IEA Heat Pump Conference was concluded with a brief closing ceremony, during which the chairs of the IOC and NOC provided closing remarks. In addition, Best Poster awards were given to Elias N. Pergantis from Purdue University for the poster namend "Thermodynamic Analysis of the Cascade Economization Cycle for High-Temperature Heat Pump Applications".

Place and dates for the 15th IEA Heat Pump Conference – “Decarbonization through innovation”

During the closing ceremony of the 14th IEA Heat Pump Conference, Thomas Fleckl announced that the 15th IEA Heat Pump Conference will be hosted in 2026 in Vienna, Austria under the theme of “Decarbonization through innovation”. The conference will take place in **Hofburg Vienna, a historical building in the center of Vienna, 26-29 May, 2026.** The Chair of the next National Organizing Committee (NOC) will be Thomas Fleckl, who served as the Chair of the International Organizing Committee (IOC) for this Conference.

15TH IEA
HEAT PUMP
CONFERENCE
VIENNA 2026

Organization
The conference was organized by the International Organizing Committee (IOC), the National Organizing Committee (NOC) and the Regional Coordinators (RC) on behalf of the Executive Committee of the IEA HPT TCP. The Scientific Committee (SC) consisted of the IOC Chairs, the NOC Chair and the RCs. Moreover the Heat Pump Centre supported the conference organization.

International Organizing Committee (IOC)
Thomas Fleckl, chair IOC
Sophie Hosatte, vice-chair IOC
Minsung Kim, vice-chair IOC

National Organizing Committee (NOC)
Brian Fricke, chair NOC
Members of the US National Team
of the IEA HPT TCP

Regional Coordinators
Yunho Hwang for Americas
Takahiro Asahi for Asia
Caroline Haglund Stignor for Europe

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

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), Ireland (IE), Italy (IT), Japan (JP), the Netherlands (NL), Norway (NO), South Korea (KR), Spain (ES), Sweden (SE), Switzerland (CH), the United Kingdom (UK), and the United States (US).

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

Finalized 2023

NEW

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

ADVANCED COOLING/ REFRIGERATION TECHNOLOGIES DEVELOPMENT	53	CN, DE, IT, KR, **US**	A
HEAT PUMP SYSTEMS WITH LOW GWP REFRIGERANTS	54	AT, DE, FR, IT, KR, SE, **US**	B
INTERNET OF THINGS FOR HEAT PUMPS	56	**AT**, DK, FR, DE, NO, SW, CH	D
FLEXIBILITY BY IMPLEMENTATION OF HEAT PUMPS IN MULTI-VECTOR ENERGY SYSTEMS AND THERMAL NETWORKS	57	AT, FR, DE, **DK**, NL, SE	A
HIGH-TEMPERATURE HEAT PUMPS	58	AT, BE, CA, CH, CN, DE, **DK**, FI, FR, JP, NL, NO	B
HEAT PUMPS FOR DRYING	59	**AT**, CH, CN, DK, SE, US	B
RETROFIT HEAT PUMP SYSTEMS IN LARGE NON-DOMESTIC BUILDINGS	60	AT, CA, IT, NL, **UK**	C
HEAT PUMPS IN POSITIVE ENERGY DISTRICTS	61	AT, **CH**, DE, IT, NL, US	A
HEAT PUMPS FOR MULTI-FAMILY RESIDENTIAL BUILDINGS IN CITIES	62	CN, FR, **DE**, IT	B
PLACEMENT IMPACT ON HEAT PUMP ACOUSTICS	63	AT, **DE**, FR, NL, UK	B
SAFETY MEASURES FOR FLAMMABLE REFRIGERANTS	64	AT, DE, FR, KR, **SE**	D

Selected areas for RDD&D activities in HPT TCP (2023–2028). See page 41.

RDD&D-Research, Development, Demonstration and Deployment

A)

B)

C)

D)

ANNEX 53

ADVANCED COOLING/REFRIGERATION TECHNOLOGIES DEVELOPMENT

OBJECTIVE

The objective of Annex 53 was to develop technology solutions for higher efficiency air-conditioning/refrigeration systems to help minimize/reduce projected energy consumption increases.

Annex participants investigated over a dozen different technology approaches for future air-conditioning and refrigeration (AC&R) systems. These included advances to the time-proven vapor compression (VC) cycle, electrochemical compression, absorption and adsorption, and others based on nontraditional cycles including several caloric cycles. Technology Readiness Levels (TRL) ranged from about 2 to 5 for nontraditional options and up to 8 for advanced VC options investigated by Annex work period end.

FINDINGS

1. An advanced VC AC system was a Grand Winner of the Global Cooling Prize competition. Cost reduction work is ongoing.
2. Adding a pressure exchanger to a transcritical CO_2 system demonstrated coefficient of performance (COP) improvements up to 27% in a supermarket field test.
3. Electrochemical NH3 compressor tests showed isentropic efficiencies monotonically increasing with pressure ratio in contrast with VC compressors, which exhibit a peak efficiency and then a decrease at higher pressure ratios.
4. A heat–driven elastocaloric system projected to have a COP greater than those of state-of-the-art single-effect absorption chillers and photovoltaic-driven electric ACs.
5. A proposed electrocaloric HP device using a novel high-entropy polymer achieved a COP of ~80% of Carnot.
6. Heat pipe–coupled magnetocaloric (MC) technology tests demonstrated a cooling power density of 12.5 W/g of MC working material.
7. Power density of MC devices can match that of commercially available VC compressors up to about 500 W cooling capacity.
8. A prototype of a two-stage absorption thermal energy storage system that can operate with extremely low charging temperatures (~50°C) was developed.
9. Plastic adsorber material can potentially achieve adsorber mass reduction of 50% to 65% compared to aluminum with similar performance.
10. Simulation of ideal membrane heat pumps showed potential seasonal performance factor >8.

Final report and Executive summary can be found on Annex 53 website: ***https://heatpumpingtechnologies.org/annex53/documents/***

Project duration:
January 2019 to December 2023

Participating countries:
China, Germany, Italy, South Korea, and USA

Website:
https://heatpumpingtechnologies.org/annex53/

Operating Agent:

Prof. Reinhard Radermacher, ***raderm@umd.edu*** from University of Maryland

Van Baxter, ***baxtervd@ornl.gov*** from Oak Ridge National Laboratory, USA

Brian Fricke, ***frickeba@ornl.gov*** from Oak Ridge National Laboratory, USA

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. Annex 54 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. All the efforts are accomplished from academic and industrial participating countries. The work can be a valuable reference for researchers, engineers, and policymakers across the HVAC industry. It is of particular interest for those to dive deep into the R&D of heat pump systems.

> ***LC150 project advances low-GWP heat pumps, promoting efficiency & safety for wider adoption as renewable HVAC solution.***

OBJECTIVES

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

- comprehensive review of recent R&D progress on system-level design, analysis, and optimization using low-GWP refrigerants (fulfilled),
- in-depth case studies of system-level optimization, which can provide design guidelines and real-world experiences (partially fulfilled),
- optimization of heat pump systems for low-GWP refrigerants (partially fulfilled),
- analysis of the LCCP impacts by the current design and optimized design with low-GWP refrigerants (partially fulfilled), and
- making an outlook for heat pumps with low-GWP refrigerant for 2030 (planned)

RESULTS

In 2023, 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. 3) Task 4: 2030 Outlook. 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.

Project duration:
January 2019 to December 2023 (Two-year extension request for ANNEX54 from January 2022 to December 2023 was approved by the executive committee.)

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

Participating countries:
Austria, France, Germany, Italy, Japan, Korea, Sweden, and the USA.

Further information:
All workshop presentation materials, meeting agenda, minutes, and attendee list are available from the ANNEX54 website. at ***https://heatpumpingtechnologies.org/annex54/***

The researchers in the USA reported Propane as a refrigerant for next-generation HVAC and water heating solutions and investigated the detailed performance of novel heat exchangers and system design under cold climate conditions or during transient operations, along with a brief yet informative review of low GWP refrigerants. The low GWP refrigerant review highlights the importance of low charge for flammable refrigerants and alternative refrigerants for R-410A.

The German researchers summarized the heat pump market survey, integrated fluid screening, and evaluated the SCOP of HCs, HFOs, and mixtures.

The Italian researchers reported solar-assisted heat pump water heaters using CO_2 and compared R410A alternatives for residential HPs: R32, R454B, and R454C.

The Swedish researchers presented the Swedish HP market for residential and commercial units, shared case studies and design guidelines for a geothermal R290 HP for multifamily buildings (EBOX), a CO_2 HP system for commercial buildings, and an R290 HP and chiller for the process cooling and heating.

Austrian researchers investigated identified low GWP refrigerants and provided an overview of the Austrian heat pump market and examples of low GWP refrigerants in applications.

FINAL REPORT

The Annex team started preparing a final report based on country reports from the member countries. This report will be submitted in early 2024 and uploaded to the Annex 54 website.

ANNEX
56

INTERNET OF THINGS
FOR HEAT PUMPS

OBJECTIVE

IoT enabled heat pumps are equipped with sensors, actuators, network connectivity and software to collect and exchange data. They enable optimization of operation to reduce energy consumption, lower CO_2 emissions, achieve economic benefits and increase comfort. They also enable grid services through the targeted provision of flexibility, which will be an important asset in the future energy system based on renewable sources.

The aim of the project was to provide a structured overview on IoT-enabled heat pumps in the following areas:

- Industrial Internet of Things, communication technologies and knowledge engineering in automation
- Information security, data protection and privacy
- Factsheets on IoT enabled heat pumps (research projects, products and services)
- Market review, manufacturer survey, expert interviews
- Communication architecture, interfaces and protocols
- Data pretreatment
- Data models, meta data and building information modelling (BIM)
- Data analysis
- Business models and services

FINDINGS

The IEA HPT Annex 56 project analyses the opportunities and challenges of IoT-enabled heat pumps for use in buildings and industrial applications.

1. 44 application examples were analyzed in the participating countries, which clearly show that IoT-enabled heat pumps and products based on them are already available on the market. Factsheets for the application examples are available on the Annex website.
2. Five main categories are assigned to the application examples: Heat pump operation optimization, Predictive Maintenance, Heat pump operation commissioning, Provision of flexibility and Heat as a service.
3. Relevant interfaces, data analysis methods and business models for IoT-enabled heat pumps were analyzed. The results show that the use of IoT technology and connectivity can enable or significantly improve data exchange, analysis and the services based on it.
4. For the users, IoT heat pumps enable operating cost and energy savings and increased operational reliability.
5. For the heat pump value chain (component manufacturers, heat pump manufacturers, dealers, installers), digitalization leads to new products and services that make heat pumps more attractive and future-proof. Compared to traditional business models, they have more responsibility for the efficiency of IoT-enabled heat pump systems.
6. For the energy system, the provision of flexibility is of particular importance, as it allows for better integration of the fluctuating generation of renewable energy. The exchange and use of data play an essential role.

All reports and factsheets, as well as a recording of the Final Webinar, are available on the website of Annex 56 and can be accessed on: ***https://heatpumpingtechnologies.org/annex56/publications/***

Project duration:
January 2020 to December 2022

Operating Agent:
Veronika Wilk, Austrian Institute of Technology GmbH, Austria
veronika.wilk@ait.ac.at

Participating countries:
Austria, Denmark, France, Germany, Norway, Sweden, Switzerland

Website:
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 and 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 CO_2 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 CO_2 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

Meeting with Annex 57 team.

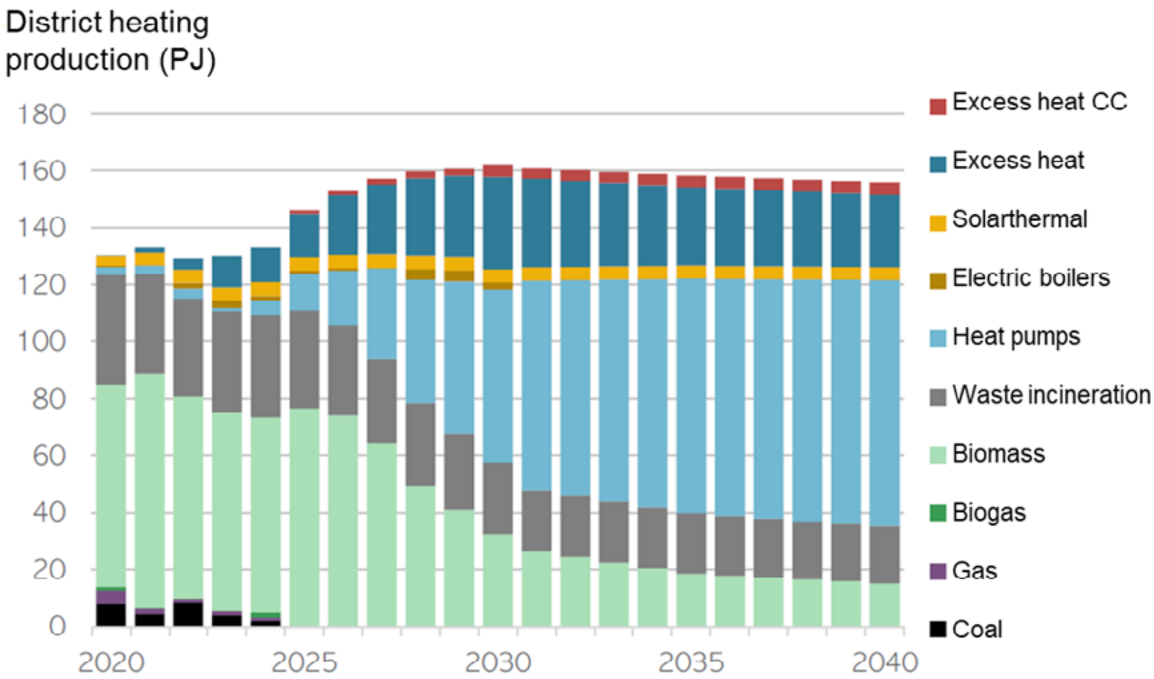


Figure 1: Scenario for the development of district heating production in Denmark until 2040 (Energy Modelling Lab, 2022)

RESULTS

Task 1: The national reports and the report from Aalborg show that with the introduction of more renewable energy in the electricity grid, the need for flexibility services will increase in the future. Furthermore, the reports show that district heating and the utilization of surplus heat, as well as larger heat pumps, will be able to cover a large part of the need for heating in Europe. In addition, the heat pumps in the district heating network will be able to provide flexibility services to the electricity grid for which there is a great need see Figure 1. Task 1 reports: National reports: Austria, Sweden can be accessed here: ***https://heatpumpingtechnologies.org/annex57/publications/***

Task 2: 28 cases with small heat pumps, which generate flexibility, as well as cases with large heat pumps, are described. For many of them, both a detailed and a short description have been made.

Task 3: Task 3 gives an overview of promising solutions for creating flexibility in single-family houses as well as by remote control. It also shows the potential for flexibility depending on temperature. Implementation of hybrid heat pumps and their potential are also described.

Task 4: Task 4 gives an overview of the ancillary service market and the different ancillary services. It also describes different types of flexibility. Regarding individual heat pumps, the task describes that there is a need to standardize the communication protocols.

Task 5: Task 5 shows that flexibility provision with heat pumps is currently a very relevant topic across Europe, and many different types of flexibility services are being researched. Some of them are already at a high market readiness level and can form the basis of successful business models in the near future.

Project duration:
January 2021 to December 2023

Operating Agent:
Danish Technological Institute,
Mr. Svend Pedersen
svp@teknologisk.dk

Participating countries:
Austria, Denmark, France, Germany, Netherlands, Sweden

Website:
https://heatpumpingtechnologies.org/annex57/publications/

ANNEX 58

HIGH-TEMPERATURE HEAT PUMPS

INTRODUCTION

The decarbonization of industrial process heating is a top priority for industries as process heating accounts for a large share of their greenhouse gas emissions. High-temperature heat pumps (HTHP) are considered a key technology for decarbonizing the industrial process heat supply, but their deployment is still limited. The transition to a heat pump-based process heat supply requires a common understanding of the technology and a strategy for various stakeholders.

Therefore, this Annex aims to support the development of HTHPs by giving an overview of available and close-to-market technologies, developing integration concepts for heat pump-based process heat supply and providing supporting material to facilitate the implementation of these concepts. The findings are disseminated to increase the awareness and understanding of various stakeholders, such as manufacturers, consultants, end-users, R&D institutes and policy makers. The different activities carried out in the Annex are shown in Figure 1.

> ***HTHP industry nears market breakthrough. Testing, demo, commercialization are ongoing. Joint stakeholder effort is key for decarbonization success.***

OBJECTIVES

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

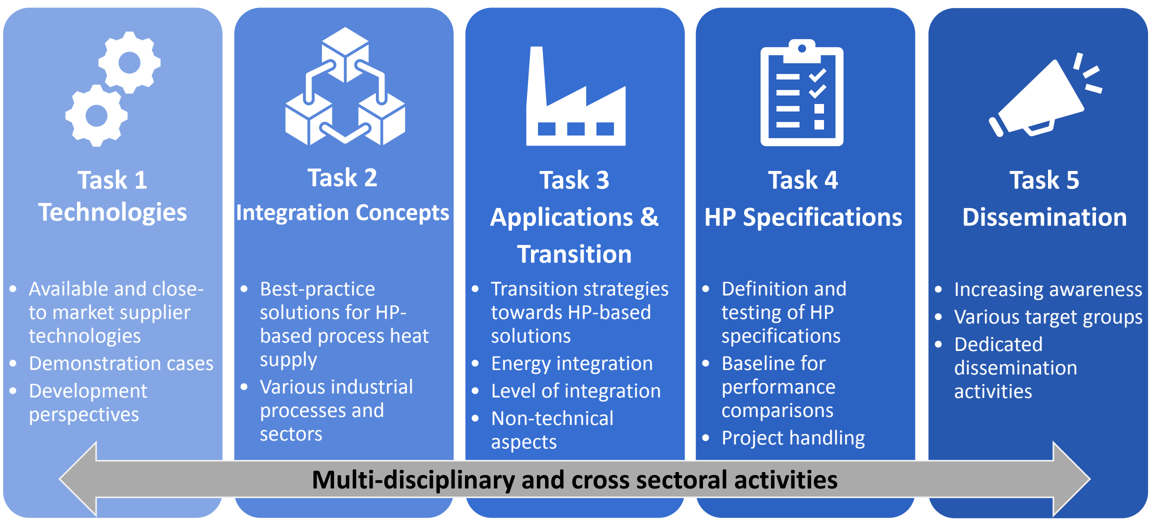


Figure 1: Overview of activities in Annex 58.

- Present strategies for the transition to heat pump-based process heat supply (Task 3 – Completed).
- Enhance the information basis about industrial heat pumps, potential applications and potential contribution to the decarbonization of the industry (Tasks 1, 2, & 3 – Completed).
- 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 – Completed).
- Disseminate the findings to various stakeholders and add to the knowledge base for energy planners and policy makers (Task 5 – Ongoing, final webinar planned in April 2024).

RESULTS

A state-of-the-art review has been conducted for commercially available and close-to-market technologies and 34 technologies and 18 demonstration cases were identified and described. The state-of-the-art review has been published and disseminated during 2023 as a part of the Task 1 report. The information about supplier technologies and demonstration cases has also been collected in informative two-page brochures, as shown in Figure 2. The technology review report has received considerable attention and has been proved to be an important resource for a variety of stakeholders, highlighting the general potential of HTHPs, but also providing concrete guidance and support to industrial players. The database and homepage remain open for additional submissions and updates of supplier technologies or demonstration cases.

The Annex activities of Task 2, dedicated to the integration of HTHPs in process heating, are in their final phases, and the report is close to publication. A description and analysis of integration concepts of HTHPs in 12 industrial processes has been completed. Subsequently, a method for selecting the optimal heat pump solution for given boundary conditions has been developed.

As a part of Task 3, the main barriers to the realization of HTHPs projects have been identified, and a guideline has been developed to support companies in the transition to HTHP-based process heating. This guideline includes methods for the definition of decarbonization targets, the mapping of the current energy system, the development and evaluation of concepts, and the implementation of the most optimal solutions. The report is close to publication.

Finally, the report of Task 4 is also in its final phase and soon to be published. The report includes a review of available standards and a description of the project management process for large-scale heat pump projects. Recommendations for the definition of heat pump specifications in commercial projects have been established, and guidelines for testing of large-scale HPs have been developed.

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

Project duration:
January 2021 to December 2023

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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.

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 state of the art of drying processes equipped with heat pumps
- Analyse drying process on a theoretical level to find optima in process design (e.g. lowering temperatures), in process operation (drying time) as well as in heat pump design and integration
- Gather experience of demonstration projects by monitoring and simulation of the entire drying system
- Recommendations for design of heat pump drying systems regarding performance, cost, etc. and compare with conventional dryers
- Recommendations for concepts of dryers regarding heat pump integration and operations which are favourable for heat pump operation
- Dissemination of information and results on the Annex by a website, publications, workshops and reports.

RESULTS

Manufacturers of drying technologies were researched, and factsheets on their drying technologies for industrial applications were produced. In addition to a technical description of how the respective technologies work, the factsheets contain information about the industrial drying applications.

On an Austrian basis, so far, 10 fact sheets have been provided.

To the same extent, we also provide an overview for applications/end users. Fact sheets from Annex partners will add up and it is envisaged to have in the end 50+ fact sheets. The aim is to combine these two approaches and have a database where the dryer manufacturers are linked with the end users and suitable heat pumps (from Annex 58) in the form of "dynamic" webpages instead of "static" documents.

> ***We give an insight into the drying process as basis for process optimization. The results are transferable to a large number of processes/ sectors.***

Integrating heat pumps in dryers requires a re-evaluation of drying conditions due to changes in energy supply and temperature levels. Experimental investigations on lab-scale and modelling of the drying process have a huge potential to increase energy efficiency. A drying process model can help either by evaluating heat recovery potentials or by optimizing process parameters, e.g., to predict the influence of environmental changes to maintain product quality, minimize down-time, and avoid product rejects. We analyzed the industrial drying process of bread dumpling cubes to study the effects of modified drying conditions on the products drying rate. For simplicity, a so-called characteristic drying curve approach assumes that the drying kinetics of the same material will always produce the same characteristic drying curve, regardless of the conditions, as long as they are constant. Thus, a single curve can be used to predict the drying rate for different conditions and can be further used for the assessment of a theoretical optimum. A laboratory instrument has been developed to measure drying kinetics and evaluate the characteristic drying curve, as seen in Figure 1 below.

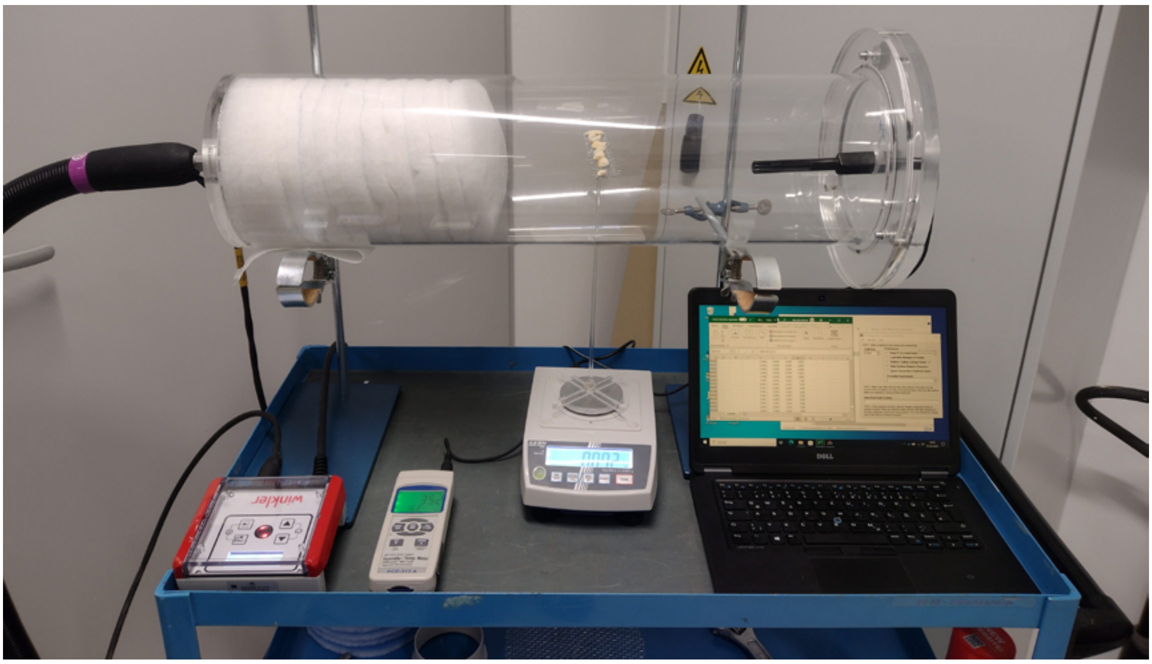

Figure 1: A laboratory instrument measuring drying kinetics and the characteristic drying curve.

Project duration:
1 January 2022 to 31 December 2025

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ANNEX

60

RETROFITTING HEAT PUMP SYSTEMS IN LARGE NON-DOMESTIC BUILDINGS

INTRODUCTION

Non-domestic buildings are responsible for around 30% of the sector's emissions. However, they are difficult to address because, unlike households, buildings vary in form, size, function and, therefore, energy use, leading to a wide variety of possible heat pump system options. Decision makers tell us that this creates confusion about which option is right for their particular circumstances.

OBJECTIVES

The principal objective of this Annex is to provide simple online guidance for decision-makers to help them identify and compare the heat pumps options available to them. The three principal target audiences for the Annex are:

- Building owners and managers who will need a general understanding of the heat pump system options available to them.
- HVAC system designers and engineers who will need more detailed information on system options and their performance.
- Policy makers and their technical advisors, who will need information to assess the costs and likely outcomes of policy instruments.

The guidance we are developing consisting of three elements:

- Case studies act as example installations that illustrate the practical application of particular combinations of systems and buildings.
- A decision support tool thet will generate a list of possible system configurations based on input from the tool user on their particular circumstances.
- An indicative ranking of the system options based on the barriers and drivers, also identified by the tool user.

PROGRESS

After a significant delay in recruiting the Operating Agent, the main work of the Annex only started in April 2023. Progress in 2023 has been largely limited to planning and data collection, with the result that tangible results such as publications and success stories are limited. This delay, coupled with the immaturity of the market, could mean that we will have to extend the Annex. A decision on this will be taken soon.

A literature search was carried out and confirmed that there was very little relevant published information: it identified several documents addressing two of the topics, "non-domestic", "heat pump", "retrofit" but hardly any that included all three.

Overall, the review found that the non-domestic retrofit market is important, complicated, and poorly understood. It is clearly still a very early-stage market, reinforcing the rationale for the Annex that many owners of fossil-fuelled heating systems are unfamiliar with the range or suitability of different heat pump-based retrofit options. However, this presents a dilemma: there is a clear market need for retrofit guidance, but the market experience on which the guidance will be built is scarce and may be a limiting factor for us.

Over 70 case studies have been identified across the participating countries (including a few in other countries). We are currently reviewing the range we have, but our initial impression is that there are large gaps in our coverage, particularly of installed systems, due to the immaturity of the market. This could cause us problems later. It is possible that we might have to seek case studies from non-participant countries.

Compiling the case studies we do have into a database for publication is underway and will reflect the similar databases used in other IEA projects. The minimum level of information required for a case study or example installation to be acceptable has been agreed upon, together with common terminology and the basis for a common 2-page reporting template.

The basic logic of the decision support tool has been agreed and is now being developed. It has three stages (Table 1), which progressively reduce the number of options being considered: initially to identify constraints that limit the range of practicable options, then to narrow this range further to focus on those that are compatible with the existing heat distribution system; and finally, to produce the shortlist of options that best match the priorities identified by the tool user (Table 2).

It is expected that, in most cases, the initial two stages will reduce the number of feasible options to a manageable number that can be ranked according to the priorities that have been expressed by the tool user.

The ranking stage is under development. This element of the guidance is potentially of great use to the tool user, but it is a new approach and will need access to operational data, for example on comparative costs and seasonal efficiencies. Initial informal discussions with building owners and system designers have taken place, but this activity needs to be expanded in 2024.

Development of the user interface is ongoing. It is expected that the tool users will have varied backgrounds, priorities, and levels of prior knowledge, reflecting the multiple and sometimes complex procurement procedures that could be used for various levels of retrofit and type of organisation. We are currently considering how best to make the guidance and the data it presents relevant and understandable, given the resources at our disposal.

Finally, we have begun to consider the web development needed to publish the guidance. This is a task that was not explicitly considered when the Annex was originally set up, so we will need to find additional resources, both in terms of funding and expertise. Our Canadian colleagues have indicated that they might be able to help, but this is to be confirmed. We have had preliminary discussions with the web development team in RISE and agreed that we would prefer to host the guidance on the HPT website. However, the HPT website is currently under review.

TABLE 1: Decision support tool logic

Decision tool logic stages	Examples
Filter by constraints	Access to heat source, electricity supply constraint, extreme climate
Preferred extent of system replacement	Heat generator only, modify distribution system, whole system replacement
Ranking based on user priorities and preferences	Maximise carbon saving, minimise capital cost, minimise disruption

TABLE 2: Indicative range of possible system options

Possible System Configurations			
Heat source	**Scope of service**	**Heat distribution**	**Monovalent or bivalent**
7 options	4 options	4 options	2 Options
Outdoor air	Heating only with separate (or no) hot water service	Water (can be further divided by flow temperature)	Monovalent
Ground	Heating and integrated hot water	Air	Bivalent
Surface water	Heating and cooling with separate (or no) hot water service	Refrigerant	
Aquifer	Heating, cooling, and integrated hot water	None (single space)	
Exhaust air			
Waste heat from chiller			
Other waste heat			

Project duration:
Current end date December 2024, subject to review.

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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 levels. 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 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.

Figure 1: District Quarree 100 of 50% new built and 50% retrofitted buildings supplied by a heating grid with centralised heat pump.

OBJECTIVES

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

RESULTS

A literature review and cross-country comparisons of existing heat pumps with PED have been performed. Both in Switzerland and in Germany, each about 50 districts certified as energyplus- or 2000-W-districts have been identified and evaluated according to different criteria. The evaluation confirms that heat pumps are the dominating building technology in these high-performance districts.

A load generator for PED evaluation has been created and will be further developed. The load generator can model different building types and heat sources as well as PV production. With the resulting load curves on an hourly basis, the options or gaps for reaching a PED can be evaluated and synergies among load profiles, but also load mismatch between production and consumption can be evaluated and visualized for different building combinations.

10-14 monitoring projects of heat pumps in high-performance building clusters or districts are contributed to the Annex work, which also incorporates the transformation of existing districts to high energy performance. Different monitorings has started, and the first results have been evaluated.

Some of the monitoring systems are also modelled for simulation and an in-depth techno-economic evaluation of the heat pump system regarding design, control, energy flexibility and storage integration. This can also serve to optimize the real system while monitoring data can

Figure 2: Papieri district, Cham, CH

Figure 3: Campagne district, Innsbruck, AT

validate and improve the simulation models. By simulations also, system comparisons are enabled. Figure 1 and F Figure 2 show two districts which are both simulated and monitored.

Generic system solutions of heat pump integration in clusters or districts, starting from the individual building level to a centralized heat pump integration of district heating and cooling system, have been categorized and are further specified and technically described. This work is also linked to the simulation and the monitoring, which will contribute to the technical description and evaluation.

Furthermore, system boundaries and KPIs for the PED evaluation for the work in Annex 61 have been defined as a set of energetic, environmental, and economic KPIs in line with KPIs found in the literature review. Archetype PEDs have been defined, e.g. "only residential new buildings" or "mixed residential and office use", which can be used to evaluate characteristics and favourable system solutions.

Project duration:
Septmber 2022 to December 2025

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ANNEX

62

HEAT PUMPS FOR MULTI-FAMILY RESIDENTAL BUILDINGS IN CITIES

INTRODUCTION

One of the significant sources of CO_2 emissions amplifying the negative climate changes are the heating and cooling needs of people living in buildings. A major solution to preventing CO_2 emissions in the heating and cooling sector is to use heat pumps instead of technologies based on fossil fuels.

As regards multi-family buildings, there exist good examples of heat pumps implementation; however, it is not yet a widely chosen solution, neither in new nor in existing buildings. At the same time, there is an ongoing trend for migration to high-density cities and consequently, the significance of multi-family houses is on the rise.

This Annex will focus on heat pump solutions for multi-family houses in high-density cities. In respect to the demand of the participating countries, new buildings and retrofit will be considered, as well as buildings with higher specific heating demand.

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

> ***This Annex will focus on heat pump solutions for multi-family houses in high-density cities.***

OBJECTIVES

Continuation from Annex 50

- Extension of the "matrix tool", especially further description of each general concept with the aim of finding and establishing standard solution.
- Implementation and extension of the toll "solution finder" with the aim of creating an easy-to-use pre-planning tool, allowing for quick recognition of possible heat pump solutions for specific cases.

New Objectives of Annex 62

- Identify a robust and proofed solution regarding the heat sources.
- Standardized solutions are necessary to allow implementations of heat pumps on a large scale, despite many individual cases with individual solutions.
- For cities, it is necessary to search solutions for whole quarters or for groups of buildings; both for new and retrofitted residential areas.
- Extension of the case studies database- From about 20 examples at the beginning of the Annex, the number of case studies has more than doubled, with more being uploaded to the website every month: Still ongoing.

Fulfilled Objectives

- Extending the range of participating countries. Success: Formerly 8 European countries, now 12 contributing countries from Europe, Asia and N. America
- Besides the "classical" heat sources, new or not yet widely used ones shall be identified. (Already identified: Exhaust air, ice, sea water, waste heat)

PROGRESS

In 2023, the Annex managed to massively extend the case study database. The amount of reference countries has doubled compared to Annex 50, for the first time including countries that are not central-European. Early results of the case study database revealed a new, previously unheeded 'Family Member' of the Solution Matrix that will be added soon (individual heat pumps that source heat from an internal loop fed by a central heat pump).

Other results or progress:

During the last six months, the results from the first two Annex meetings were further developed. One of the most important highlights was the creation of the 'Progress Dashboard' (see Figure 1). It provides an overview of the different project goals of the Annex as well as the interdependencies at play.

The meeting in Fontainebleau, France, shifted focus onto the goal of refining and filling the databank as well as discussing the filtering methods for the case study maps. It was decided that the maps would be extended by the various categories of the classification in order to be able to offer five filtering methods in each of the six maps. The filtering methods will be as follows:

- » Only heat pump/hybrid
- » Newly built / retrofit
- » Energy demand high/low
- » Size of the building: small (<11), medium(11-20), large (>20)
- » Other possible filtering options: Heating only / heating and cooling

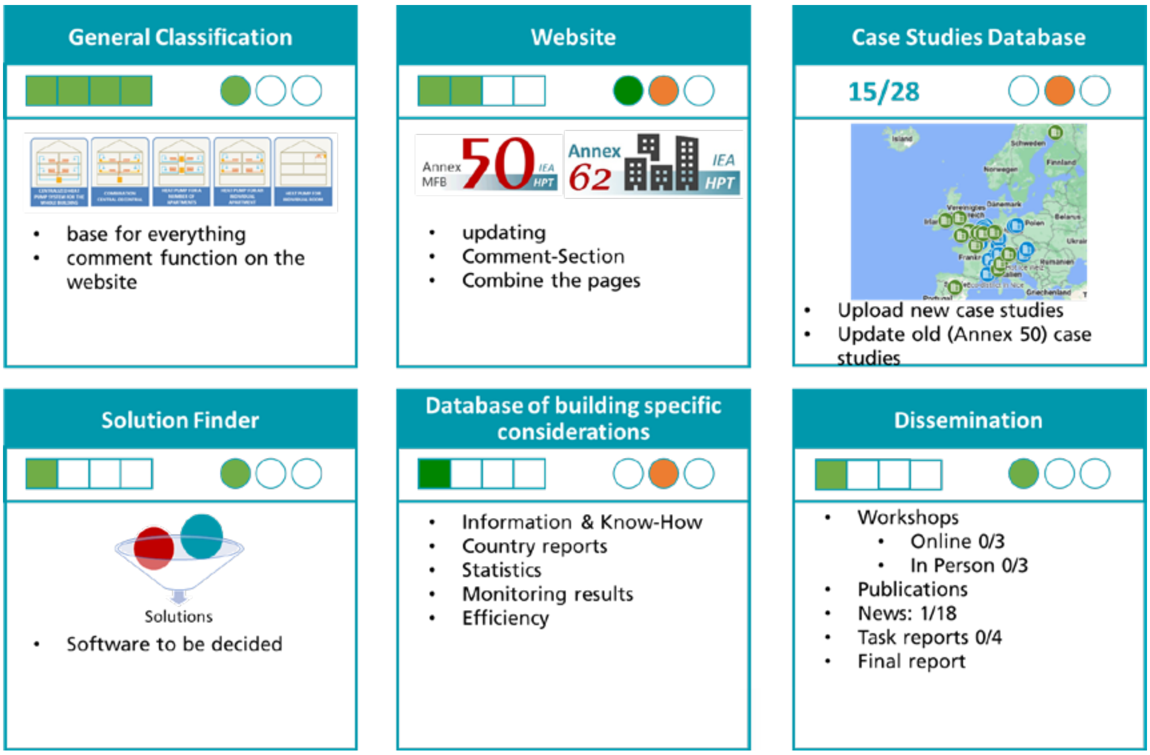

Figure 1: Progress Dashboard' outlining all the ongoings within Annex 62.
Source: IEA HPT Annex 62

Project duration:
January 2023 to December 2025

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ANNEX 63

PLACEMENT IMPACT ON HEAT PUMP ACOUSTICS

INTRODUCTION

The new IEA HPT Annex "Placement Impact on Heat Pump Acoustics" has been set up as a follow-up to the finalized IEA HPT Annex 51 "Acoustic Signatures of Heat Pumps" conducted by Austria, Denmark, Germany, France, Italy, and Sweden. There, the acoustic groundwork has been laid, the basics have been successfully covered, and its deliverables, executive summary and documents guide, as well as its umbrella report, are available for download at the IEA HPT Annex 51 website.

The results have made their way into the development of standards. In the framework of IEA HPT Annex 51 psychoacoustics effects of heat pump acoustics have been studied with tests performed in Sweden and Austria. The acoustic effects of heat pump placement and the dependence on the operating conditions were reported. Guidelines for installers have been developed and made available.

In the course of finalizing IEA HPT Annex 51 and following recent industry requests and demands, special fields of interest emerged, which need international experience and collaboration to be treated effectively. Thus, IEA HPT Annex 63 enriches independent information and expertise on the benefits of heat pumping technologies by focusing on the field of acoustics. Noise emissions are a potential threat to further spreading of heat pumps in the years to come. Thus, working on the acceptance of heat pumps by minimizing these adverse environmental impacts while keeping high energy efficiency is of great importance and in line with the Heat Pump Technologies (HPT) Technology Collaboration Programs (TCP) vision of the International Energy Agency (IEA).

OBJECTIVES

IEA HPT Annex 63 is primarily focused on the "Placement Impact on Heat Pump Acoustics" but leaves room for special topics of heat pump acoustics covering selected applications and the refinement of methods.

The main objective from IEA HPT Annex 51 – removing acoustic market barriers to establish heat pumps as the number 1 choice as renewable energy and energy efficiency option for HVAC applications – remains. Intense discussions, however, emphasized that avoiding showstoppers in the rapidly growing deployment of heat pumps is gaining significance. Therefore, consumer boards will be screened to identify the challenges in the field. Furthermore, as the cooling capability of heat pumps gets more and more important, Annex 63 will include the acoustics of heat pumps in cooling modes in its focus.

Revision of cases of complaints showed, that each placement situation is unique, and several aspects contribute to a successful installation. Therefore, as a proper installation is key to low acoustic impact on the environment, the existing guides will be revised and linked to the developed placement tools. Thus, the consortium will work on

- Building Acoustics Impact of Heat Pumps
- Urban Acoustics Impact of Heat Pumps
- Psychoacoustics of Heat Pumps
- Digitally Assisted Heat Pump Placement
- Dissemination

> ***"Avoiding show-stoppers – like unwanted acoustic emissions – in the rapidly growing deployment of heat pumps is gaining significance."***

Figure 1: Augmented Reality Demonstration.

PROGRESS

The workshop "WS 2.2. Acoustic Signatures and Placement Impact of Heat Pumps, Interactive Augmented Reality and psychoacoustics" at the IEA HPT Conference in Chicago 2023 started with a presentation of the IEA HPT Annex 63 "Introduction to IEA HPT Annex 63 (and Annex 51)". HEAD Acoustics introduced the psychoacoustic demonstration, which was offered for all participants in form of a panel test. The contribution "Utilizing Augmented Reality for Noise Propagation Modelling and Mapping of HVAC Sound Sources" focused on using mobile devices for increasing acoustic awareness. Participants could try out the actual version of the App on handheld devices on the Holo Lens. In the afternoon, feedback from the Augmented Reality tryout and the panel test was presented and discussed.

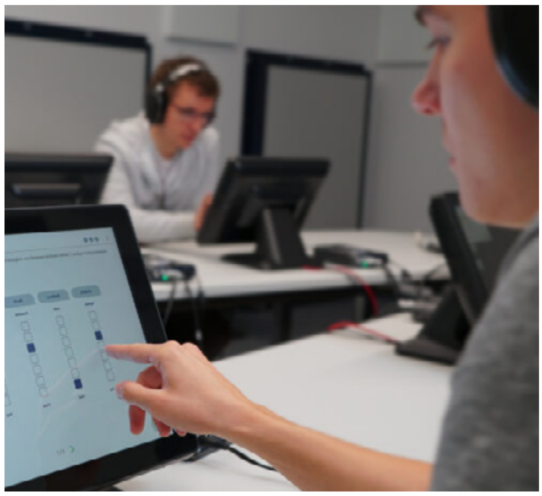

Figure 2: Panel Test.

Activities also continued national levels. the website of the Augmented Reality App (https://raara.ait.ac.at/) has been translated into English language and a video showing its capabilities has been generated. Work on a database linking thermodynamic and hydraulic meta data to intensity sound measurements during heat air-2-water pump performance tests has begun. As for these measurements, the sound intensity had been measured on 5 faces surrounding the heat pump, conclusions with respect to directivity will be available.

Project duration:
June, 1st, 2023 – May, 31st, 2026

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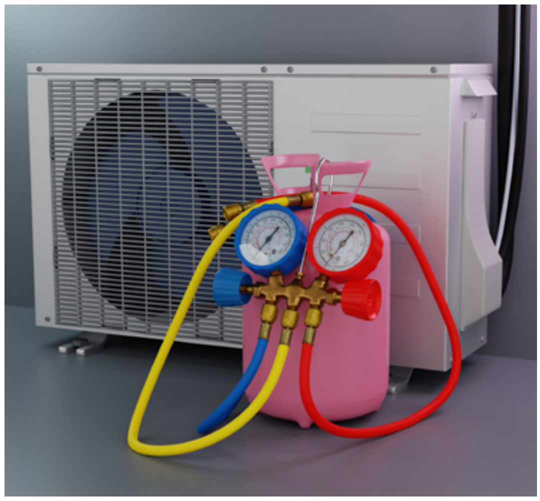
ANNEX
64

SAFTEY MEASURES FOR FLAMMABLE REFRIGERANTS

INTRODUCTION

Global warming is a major threat to society, and all measures must be taken to decrease the emissions of gases contributing to this threat. The use of fossil fuels must, therefore, be abandoned as agreed in the Paris agreement. As a consequence, heating of buildings and heating within industry must be based on renewable energy, harvested in the form of electricity. This means that the use of heat pumps will increase tremendously in the coming decades, in line with predictions, scenarios and plans from many different authorities and organizations worldwide, including the IEA and the EU. The refrigerants used until recently have global warming potentials (GWP) one to four thousand times higher than carbon dioxide. Large efforts have been spent on identifying new fluids with low GWP which can be used as refrigerants in heat pumps and refrigeration systems. The conclusion from these studies is that we cannot expect to find new fluids which have low GWP and at the same time, are non-flammable. The only notable exception for ordinary temperature levels is carbon dioxide, which is already successfully used in e.g. supermarket refrigeration but which may be difficult to use with high efficiency for some other applications. The alternative mainly being promoted by the chemical industries is the use of Hydro Fluoro Carbon (HFC) refrigerants with double bonds, often called Hydro Fluoro Olefins (HFO), or blends of HFOs. These fluids/blends have lower GWP than most HFCs traditionally used because of the shorter atmospheric lifetime. However, these fluids/blends also suffer from the trade-off between low GWP and low flammability, and it is not possible to find non-flammable refrigerants with GWP less than about 150. In addition, HFOs like HFCs are synthetic substances not existing in the atmosphere, on land or in freshwater. Therefore, these fluids or their decomposition products may have unexpected effects on the environment in the long term. Already, there is a concern about the formation of TriFluoroAcetic acid (TFA) from the decomposition of some HFOs (and HFCs). TFA is an



extremely stable compound which may accumulate in the natural environment for hundreds of years. It should also be mentioned that many HFCs and HFOs are, by definition, belonging to the group of substances called PFAS. Members of this group are known to cause decreased fertility, certain types of cancer, and hormone disorders, to mention a few . At this moment, European authorities are working on a suggestion to ban all PFAS. This may affect the use of HFC and HFO refrigerants in the near future. Already, a new F-gas regulation has been decided on in Europe. According to the new regulation, the phase-out of F-gases is speeded up. For systems with a capacity below 12 kW, no F-gases, not even HFO, will be allowed from 2035.

Because of the environmental effects and (in Europe) because of the expected phase out of F-gas refrigerants, heat pump manufacturers are developing products for hydrocarbon refrigerants, which are highly flammable. It is highly likely that we, in the near future, will see a market dominated by flammable synthetic refrigerants and, in Europe, by flammable hydrocarbons. It is, therefore imperative that we learn how to design systems which are safe even if the refrigerant is flammable.

OBJECTIVES

- The ultimate goal of the Annex is to contribute to a broader safe use of flammable refrigerants.
- To reach this goal, the aim of the Annex is to increase the understanding of the risks related to the use of flammable refrigerants and to develop methods and system designs to maintain the risks at acceptable levels.
- The goal is that the findings generated in the Annex will be used as background information when regulations regarding the use of flammable refrigerants are updated.
- It is expected that one outcome of the Annex is a set of recommendations for updates of the regulations.

PROGRESS

The OA had individual contacts with the other two countries, and the representatives had the chance to meet at the International Congress of Refrigeration, ICR, arranged by the International Institute of Refrigeration, in Paris in August 2023.

The themes of the work in the three countries were as follows:

Sweden:

- Recruitment of PhD students.
- Simulation of leakage scenarios in preparation.
- System design for a reduced charge of refrigerant, including heat exchanger development and identification of new compressor designs for a low charge, is ongoing within the project EcoPack. A system with isobutane as a refrigerant has been demonstrated with a charge of 120g and a capacity of up to 12 kW.

Germany:

- Studies on system design for charge reduction have been initiated.
- Simulation and experimental verification of leakage scenarios are initiated.
- Compilation of information on safety with flammable refrigerants through literature surveys and interviews/personal contacts underway.
- Compilation of market data in Germany, identifying in particular the market share of flammable refrigerants.

Korea:

- Studies on system design for charge reduction have been initiated.

France and Austria joined the Annex during the last two months of 2023 and did not report any activities for this year.

> ***Heat pump makers shift to flammable refrigerants. There is an urgency to design safe systems for future markets.***

Project duration:
April 1, 2023 – March 31, 2026

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Participating countries:
Austria, France, Germany, Korea, Sweden

Website:
https://heatpumpingtechnologies.org/annex64/

Outlook into the Future

In 2024, HPT TCP will continue the implementation of the strategic work plan for 2023–2028 (see page 9).

The TCP has selected some prioritized achievements to be reached during 2024. The defined achievements for 2024 are based on the conclusions from the development of the renewed HPT TCP Strategic Work Plan 2023-2028 in combination with the present status for heat-pumping technologies within IEA and on different policy levels. Also, output from the different IEA reviews of TCP best practices on communications and on areas of improvement in CERT, its Working Parties and TCPs initiated by IEA CERT have been taken into account.

The selected achievements for 2024 are:

» Strengthened TCP communication through
  – renewed and improved HPT TCP website
  – Modernized HPT Magazine and extended HPT Newsletter

» Improved organization of HPT TCP

» Formalized collaboration with other Heat Pump related TCPs, business organizations, European Commission (DG ENER) and governmental organizations in all regions

» New ideas and proposals for Annexes according to the strategic work plan 2023-2028

The HPT TCP plans to take an active role in the possible future establishment of TCP Coordination Groups within IEA, especially in the one pro-

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).
• Annex 57: Heat pumps in multi- vector energy systems • Annex 61: Heat Pumps in Positive Energy Districts • Comfort and Climate Box solutions for cooling and dehumidification • Heat Pumps enabling Flexibility and Sector Coupling • Digital Services for Heat Pumps	• Annex 63 Placement Impact on Heat Pump Acoustics NEW • Annex 65 Heat Pumps in a Circular Economy NEW • New or alternative business models for heat pumps • Enhanced miniaturized components	• Annex 60: Retrofit Heat Pump in Larger Non-domestic Buildings • Annex 58: High Temperature Heat Pumps • Annex 59: Heat Pumps for Drying • Annex 62: Heat Pumps in residential multifamily buildings in cities • Process Integration of High Temperature Heat Pumps	• Annex 54: Heat Pump Systems with low GWP Refrigerants • Annex 64: Safety Measures on Flammable Refrigerants NEW • Monitoring of Advanced Vapor-Compression and non-Vapour-Compression Technologies for Heating, Cooling and efrigeration

* Research, Development, Demonstration and Deployment

posed for Heat Pumps, but also others could be of certain relevance and interest. To have a successful outcome the proposed Heat Pump Coordination Group should have a tight interaction with business organizations, European Commission (DG ENER) and governmental organizations in all regions.

According to the work plan for 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 "infovisual" above 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. During 2024 the Annexes will be renamed to Projects in accordance with the newly updated TCP framework.

In early 2024, the Annex 65 Heat Pumps in a Circular Economy started. The background to this project is that IEA's Net Zero Roadmap estimates that the global heat pump stock capacity will triple from 1,000 GW to 3,000 GW. The increased deployment of heat pumps will also increase the material footprint and could influence supply chains of materials. To align this with a circular economy, the products need to be optimized in a lifecycle perspective with a long lifetime and with the possibility for lifetime extension through repairs. The requirements and the associated documentation are expected to increase in the coming years as the carbon footprint in all use phases becomes a competitive parameter. This is already happening in some markets where limits are introduced on the building level to restrict the lifecycle carbon footprint of buildings.

To ensure cost-effectiveness and competitiveness in the transition to a circular economy, the heat pump industry needs to have access to a forum where knowledge is collected and shared. This is the overall objective of the Annex, which will provide an overview of the status of heat pumps in relation to a circular economy, highlight the technological possibilities for improving the circularity as well as develop best practice recommendations.

This project will provide an overview of current national initiatives and, improve the understanding of the circular economy framework and promote strategies to switch to a circular economy with a focus on repairability, reused materials and components, lifetime extension and new business models.

List of Publications for all Annexes 2023

Annex 53

Radermacher, R and Baxter, Van D 2023 Final Report Annex 53: Advanced Cooling/Refrigeration Technologies Development. (HPT TCP) Report no. HPT-AN53-2. DOI: 10.23697/rfhs-wc33

Radermacher, R and Baxter, Van D 2023 Executive Summary Annex 53: Advanced Cooling/Refrigeration Technologies Development. (HPT TCP) Report no. HPT-AN53-SUM

2-page summary Annex 53: Advanced Cooling/Refrigeration Technologies Development (HPT TCP)

Annex 54

Cheng-Yi Lee, Timothy Kim, Yunho Hwang and Reinhard Radermacher, Development of a Near-isothermal Compressor for Transcritical Carbon Dioxide Cycle, 14th IEA Heat Pump Conference, Paper 217, May 2023, Chicago, USA.

Zhenning Li*, Samuel F. Yana Motta, Bo Shen, Hanlong Wan, Optimization of a Residential Air Source Heat Pump using Refrigerants with GWP <150 for Improved Performance and Reduced Emission, 14th IEA Heat Pump Conference, Paper 1974, May 2023, Chicago, USA.

Michael Petersen*, Steve Kujak, Gurudath Nayak, Evaluation of lower GWP alternatives to R410A in AC and HP applications, 14th IEA Heat Pump Conference, Paper 123, May 2023, Chicago, USA.

Thore Oltersdorf*, Hannes Fugmann, Lena Schnabel, European heat pump market data – evolution of the state of the art heat pump over time and its possible knowledge gain, 14th IEA Heat Pump Conference, Paper 895, May 2023, Chicago, USA.

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Annex 56

Wilks, V et al. 2024. Final Report Annex 56: Digitalization and IoT for Heat Pumps (HPT TCP) Report no. HPT-AN56-5. DOI: 10.23697/5cj7-v747

Wilks, V et al. 2024. Executive Summary Annex 56: Digitalization and IoT for Heat Pumps (HPT TCP) Report no. HPT-AN56-SUM. DOI: 10.23697/5cj7-v747

2-page summary Annex 56: Digitalization and IoT for Heat Pumps (HPT TCP)

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V. Wilk, R. Jentsch, T. Barz, Interconnected heat pumps in Austria: A technology implementation survey, Session Keynote and Paper with Peer Review, 13rd IEA Heat Pump Conference, Chicago, 2023.
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R. G. Junker, G. Tsaousoglou, H. Madsen: Incentivising and Activating Multi-Purpose Flexibility for the Future Power System (submitted), 2023.

C. Thilker, H. Madsen, et. al.: A Review on Sensor-Based Real-Time Controllers for Buildings in Smart Grids (submitted), 2023.

H. G. Bergsteinsson, M. L. Sørensen, J. K. Møller, H. Madsen, Localizing: Weather Forecasts for Enhanced Heat Load Forecast – Accuracy in Urban District Heating Systems (submitted), 2023.

Workshop on Digitalization and Artificial Intelligence for Heat Pumps and Refrigeration systems, 26th International Congress of Refrigeration, Paris, 2023:

» C. Vering: Applying machine learning to boost operating performance of heat pump systems.
» D. Rolando: Data-driven approaches for improving control and monitoring of heat pump systems.
» V. Wilk: IoT and digitalisation for heat pumps – opportunities and challenges

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Annex 58 – High -Temperature Heat Pumps. Task 1 – Technologies. Task Report.

Heat Pump Centre, RISE – Research Institutes of Sweden, August 2023.

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Annex 59

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Annex 64

Jeong Y., Lee S., Kim M. S., Investigation on the performance change of a heat pump system with refrigerant mixtures during leakage process, Proceedings of the 26th IIR International Congress of Refrigeration: Paris, France, August 21-25, 2023, DOI: 10.18462/iir.icr.2023.0426.

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